

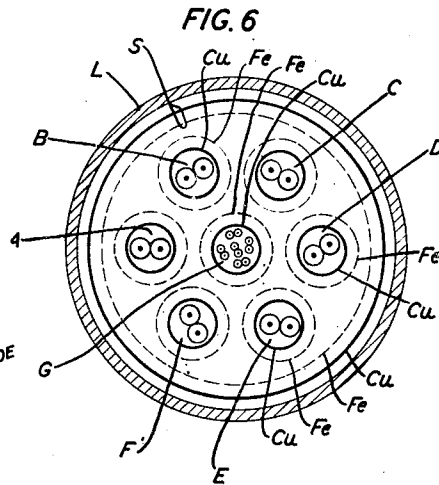
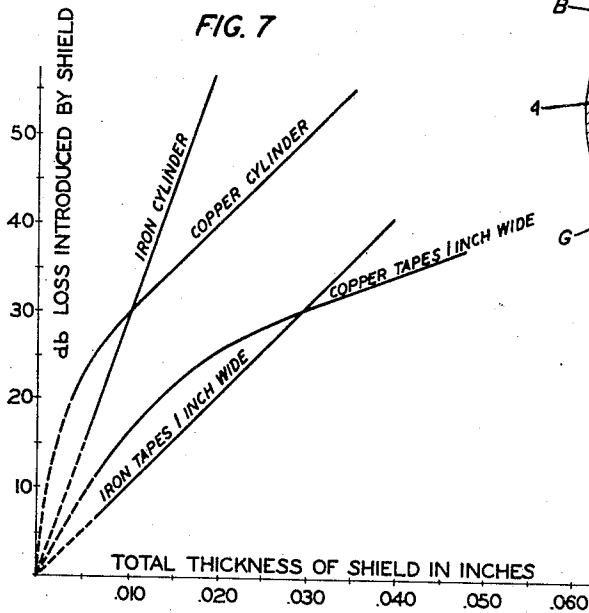
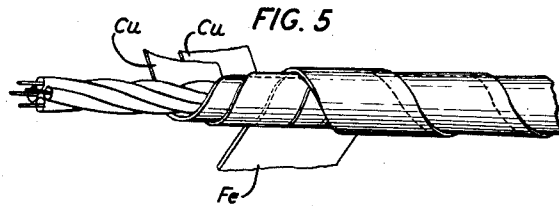
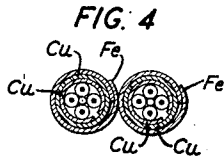
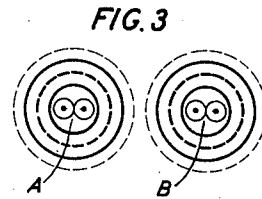
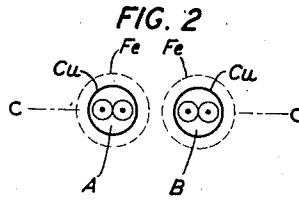
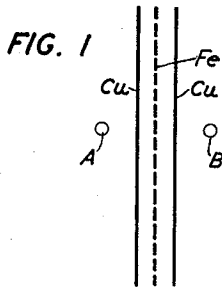
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2,152,706

SHIELDING FOR ELECTRICAL CIRCUITS

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SHIELDING FOR ELECTRICAL CIRCUITS

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This invention relates to shielding of electric circuits and particularly to shielding of circuits for transmission of high frequency signals such as telephone voice currents or higher frequency carrier currents. The invention is particularly related to the shielding of conductor units, such as pairs or quads, as they appear in multiconductor cables, and the shielding may be used to reduce mutual interference between such circuits or for protection of such circuits against interference from external sources.

The art of shielding for purposes similar to those contemplated by the invention has been developed to a high degree of usefulness and the invention may be viewed as an improvement on existing shielding arrangements in that it has for one of its main objects a more efficient utilization of such arrangements than has hitherto been contemplated.

For examples of high frequency shielding arrangements, representative of the prior art in its more advanced stages, reference is made to the disclosures in Patent 1,871,906, issued to Nyquist on August 16, 1932; in Patent 1,933,261, issued to H. J. Harris on October 31, 1933; and in Patent 1,979,402, issued to H. Nyquist on November 6, 1934.

Nyquist, in his patents referred to above, laid down a criterion according to which a high degree of shielding could be obtained by a composite shield made up of a layer of highly conducting metal such as copper and a layer of high permeability metal such as iron, contiguous thereto, such layers to be repeated in alternations as higher degrees of shielding are desired.

Harris, according to his patent referred to above, further discovered that for a high efficiency of shielding, i. e., for the least amount of shielding material to produce a given shielding effect, there exists certain "critical" thicknesses for the copper layers and certain "characteristic" thicknesses for the iron layers.

In accordance with the invention the principles laid down by Nyquist and Harris are used in a novel manner in designing the shields required for mutual shielding of a plurality of circuits such as those existing in a multiconductor cable for high frequency signaling.

Considering, for example, a cable with at least three conductor units or circuits, each made up of a group of twisted conductors, and each constituting a source of disturbance for the other circuits, it is evident that if each circuit were encased within a shield of copper and iron as proposed by Nyquist, and if the shield were designed as to

thickness and number of layers as if the other units were unshielded as proposed by Harris, there would be an unnecessarily high shielding effect between any two of the circuits and the cable would contain an excessive amount of shielding material thereby uselessly increasing the cost.

It is therefore an object of the invention to provide individual shields for a plurality of disturbing circuits in accordance with the teachings of Nyquist and Harris but with a more efficient utilization of the shielding material in producing the mutual shielding effect between adjacent circuits. Thus, in accordance with the invention the shielding required between mutually disturbing circuits is planned in such a way that duplication of shielding layers is reduced to a minimum thereby reducing the size and weight of the cable, and also its cost.

More particularly the two shields enclosing two mutually disturbing circuits are, in accordance with the invention, designed so that by their combined shielding effects the disturbing field from one circuit is reduced to the desired degree at a point within the shield of the other circuit instead of at a point on the outside of the shield of the first circuit, as in the prior art referred to.

For a more complete understanding of the invention reference should be had to the following description taken in connection with the attached drawing, in which

Fig. 1 shows a theoretical shielding arrangement between two disturbing circuits for given requirements;

Fig. 2 shows schematically how the shielding required in accordance with Fig. 1 may be placed to surround the two circuits;

Fig. 3 shows a similar distribution of shields between two circuits where a higher degree of shielding is required;

Fig. 4 shows a cross-section of two quads shielded in accordance with Fig. 2;

Fig. 5 shows a side elevation of one of the quads in Fig. 4 in the state of application of the various shielding layers;

Fig. 6 shows schematically a cross-section of a multi-conductor cable with mutually shielded conductor groups and supplementary shielding of the entire cable against external disturbances; and

Fig. 7 shows a set of curves, similar to those disclosed by Harris, for illustrating the behavior of copper and iron under different shielding conditions.

To aid the study of the schematic Figs. 1, 2, 3

and 6, the copper layers Cu are drawn with full lines and the iron layers Fe with dotted lines.

The term "critical thickness" as applied to a copper layer and the term "characteristic thickness" as applied to a magnetic layer, and as used in the appended claims, are intended to have the same meaning as that given to them by Harris in his Patent 1,933,261. Thus, the critical thickness of copper will be different for different types of shields and will vary with the dimensions of the shield; but in general the critical thickness of a copper shield falls below a range at which its effectiveness per unit of thickness shows a marked decline as the thickness of the layer increases. As to the characteristic thickness of the iron, this also varies somewhat with the dimensions of the shield but in general it is approximately the minimum thickness of iron shield which must be interposed between two copper layers to insure substantially the same shielding effect of each copper layer as it would have if used alone.

The curves in Fig. 7 show the following points: (a) that iron has a shielding effect very nearly proportional to the thickness of the layer; (b) that copper, on the contrary, has a shielding effect per unit of thickness which is much less for thick than for thin layers; and (c) that the effectiveness of a shield is a function of its physical conformation. The measurements from which the graphs of Fig. 7 are taken were made at a frequency of 45,000 cycles per second. The procedure was to determine the difference in electrical energy in the circuits of two coils and then without materially changing their geometrical position with respect to one another to insert between them a shield and again determine the difference in energy. The increased difference in energy was considered as a loss due to the shield.

Consider first two substantially equal disturbing sources A and B as shown in Fig. 1. The source A may be a group of conductors in a cable and the source B may be another similar group of conductors in the same cable, both subject to disturbance. Assuming that in accordance with the teachings of Nyquist and Harris it has been determined that in order to reduce the disturbing field from A to a desired degree at the location of B, a shield is required between these two sources which consists of two copper layers Cu, each of the critical thickness, separated by a layer of iron of the characteristic thickness; this same shield, being of symmetrical design, will similarly reduce the disturbing field from B at the location of A.

Consider now a practical case such as shown in Fig. 2 where the disturbing sources A and B are circuits, each composed of a pair of twisted telephone conductors subject to disturbance and requiring the same shielding as that determined for the case illustrated in Fig. 1. In accordance with the invention, the total shielding illustrated in Fig. 1 is divided into two sub-shields, each formed to entirely enclose one of the pairs of twisted conductors throughout their length. Thus, one copper layer Cu and one-half of the iron layer Fe are placed about the pair A with the copper nearest to the conductors. The other copper layer and the other half of the iron layer are placed about the pair B with the copper nearest to the conductors. It is evident that as far as the two pairs A and B are concerned the combined shielding effect obtained in both directions by the two half-shields is the same as in the arrangement shown in Fig. 1.

If a somewhat higher degree of shielding is required than that assumed in the discussion of Fig. 1, the most economical design may be obtained by increasing the thickness of the iron layers; the limit of this increase is determined largely by the desired flexibility of the cable. A still higher degree of shielding would require additional copper layers of not more than the critical thickness, separated by iron layers at least of characteristic thickness. Thus, in Fig. 1 each iron layer Fe may be increased to its characteristic thickness and a copper layer of critical thickness interposed therebetween, for example, by applying a copper layer of half the critical thickness to each shield. The shielding may be still further increased by applying two intermediate copper layers or sheaths, each of critical thickness and separated by a third iron layer at least of characteristic thickness in order that the full shielding effect of the copper layers may be secured. In this particular case the shielding may, in accordance with the invention, be divided into two halves by again dividing the central iron layer into two halves and placing an equal number of copper and iron layers about the two strands A and B as shown in Fig. 3. It is evident that the principles of the invention may be similarly applied to still more complex shields.

Though in practice it usually will be advantageous to divide a certain shielding between two disturbing sources into two equal half-shields, it may sometimes be simpler or even more effective not to divide the center layer of the shield into halves and instead place the entire center layer in one of the sub-shields. It is not essential either that the two sub-shields contain equal numbers of layers even when an intermediate layer is divided into two sheaths.

In applying the shields to long continuous strands of conductors such as pairs or quads, the copper layer may be formed of a copper ribbon applied helically about the strand to form a continuous sheath; in this case the length of layer and amount of overlap would be such as to permit the usual bending of the cable. The copper layer may also be formed of two sheaths, each comprising a copper tape applied helically and of approximately half the total required thickness; in this case, as illustrated in Figs. 4 and 5, each copper tape Cu may be applied without overlapping edges and with a slight spacing between adjacent turns to permit bending of the cable, and the outer copper tape will have its turns centered over the gaps between the turns of the inner sheath. The outer magnetic layer Fe may be applied in the same manner as the copper layers, that is, as a plurality of helically wound tapes; as shown in Figs. 4 and 5 the layer is applied as a single tape with overlapping edges wound in the opposite direction of the copper tapes to insure flexibility of the cable.

Whereas in the case of a cable with only two shielded circuits, the shielding effect between them may be substantially the same whether the shield be placed entirely about one circuit or divided between them, there are certain advantages in dividing the shield. Thus, from the viewpoint of efficient utilization of the shielding material it can readily be understood that since both circuits are enclosed in shields they will both have shielding relative to a third source of disturbance, whether this source be external of the cable or be a third circuit within the cable. This additional shielding is thus obtained without additional material beyond that required for mutual shielding

between the two circuits. Some simplification in manufacturing may also be attained by dividing the shield equally between the two conducting strands, since the two strands thus may be produced by the same machinery.

The invention thus is particularly of advantage when applied to cables with at least three conductor units or circuits. With the circuits each encased in a sub-shield or half-shield, the shield on any one circuit will constitute a part of each of the several shieldings required between that circuit and all the others and is supplemented by the similar shields on the others to complete the several mutual shieldings. The individual shields may similarly be supplemented by a common shield against an external source of disturbance when necessary.

In view of the well-known fact that copper, rather than iron, must be used in the layer of the shield closest to the protected circuit, and of the further fact that the cost of copper is higher than that of iron, it is a particular feature of the invention that, for the most efficient use of copper, the copper layers should be of not more than the critical thickness and should in all cases be separated by iron layers of at least the characteristic thickness. Each layer of copper or of iron may be divided into sub-layers or sheaths, as when made up of a plurality of wrappings of tape, and at the point of subdivision of the shielding the sub-layers of copper or iron, as the case may be, may be placed about two adjacent circuits.

The advantages of the invention will therefore appear more distinctly from a consideration of the arrangement shown in Fig. 6 which shows diagrammatically a cross-section of a multi-conductor cable comprising seven strands of signaling conductors A, B, C, D, E, F and G, all enclosed within a lead sheath L.

Each of the strands or units of conductors is enclosed within a half-shield in accordance with the arrangement in Fig. 2 comprising an inner copper layer Cu of not more than critical thickness and an outer iron layer Fe of at least half the characteristic thickness. If the individual half shields do not provide sufficient protection against disturbances from sources external of the cable, all the individually shielded strands may furthermore be enclosed within a common shield S which may supplement the individual shields by having an outer copper layer Cu of critical thickness and an inner layer Fe of at least half the characteristic thickness thereby insuring the most efficient use of the copper.

With this arrangement of half-shields, the strands of conductors are uniformly shielded, which is an advantage in the manufacture of the cable, and a complete shield is established between any two strands of conductors for a given desired shielding effect. The individual half-shields on all the strands furthermore supplement the common shield S to effectively reduce disturbing effects from a source outside the cable upon the circuits of the individual strands.

The cable shown in Fig. 6 is one of several designs to which the invention may be applied. The strands of conductors may be pairs or quads or may each contain a larger number of conductors. The conductors within the strand may be insulated from each other in any known manner, such as by wrapped paper strips or by spaced discs of insulating material.

The couplings between the strands A, B, C, D, E and F may be different from the coupling be-

tween these strands and the strand G, for which purpose the strand G may have a shield differing from those of the other strands, for example, by having a heavier magnetic layer Fe. In the design of the common shield, the shielding effect of the lead sheath L may, of course, be taken into account. The common shield S may also have an additional copper layer on the outside of that shown in Fig. 6 and separated therefrom by another iron layer.

It should be understood that the various layers or shields which build up to produce a given shielding effect need not be in metallic contact for the purposes of the invention but may be separated by coatings or by braidings or bindings without a departure from the invention.

What is claimed is:

1. Two adjacent strands of high frequency signaling conductors, continuous shielding means placed close about one of said strands to form a unitary structure therewith and comprising an inner layer of copper of not more than critical thickness and an outer layer of iron, other continuous shielding means entirely surrounding the other of said strands and comprising a layer of copper of critical thickness and contiguous thereto a layer of iron immediately adjacent to the first said layer of iron throughout their common length, the total thickness of said two layers of iron being at least equal to the characteristic thickness.
2. Two adjacent strands of high frequency signaling conductors, continuous shielding means for said strands comprising a plurality of layers alternately of highly conducting, substantially non-magnetic material such as copper or aluminum of not more than critical thickness and of high permeability magnetic material, such as iron, at least of characteristic thickness characterized in this, that said plurality of layers is divided into two shield structures, one of which is placed directly about one of said strands to form a unitary structure therewith and the other of which entirely encloses the other of said strands.
3. Two adjacent continuous strands of high frequency signaling conductors, continuous shielding means for said strands comprising a composite shield placed close about one of said strands to form a unitary structure therewith and having an inner copper sheath of not more than critical thickness and an outer iron sheath, and a composite shield placed close about the other of said strands to form a unitary structure therewith and having an inner copper sheath of not more than critical thickness and an outer iron sheath, said iron sheaths being adjacent and their combined thickness being at least equal to the characteristic thickness.
4. The combination in accordance with claim 3 in which said shielding means further comprises a composite shield common to both of said strands and having a copper sheath of not more than critical thickness and an iron sheath adjacent to said outer iron sheaths, the combined thickness of said last iron sheath and either of said outer iron sheaths being at least equal to the characteristic thickness.
5. Two adjacent strands of high frequency signaling conductors, continuous shielding means for reducing mutual electrical disturbing effects between said strands, said shielding means comprising two sheaths, each of not more than the critical thickness of a highly conducting, substantially non-magnetic material such as copper

or aluminum, said sheaths being separated by sheathing of magnetic material such as iron, of at least the characteristic thickness, one of said non-magnetic sheaths being placed to entirely surround one of said strands and exclude the other and the other of said non-magnetic sheaths being placed to entirely surround the other strand and exclude the said first strand.

6. In a multiple conductor cable two strands of conductors and continuous shielding means between said strands comprising a plurality of metallic layers alternately of copper and iron formed into two shields each enclosing one strand to the exclusion of the other respectively, said shields each having an inner layer of copper of not more than critical thickness, and an outer layer of iron of at least half the characteristic thickness.

7. Two adjacent strands of high frequency signaling conductors, continuous shielding means placed close about one of said strands to form a unitary structure therewith and comprising an inner layer of copper and an outer layer of iron, other continuous shielding means entirely surrounding the other of said strands and comprising a layer of copper and contiguous thereto a layer of iron immediately adjacent to the first said layer of iron throughout their common length, the total thickness of said two layers of iron being at least equal to the characteristic thickness of the iron.

8. Two adjacent continuous strands of high frequency signaling conductors, continuous shielding means for said strands comprising a composite shield placed close about one of said strands to form a unitary structure therewith and having a thin inner copper sheath and an outer iron sheath, and a composite shield placed close about the other of said strands to form a unitary structure therewith and having a thin inner copper sheath and an outer iron sheath, said iron sheaths being adjacent and their combined thickness being about equal to the characteristic thickness of the iron.

9. In a multiple conductor cable, two strands of conductors and continuous shielding means between said strands comprising a plurality of thin metallic layers alternately of copper and iron formed into two shields each enclosing one strand to the exclusion of the other respectively, said shields each having an inner layer of copper and an outer layer of iron of about half the characteristic thickness.

10. Two adjacent strands of high frequency signaling conductors, continuous shielding means for said strands comprising a plurality of layers alternately of highly conducting, substantially non-magnetic material, such as copper or aluminum, of not more than critical thickness as determined at frequencies of the order of 45,000 cycles per second, and of high permeability magnetic material, such as iron, at least of characteristic thickness characterized in this, that said plurality of layers is divided into two shield structures, one of which is placed directly about one of said strands to form a unitary structure therewith and the other of which entirely encloses the other of said strands.

11. Two adjacent strands of high frequency signaling conductors, continuous shielding means for reducing mutual electrical disturbing effects between said strands, said shielding means comprising two sheaths, each of not more than the critical thickness of a highly conducting, substantially non-magnetic material such as copper or aluminum, said sheaths being separated by sheathing of magnetic material, such as iron, of at least the characteristic thickness, one of said non-magnetic sheaths being placed to entirely surround one of said strands and exclude the other and the other of said non-magnetic sheaths being placed to entirely surround the other strand and exclude the said first strand the critical thickness of said highly conductive sheaths being that which may be observed at any of the frequencies of signaling over said two strands.

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