(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 243 023**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **87302894.8**

(51) Int. Cl.4: **A01B 11/00**

(22) Date of filing: **02.04.87**

(30) Priority: **07.04.86 US 848881**

(43) Date of publication of application:
28.10.87 Bulletin 87/44

(84) Designated Contracting States:
AT BE CH DE ES FR GB GR IT LI LU NL SE

(71) Applicant: **W.L. GORE & ASSOCIATES, INC.**
555 Paper Mill Road P.O. Box 9329
Newark Delaware 19711(US)

(72) Inventor: **Hubis, Paul Everett**
920 Linfield road
Newark, Delaware 19713(US)
Inventor: **Vana, James George**
2121 Cervin blvd
Austin, Texas 78728(US)
Inventor: **Miller, Stephen Charles**
1410 Vista Ridge Cove
Austin, Texas 78754(US)

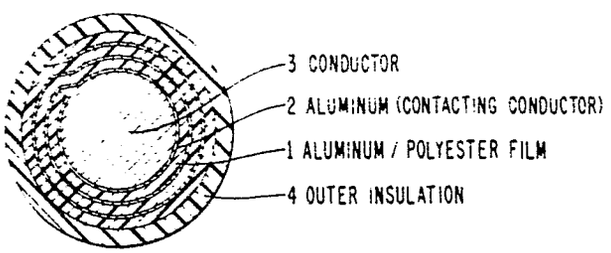
(74) Representative: **Taylor, Derek George et al**
Mathisen, Macara & Co. The Coach House
6-8 Swakeleys Road
Ickenham Uxbridge UB10 8BZ(GB)

(54) Transmission line cable.

(57) An electrical transmission wire consisting of a single or a twisted pair of wires has the effective electrical diameter of the primary conductor increased by wrapping conductive foil (2), or conductive foil (2) laminated to a substrate layer (1), on to a primary conductor (3) with a diameter less than 20 mils (0.508mm), the foil being in contact with the conductor. An outer insulating cover (4) may be applied over the wrapped wire.

The conductive wrapping can be a spiral wrapping or a longitudinal wrapping around the electrical conductor. A desired characteristic impedance along the length of the wire(s) can be achieved with easy removal of the wire covering for standard termination and increased cut-through resistance.

FIG. 1



EP 0 243 023 A2

TRANSMISSION LINE CABLE

This invention relates to the manufacture of an electric transmission wire including a primary conductor wherein the characteristic impedance along the length of the wire is low, yet the wire is capable of being terminated using standard termination equipment. This invention is particularly useful for solderless wrap connections to printed circuit boards or panels and for twisted wire and single wire interconnections.

Prior to this invention, transmission wire with a low impedance (less than 100 ohms) was not available for use with standard termination equipment. Typically, a primary conductor with a diameter greater than 20 mils (0.508mm) had to be selected in order to achieve a low characteristic impedance. Only a thin wall of insulation could be wrapped around the primary conductor without increasing the characteristic impedance. Since only a thin wall of insulation could be used, there was a poor cut-through resistance of this outer wall of insulation and there were other stripping difficulties.

Because of the low cut-through and abrasion resistance of these thin outer insulation walls, it was often necessary to apply a protective jacket over the wire. This further aggravated the stripping problem as the jacket first had to be removed during termination. During removal, the primary conductor is frequently damaged by the stripping blades. These difficulties have been eliminated, or at least substantially reduced, by the present invention.

According to the present invention there is provided an electric transmission wire comprising a primary conductor with a diameter of less than 20 mils (0.508mm) wrapped with at least one layer of material characterised in that said material comprises a conductive layer in continuous contact with the primary conductor, said primary conductor and wrapped conductive layer further wrapped with at least one layer of an insulating film such that the overall transmission wire maintains a characteristic impedance below 100 ohms.

Since the layer of conductive material, which can be conductive foil or a conductive foil laminated to a substrate layer, is in contact with the primary conductor, the effective electrical diameter of the primary conductor is increased. An outer layer of insulation may be applied over the foil and primary conductor.

The foil or foil laminate may be applied by either spiral wrapping or by longitudinal wrapping around the primary conductor. This invention provides a desired characteristic impedance along the length of the wire and allows easy removal for standard termination and increased cut-through resistance.

The invention will now be particularly described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a schematic representation of a cross-section of a single insulated wire according to the invention;

Figure 2 is a schematic representation of a cross-section of a twisted pair of insulated wires according to the invention, and

Figure 3 is a graphical representation depicting the relation between impedance and the ratio D/d where D is the diameter of the insulated wire and d is the actual diameter of the conductor.

In the present invention the effective electrical diameter of a primary conductor of less than 20 mils (0.508mm) diameter is increased by wrapping conductive foil, or conductive foil laminated to a substrate on to the primary conductor, the foil being in contact with the conductor. This may be accomplished by conventional wire wrapping techniques and equipment.

The primary conductor with conductive foil or laminate in contact with it is able to maintain a low characteristic impedance and still be compatible with standard termination equipment and printed circuit boards.

A thicker layer of outer insulation may be applied over the wrapped primary conductor and will not affect the characteristic impedance. This provides increased cut-through resistance. Conventional stripping equipment may be used with the wrapped wire and the thicker layer of outer insulation is easily removed for termination.

The invention also provides benefits for applications in state of the art electronic equipment. The primary conductor with a diameter of less than 20 mils (0.508mm) is compatible with terminal and grid spacings of a printed circuit board having 0.025 square inch (0.16 sq.cm) terminal with grid spacing of 0.100 inch (0.254cm).

An inventive embodiment may be used either as a single insulated wire or two insulated wires may be twisted together and be used as a pair of twisted wires.

Referring to the cross-sectional view of a single insulated wire depicted in Figure 1, a conductive metal foil laminate, consisting of a metal foil coating 2 on a laminar support 1, is spirally wrapped

around a primary conductor 3 with the metal foil 2 facing into and in continuous contact with the primary conductor 3 and making electrical contact between the primary conductor 3 and foil 2. The preferred metal foil laminate comprises aluminum foil bonded to polyester or polyimide base film 1 or aluminum foil bonded to a film of expanded polytetrafluoroethylene 1. The primary conductor 3 may have a single wrapping of metal foil or it may have a plurality of wrappings, depending on the desired thickness of the wall, as depicted in Figure 1. Additional insulation 4, if required, is applied over the top of the metal foil laminate wrapping.

Figure 2 shows a cross-sectional view of a twisted pair of insulated wires in which a conductive metal foil laminate, consisting of metal foil 12 on a laminar support 10, is spirally wrapped around each primary conductor 13 with the metal foil 12 facing the wires and in continuous contact with primary conductors 13 making electrical contact between the primary conductors 13 and the foil 12. Additional insulation 14, if required, is applied over the top of the metal foil laminate wrapping.

Figure 2 also shows the initial diameter of the primary conductor 13 as being d_i. As the conductive metal foil is wrapped around each conductor, the effective electrical diameter is increased and is measured as d_{eff} . Without the conductive wrapping, the primary conductor actual diameter d_i is also its effective electrical diameter. Additional insulation 14 may be applied over the top of the metal foil laminate wrapping. The total diameter of the conductor 13, wrapped conductive foil 12, support 10 and outer insulation covering 14 is measured as D. The characteristic impedance Z is logarithmically related to the diameter of the insulated wire by the ratio D/d. Where the invention is used, the diameter of the primary conductor (d) is substituted by d_{eff}. Thus, by using the invention, the characteristic impedance is reduced because the effective electrical diameter of the primary conductor is increased.

In a preferred embodiment, the additional insulation 14 may be a polyester film or polyimide based film insulation. This additional insulation may be applied by extrusion or by additional wrapping to a desired outside diameter. Cut-through resistance is increased by the addition of this insulation.

EXAMPLE 1

Existing solderless wrap on a primary conductor, and a primary conductor wrapped according to the present invention, for a single 50 ohm insulated wire are contrasted. A final outer diameter of wire of 19.6 mils. (0.498mm) is desired as this is the optimum size for automatic wire stripping equipment.

Using conventional technology, a single 28(I) AWG (American Wire Gauge) primary conductor with an actual diameter of 12.6 (0.32mm), delectric constant E = 3.1 and a characteristic impedance of 50 ohms, was covered by an outer layer of polyester film insulation. Here, the final diameter of 14.1 mils (0.358mm) was attained without increasing the characteristic impedance. A D/d ratio of 1.12 was calculated by referring to Figure 3.

Using the present invention, a single 28(I) AWG primary conductor of actual diameter 12.6 mils (0.32mm) was wrapped with three layers of aluminum foil laminated tape whereby the foil was in constant physical contact with the primary conductor. An outer layer of polyester film insulation was applied over the primary conductor foil combination. The final diameter of this embodiment was 19.6 mils (0.498mm).

By wrapping the foil around the primary conductor, the diameter of the primary conductor of 12.6 mils (0.32mm) was increased to an effective electrical diameter of 17.5 mils (0.445mm).. The characteristic impedance was maintained at 50 ohms and the resulting wire had a calculated D/d ratio of 1.13.

The following chart summarizes results of the calculated outer wall thickness and cut-through radius of curvature for both conventional solderless wrap on a primary conductor and the present invention.

CHART 1

Comparison of 28(1) AWG Primary Conductors
Using Existing Technology And The
Present Invention for 50 ohms Impedance

	Z_0 ohms	d mils (mm)	d_{efff} mils (mm)	D/d	D/d_{eff}	D mils (mm)	Outer Wall mils (mm)	Cut-through Radius of Curvature mils (mm)
Conventional Technology	50	12.6 (0.32)	-	1.12	-	14.1 (0.358)	0.75 (0.019)	7.05 (0.179)
Foil-Wrapped	50	12.6 (0.32)	17.5 (0.445)	-	1.13	19.6 (0.498)	1.05 (0.027)	9.8 (0.249)

Wall = (D-d) $\div$ 2

Cut-through radius of curvature = D $\div$ 2

An insulated wire with an outer wall thickness of 0.75 mils (0.019mm) does not fit standard automated stripping machines. The standard wire cutting equipment is not able to cut into, grab and pull off the outer wrapping without injury to the primary conductor. Further, a radius of curvature of 7.05 mils (0.179mm) does not meet conventional wire cut-through requirements.

In contrast, the present invention provides a primary conductor with an increased electrical diameter and increased outer wall diameter and cut-through radius of curvature so that standard automated stripping machines could be used.

EXAMPLE 2

A comparison similar to that described in Example 1 was also made with a 28(l) AWG primary conductor with an actual diameter of 12.6 mils (0.32mm), dielectric constant E = 3.1 and a characteristic impedance of 55 ohms. Here the D/d ratio was found to be 1.15 by referring to Figure 3.

Test data was accumulated and calculations made were similar to those as described in Example 1. Test results are summarised in Chart 2 shown below.

CHART 2

Comparison of 28(1) AWG Primary Conductors
using Existing Technology And The Present Invention
for Wire With A Characteristic Impedance of 55 ohms

	Z_0 ohms	d mils (mm)	d_{efff} mils (mm)	D/d	D/d_{eff}	D mils (mm)	Outer Wall mils (mm)	Cut-through Radius of Curvature mils (mm)
Conventional Technology	55	12.6 (0.32)	-	1.15	-	14.5 (0.368)	0.95 (0.024)	7.25 (0.184)
Foil-Wrapped	55	12.6 (0.32)	17.5 (0.445)	-	1.15	20.1 (0.51)	1.30 (0.031)	10.1 (0.257)

Wall = (D-d) ÷ 2

Cut-through radius of curvature = D ÷ 2

Here again, one skilled in the art can see that the inventive entity allows the impedance to remain at 55 ohms but the outer wall and cut-through radius are increased (by 39%) and can be used with existing wire stripping equipment.

EXAMPLE 3

Existing solderless wrap of primary conductors and the present invention for a 75 ohm twisted pair of insulated wires are compared. An outside diameter of 19.5 mils (0.495mm) is desired as this is the optimum size for the automatic wire-stripping machines.

Using conventional technology, a pair of 30(l) AWG primary conductors with initial diameters of 10.1 mils (0.257mm), dielectric constant of 3.12, a characteristic impedance of 75 ohms is extrapolated from Figure 3 to have a D/d ratio of 1.36.

Similarly, a pair of 30(l) AWG primary conductors are individually wrapped with aluminum foil laminated tape so that the foil is in constant physical contact with each primary conductor. Here, the outer diameter D is 19.5 mils (0.495mm), the effective electrical diameter d_{eff} is 14.4 mils (0.366mm), and the ratio of D/d_{eff} is found to be 1.31.

The following chart summarizes physical characteristics of a 30(l) AWG twisted pair using existing art and a twisted pair as constructed by the present invention.

CHART 3

75 ohm Twisted Pair 30(1) AWG

	Z_0 ohms	d mils (mm)	d_{efff} mils (mm)	D/d	D/d_{eff}	D mils (mm)	Outer Wall mils (mm)	Cut-through Radius of Curvature mils (mm)
Conventional Technology	75	10.1 (0.257)	-	1.36	-	13.6 (0.345)	1.8 (0.046)	6.8 (0.173)
Foil-Wrapped	75	10.1 (0.257)	14.4 (0.366)	-	1.31	19.5 (0.495)	2.60 (0.066)	9.75 (0.248)

Wall = (D-d) ÷ 2

Cut-through radius of curvature = D ÷ 2

In this example, we achieve the desired combination of a 30(I) AWG twisted pair of wires with an outer diameter of 19.5 mils (0.495mm) and maintain the desired impedance of 75ohms. If one were simply to insulate the 30(I) AWG with polyester film insulation to make an outer diameter of 19.5 mils (0.495mm), the characteristic impedance would be 100 ohms.

Also for a 75 ohm twisted pair 30(I) AWG, the wall thickness has been increased to add cut-through resistance without increasing the characteristic impedance in this invention. Further, the cut-through radius of curvature is increased by 43% and is easily compatible with existing stripping equipment.

Claims

1. An electric transmission wire comprising a primary conductor with a diameter of less than 20 mils (0.508mm) wrapped with at least one layer of material characterised in that said material comprises a conductive layer in continuous contact with the primary conductor, said primary conductor and wrapped conductive layer further wrapped with at least one layer of an insulating film such that the overall transmission wire maintains a characteristic impedance below 100 ohms.

2. An electric transmission wire according to claim 1 characterised by a second primary conductor with a diameter of less than 20 mils (0.508mm) wrapped with a said conductive layer in continuous contact therewith and further wrapped with at least one layer of an insulating film, the two wrapped conductors twisted together.

3. An electric transmission wire according to claim 1 characterised in that said wire maintains a characteristic impedance less than 75 ohms.

4. An electric transmission wire according to claim 1 characterised in that the conductive wrapping material is aluminum laminated to polyester film.

5. An electric transmission wire according to claim 1 characterised in that the conductive wrapping material is aluminum laminated to an expanded PTFE film.

6. An electric transmission wire according to claim 1 characterised in that the conductive wrapping material is aluminum laminated to a polyimide film.

7. An electric transmission wire according to claim 1 characterised in that the conductive wrapping material is wrapped spirally around said primary conductor.

8. An electric transmission wire according to claim 1 characterised in that the conductive wrapping material is wrapped longitudinally around said primary conductor.

FIG. 1

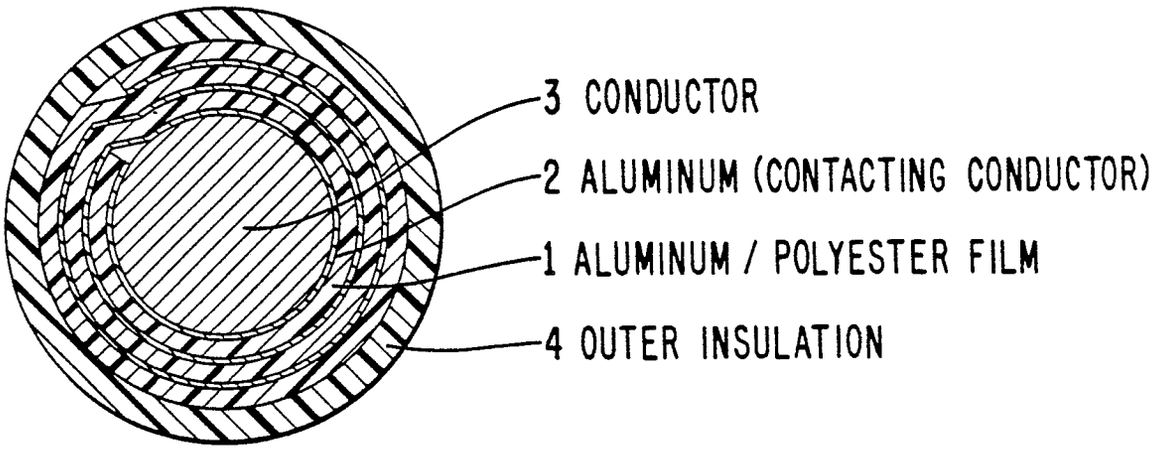


FIG. 2

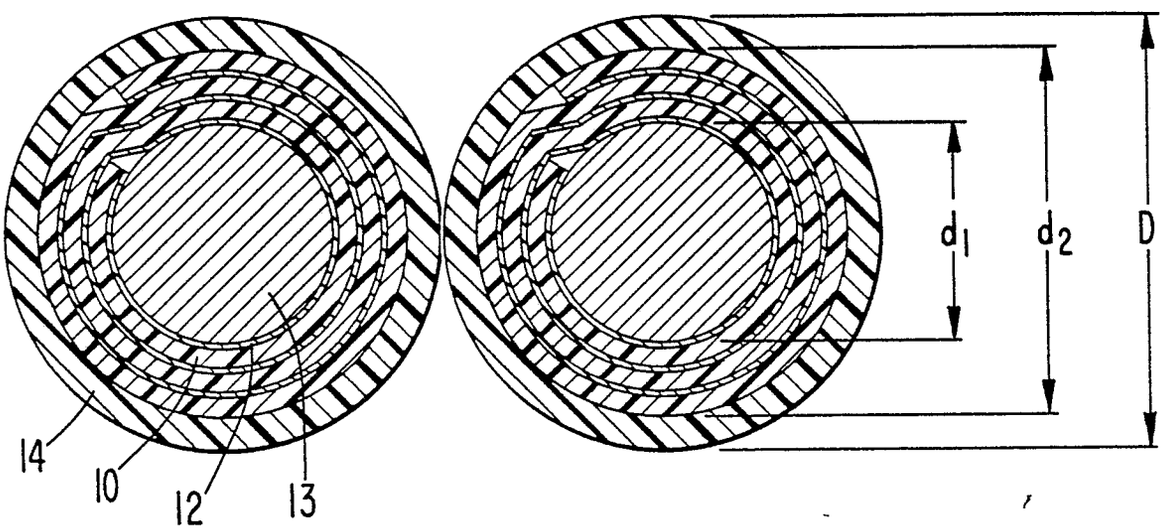


FIG. 3