

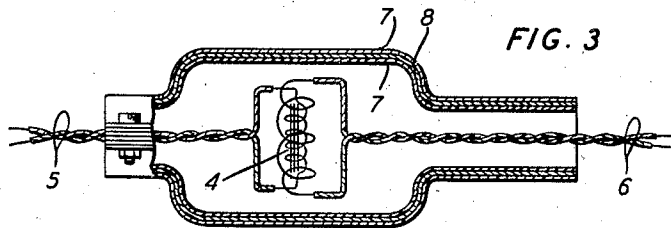
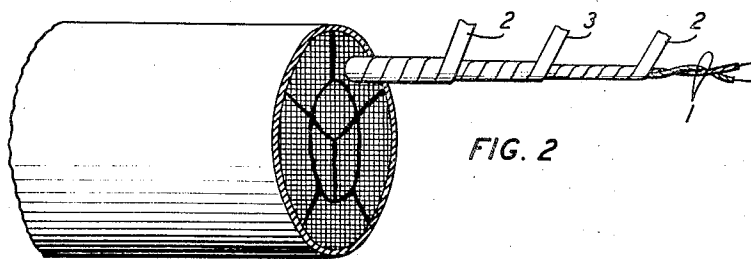
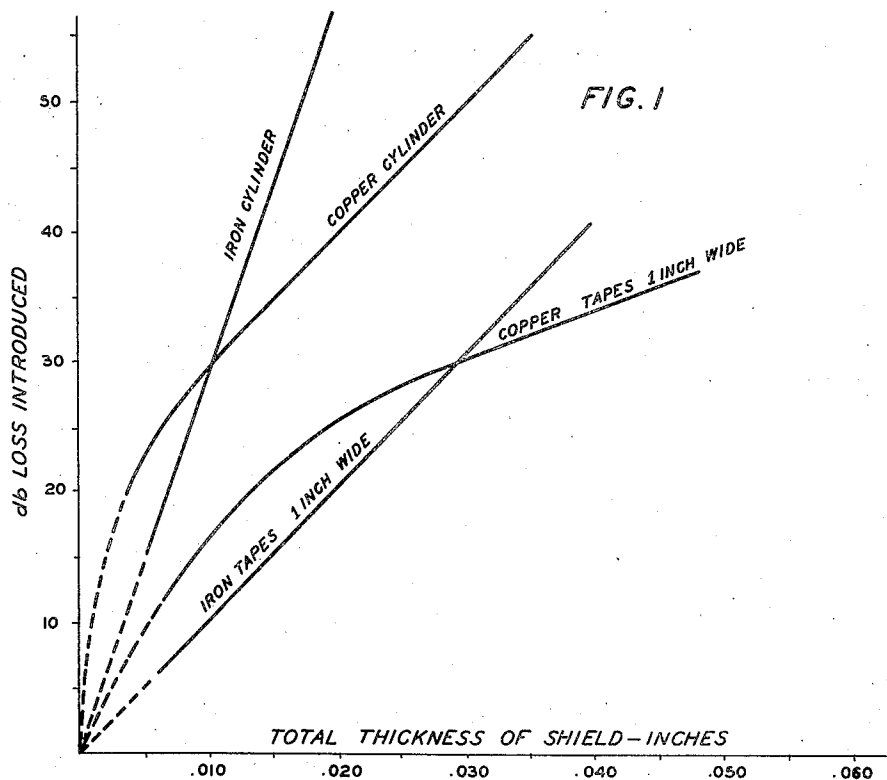
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SHIELDING

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SHIELDING

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This invention relates to shielding of electrical circuits and the constituent elements of electrical circuits.

It is important that circuits employed for transmitting telephone voice currents or other high frequency currents of communication systems be protected against electromagnetic as well as electrostatic disturbances from outside sources. This is more important in the case of circuits used for transmission of currents of the lowest range of values since in such cases the energy picked up from the outside source may exceed that of the signal conveying currents which the apparatus transmits. In telephony it has long been the practice to shield certain circuits or groups of circuits in cables by means of metallic tapes applied helically over the circuits. At low frequencies thin lead tapes have been found sufficient to eliminate interference due to the electrostatic interaction of adjacent circuits or to shield circuits from disturbing waves from outside sources, but when circuits transmitting high frequency currents are involved, lead in reasonable quantities has been found insufficient to effectively eliminate electromagnetic interference. Copper and iron tapes have also been used to some extent.

Also in the field of radio communication shielding is a problem of considerable importance in many instances. Here too it is the practice to shield with metallic netting, thin metallic sheeting and heavy metallic sheeting depending upon the degree of protection required. It has generally been found, however, that a very high degree of protection from outside interference in any case can only be obtained by the use of an excessively thick shield.

It is an object of the invention described herein to provide an electromagnetic shield capable of giving a high degree of protection against electromagnetic disturbances of all kinds and at the same time containing less material than the usual type of shields giving the same protection would contain. The principles embodied in the construction of this shield may be briefly stated as follows:

It has been determined experimentally that the protection afforded by copper shields, or in other words the decrease in the energy of electromagnetic disturbances traveling through copper shields, increases very rapidly with increase in the thickness of the shield when the thickness is relatively small (usually less than 0.01"). When, however, the thickness of the shield exceeds a certain critical value, dependent

upon the construction of the shield, the ratio of the shielding effect to the thickness is reduced. As an example of the above facts the following observations made on copper cylinders at a frequency of 45 kilocycles are presented.

Aggregate thickness of wall of cylinder	Energy loss in decibels	Loss in db. per 0.001"
0.004 inch	22	5.5
0.0063 inch	25	4.0
0.010 inch	30	3.0
0.020 inch	40	2.0
0.030 inch	52	1.7

The kind of results indicated by this data has been observed in experiments with a number of other types of copper shields. Variations of construction such as replacement of cylinders by helically applied tapes alter the absolute values but in each case wherein a copper shield is employed there is apparently a certain "critical thickness" beyond which the transmission loss per unit of thickness falls off rapidly. In the case of copper according to the data given above, the critical thickness is around 0.004 inch.

Similar experiments with iron shields have indicated that iron has shielding characteristics somewhat different from those of copper. It has been found that the energy loss is almost directly proportional to the thickness over the entire experimental range of thicknesses with a considerable variety of different constructions. Accordingly it would seem that where one material is used and a high degree of protection is required the shield should be of iron.

Following along the lines indicated above, however, it becomes apparent that if the total thickness of a copper shield is divided up into a number of critical thicknesses each having the shielding effect of a single critical thickness the resultant shield will have a high total loss of energy on an absolute basis and in addition will have a high ratio of shielding effect to total shield thickness. It has been found that such a result may be obtained by placing shields of iron between shields of copper. That is, two thin copper shields separated by an iron shield of suitable thickness act individually to introduce a loss corresponding to a shield of their individual thickness rather than as a single copper shield having an aggregate thickness equal to that of the two. The following table demonstrates this point: (In securing the data in this table, tests were made upon circuits shielded with layers of tape 3 inches in width, the number of

layers, the thickness and the arrangement being as stated).

5	Construction of shield	Energy loss in db. noted with each component	Loss in db. due to composite shield
10	2 layers copper tape 0.002" thick.....	19	60
	2 layers iron tape 0.005" thick.....	21	
	2 layers copper tape 0.002" thick.....	19	
	4 layers copper tape 0.002" thick.....		
	2 layers iron tape 0.005" thick.....		
			26
			21

Thus the sum of the measured energy losses of each component of the composite shield is approximately equal to the total measured loss of the combination of the three shielding elements separately but the total loss due to the same thickness of copper in one layer and the same thickness of iron was 13 db. less.

Thus the shielding effect obtained by using two thin copper shields separated by an iron shield is in this case approximately 13 db. greater than that which might be expected were the copper shields adjacent and of the same aggregate thickness. All of the figures presented here are for purposes of comparison only and are not to be taken as measures of shielding effect except under a special condition.

In completing a statement of the principles involved in this invention it is desired for purposes of emphasis and clarity to clearly define two terms already used:—

The "critical thickness" of a shield of one material is here defined as that thickness beyond which the shielding effect per unit of total thickness shows a noteworthy decrease. The critical thickness is dependent upon the construction of the shield as well as the characteristics of the material. In the case of some materials there is no critical thickness. In the case of the cylindrical copper shield for which data is given above, the critical thickness is around 0.004 inch.

The "characteristic thickness" of a shield of magnetic material of one material is here defined as that thickness which is sufficient to separate two shields of non-magnetic conducting material, one on either side, so that each of those shields has the same shielding effect as it would have if taken individually.

It is noted that the division of a layer of homogeneous material into thinner layers with a small air gap between produces very little change in shielding effect. Thus two adjacent layers of copper or iron 0.005 inch thick are very little different in shielding effect from a single layer of copper or iron respectively, 0.010 inch thick.

Therefore, shields in accordance with the present invention comprise generally an electrostatic and electromagnetic shielding structure built up from several thin shields of two types of material; each type occurring alternately. The first type of shield is of some material, generally copper, which has a relatively high conductivity and exhibits a high shielding effect per unit thickness up to a certain thickness which has already been described as a "critical thickness". The second type of shield is of some material, generally iron, the characteristics of which are sufficiently different from those of the first type to result in its separating two shields of the first type on either side of it so that those two shields act as individuals and not as a single shield having the aggregate thickness of the two. It is desirable that the second type of shield be effective as a shield in

itself, but its primary purpose is to separate the two shields of the first type on either side of it. The thickness of each shield of the first type should be the critical thickness for the material and construction used. This can be determined experimentally upon a single shielding layer. The thickness of each shield of the second type should be sufficient in the case of that particular material and construction to effectively separate the shields of the first type on either side of it so that each of those shields has the same efficiency as it would have were it taken alone; that is, it should be of characteristic thickness or greater. As has been stated these two types of shields should be placed alternately and generally although not necessarily both outside layers should be shields of the first type to obtain a maximum loss with a given total thickness.

In the accompanying drawing:

Fig. 1 comprises graphs indicating variation in attenuation loss with thickness of iron and copper shields of various forms;

Fig. 2 illustrates a telephone cable comprising a group of insulated conductors protected by a shield in accordance with the invention; and

Fig. 3 illustrates a transformer coil protected from disturbances by a shield in accordance with the invention.

Fig. 1 shows the following points, (a) that iron has a shielding effect very nearly proportional to the thickness, (b) that copper, on the contrary, has a shielding effect per unit of thickness which is much less for thick than for thin shields and (c) that the effectiveness of a shield is a function of its physical conformation. The measurements from which the graphs of Fig. 1 are taken were made at a frequency of 45000 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.

Fig. 2 shows a telephone conductor pair 1 shielded with alternate copper tapes 2 and iron tape 3. The copper tapes are preferably no thicker than the critical thickness which in this case with tapes three inches wide with fairly closely abutting edges is about 0.005 to 0.007 inch. If more copper is employed to increase the shielding effect than is necessary to make a layer of the critical thickness it is profitable to divide the copper into additional layers separated by iron or equivalent magnetic material of at least the characteristic thickness. The conductors 1 typify a single pair as well as a quad, a larger bundle of conductors, or an entire cable. In the latter case the shield may be applied just under or over the lead sheath.

Fig. 3 is a diagrammatic indication of a transformer coil 4 with primary leads 5 and secondary leads 6 shielded with layers 7 composed of copper and a layer 8 composed of iron. For best results with a given amount of material the copper need not be over about 0.004 inch in thickness. This iron may be any suitable value such as 0.005 or 0.010 inch in thickness. The coil 4 is typical of any desired apparatus to be shielded, such as a vacuum tube repeater, a detector, or a sensitive relay.

With 3-layer shields constructed in accordance with the foregoing principles, it has been found possible to introduce an additional loss of as high

as 60 db. between closely adjacent coils or circuits. Although developed principally for shielding high frequency carrier current conductors from cross talk and disturbances, shields in accordance with the invention are generally applicable. They may be constructed of spirally wrapped tape, or in the form of enclosures with unbroken surfaces, as the necessities of the case demand.

Two kinds of attenuation are of importance in many shields. Let us consider, for example, the shield between adjacent circuits as shown in Fig. 2. The attenuation of the interfering energy passing from one circuit to the other has been discussed heretofore and the attenuation of this should be large, the larger the better. The other kind of attenuation, not previously discussed herein, but which is of some consequence, is the attenuation of the energy of alternating currents traversing a pair of shielded conductors from one end of a circuit to the other. Obviously this attenuation per unit length of the circuit should be small, in most cases the smaller it is the more desirable is the shield. Applicant has experimentally determined that an all-copper shield causes less attenuation in the circuits immediately adjacent to it than a shield consisting wholly of iron or other magnetic material. Moreover, the copper-iron-copper shield such as disclosed in Fig. 2 possesses the characteristic property of producing the same low attenuation in adjacent circuits as though the shield consisted entirely of copper. However, the shielding effect is superior to either all iron or all copper shield of the same total thickness. Apparently these properties are of general application, that is, in all cases of composite shields consisting of alternate layers of highly conducting non-magnetic material and conducting highly magnetic material, the least attenuation results in adjacent circuits if the non-magnetic material forms the external layer of the shield next to the adjacent circuit or circuits in question.

What is claimed is:

1. An electromagnetic and electrostatic shield consisting of alternate substantially complete layers of at least two conducting materials at least one of which is highly ferro-magnetic and at least one of which is less ferro-magnetic, characterized in this that said material which is less ferro-magnetic is arranged in a layer not appreciably in excess of the critical thickness i. e. the thickness beyond which, for a given configuration and given material, the shielding effect per unit of thickness shows a noteworthy decrease.

2. An electromagnetic and electrostatic shield built up from a number of component conductive

and magnetic shields; the component shields consisting of shields of critical thickness of one material and shields of characteristic thickness of some other material arranged alternately, critical thickness being defined as the thickness of conductive material beyond which, for a given configuration and a given conductivity of material, the shielding effect per unit of thickness shows a noteworthy decrease, and "characteristic thickness" being defined as that thickness of magnetic material which is sufficient to separate two shields of conducting material so that each of those shields has the same effect as it would have if taken individually.

3. A high frequency conducting circuit shielded with an electromagnetic and electrostatic shield consisting of alternate spirally applied layers of at least two conducting materials at least one of which is highly ferro-magnetic and at least one of which is negligibly ferro-magnetic, characterized in this that said material which is negligibly ferro-magnetic is arranged in a layer not appreciably in excess of the critical thickness, critical thickness being defined as the thickness of conductive material beyond which, for a given configuration and a given conductivity of material, the shielding effect per unit of thickness shows a noteworthy decrease, and "characteristic thickness" being defined as that thickness of magnetic material which is sufficient to separate two shields of conducting material so that each of those shields has the same effect as it would have if taken individually.

4. The combination of two electrical circuits to be shielded from one another with a shield separating said circuits, said shield consisting of a layer of copper, a layer of highly magnetic material, and another layer of copper, the copper layers constituting the external surfaces of the shield.

5. An electrical shield consisting of a plurality of adjacent layers of iron and copper wherein the outside layers consist of copper.

6. An electrical shield consisting of a plurality of layers of material, said layers comprising highly magnetic material alternating with substantially non-magnetic material of high conductivity, the external layers consisting of said non-magnetic material.

7. An electrical circuit provided with a shield for shielding said circuit from disturbing electromagnetic waves originating externally to said circuit, said shielding means consisting of alternate layers of conducting non-magnetic material and highly magnetic material with the layer of material adjacent to said circuit being conducting non-magnetic material.

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