UNITED STATES DISTRICT COURT

DISTRICT OF DELAWARE

BELDEN TECHNOLOGIES, INC. and BELDEN CDT (CANADA) INC., Plaintiffs, v. SUPERIOR ESSEX INC. and SUPERIOR ESSEX COMMUNICATIONS LP, Defendants.	Civil Action No. _____ JURY TRIAL DEMANDED

COMPLAINT

1. Plaintiff Belden Technologies, Inc. is a Delaware corporation having a principal place of business at 7701 Forsyth Boulevard, Suite 800, St. Louis, Missouri 63105.

2. Plaintiff Belden CDT (Canada) Inc. is organized under the laws of Canada and has a principal place of business at 100 King Street West, Toronto, Ontario, Canada M5X 1G5. (Herein, "Belden" may be used to refer to either of Plaintiffs or both of them collectively.)

3. On information and belief, Defendant Superior Essex Inc. is a Delaware corporation having a principal place of business at 150 Interstate North Parkway, Atlanta, Georgia 30339.

4. On information and belief, Defendant Superior Essex Communications LP is an entity organized under the laws of Delaware and has a principal place of business at 150 Interstate North Parkway, Atlanta, Georgia 30339.

5. This action arises under the patent laws of the United States, Title 35 of the United States Code. This Court has jurisdiction over the subject matter of this action pursuant to

28 U.S.C. §§1331 and 1338(a).

6. As alleged herein, Defendants – individually, together, and/or either or both Defendants jointly with others – have infringed (literally and/or by equivalents), and continue to infringe, Belden's patent rights by making, using, importing, selling, and/or offering to sell products covered by one or more patent claims – or by performing any method claimed therein – within the United States, and/or by contributing to or inducing such infringement.

Count I
Infringement of U.S. Patent No. 5,424,491

7. Belden repeats and realleges the foregoing paragraphs.

8. Belden is the owner of United States Patent No. 5,424,491, entitled "Telecommunications Cable," ("the '491 patent") and has the right to sue on the '491 patent. A copy of the '491 patent is attached as Exhibit A.

9. Defendant Superior Essex Inc. has infringed (literally and/or by equivalents), and is continuing to infringe, the '491 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '491 patent claims within the United States, and/or by contributing to or inducing such infringement.

10. Defendant Superior Essex Inc.'s infringement of the '491 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

11. Defendant Superior Essex Communications LP has infringed (literally and/or by equivalents), and is continuing to infringe, the '491 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '491 patent claims within the United States, and/or by contributing to or inducing such infringement.

12. Defendant Superior Essex Communications LP's infringement of the '491 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

Count II
Infringement of U.S. Patent No. 6,074,503

13. Belden repeats and realleges the foregoing paragraphs.

14. Belden is the owner of United States Patent No. 6,074,503, entitled "Making Enhanced Data Cable With Cross-Twist Cabled Core Profile," ("the '503 patent") and has the right to sue on the '503 patent. A copy of the '503 patent is attached as Exhibit B.

15. Defendant Superior Essex Inc. has infringed (literally and/or by equivalents), and is continuing to infringe, the '503 patent by performing any method claimed therein, within the United States, and/or by contributing to or inducing such infringement.

16. Defendant Superior Essex Inc.'s infringement of the '503 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

17. Defendant Superior Essex Communications LP has infringed (literally and/or by equivalents), and is continuing to infringe, the '503 patent by performing any method claimed therein, within the United States, and/or by contributing to or inducing such infringement.

18. Defendant Superior Essex Communications LP's infringement of the '503 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

Count III
Infringement of U.S. Patent No. 6,570,095

19. Belden repeats and realleges the foregoing paragraphs.

20. Belden is the owner of United States Patent No. 6,570,095, entitled "Multi-Pair Data Cable With Configurable Core Filling And Pair Separation," ("the '095 patent") and has the right to sue on the '095 patent. A copy of the '095 patent is attached as Exhibit C.

21. Defendant Superior Essex Inc. has infringed (literally and/or by equivalents), and is continuing to infringe, the '095 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '095 patent claims within the United States, and/or by contributing to or inducing such infringement.

22. Defendant Superior Essex Inc.'s infringement of the '095 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

23. Defendant Superior Essex Communications LP has infringed (literally and/or by equivalents), and is continuing to infringe, the '095 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '095 patent claims within the United States, and/or by contributing to or inducing such infringement.

24. Defendant Superior Essex Communications LP's infringement of the '095 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

Count IV
Infringement of U.S. Patent No. 6,596,944

25. Belden repeats and realleges the foregoing paragraphs.

26. Belden is the owner of United States Patent No. 6,596,944, entitled "Enhanced Data Cable With Cross-Twist Cabled Core Profile," ("the '944 patent") and has the right to sue on the '944 patent. A copy of the '944 patent is attached as Exhibit D.

27. Defendant Superior Essex Inc. has infringed (literally and/or by equivalents), and is continuing to infringe, the '944 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '944 patent claims within the United States and/or by contributing to or inducing such infringement.

28. Defendant Superior Essex Inc.'s infringement of the '944 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

29. Defendant Superior Essex Communications LP has infringed (literally and/or by equivalents), and is continuing to infringe, the '944 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '944 patent claims within the United States and/or by contributing to or inducing such infringement.

30. Defendant Superior Essex Communications LP's infringement of the '944 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

Count V
Infringement of U.S. Patent No. 6,998,537

31. Belden repeats and realleges the foregoing paragraphs.

32. Belden is the owner of United States Patent No. 6,998,537, entitled "Multi-Pair Data Cable With Configurable Core Filling and Pair Separation," ("the '537 patent") and has the right to sue on the '537 patent. A copy of the '537 patent is attached as Exhibit E.

33. Defendant Superior Essex Inc. has infringed (literally and/or by equivalents), and is continuing to infringe, the '537 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '537 patent claims within the United States and/or by contributing to or inducing such infringement.

34. Defendant Superior Essex Inc.'s infringement of the '537 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

35. Defendant Superior Essex Communications LP has infringed (literally and/or by equivalents), and is continuing to infringe, the '537 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '537 patent claims within the United States and/or by contributing to or inducing such infringement.

36. Defendant Superior Essex Communications LP's infringement of the '537 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

Count VI
Infringement of U.S. Patent No. 7,179,999

37. Belden repeats and realleges the foregoing paragraphs.

38. Belden is the owner of United States Patent No. 7,179,999, entitled "Multi-Pair Data Cable With Configurable Core Filling and Pair Separation," ("the '999 patent") and has the right to sue on the '999 patent. A copy of the '999 patent is attached as Exhibit F.

39. Defendant Superior Essex Inc. has infringed (literally and/or by equivalents), and is continuing to infringe, the '999 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '999 patent claims within the United States, and/or by contributing to or inducing such infringement.

40. Defendant Superior Essex Inc.'s infringement of the '999 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

41. Defendant Superior Essex Communications LP has infringed (literally and/or by equivalents), and is continuing to infringe, the '999 patent by making, using, importing, selling, and/or offering to sell products covered by one or more of the '999 patent claims within the United States, and/or by contributing to or inducing such infringement.

42. Defendant Superior Essex Communications LP's infringement of the '999 patent is and has been willful, has caused and will continue to cause Belden to suffer substantial damages, and has caused and will continue to cause Belden to suffer irreparable harm for which there is no adequate remedy at law.

PRAYER FOR RELIEF

WHEREFORE, Belden requests that this Court enter judgment as follows ordering that:

(a) Defendants infringe the '491, '503, '095, '944, '537 and '999 patents by their making, using, offering for sale, selling and/or offering to sell products covered by one or more of the '491, '503, '095, '944, '537 and '999 patent claims within the United States, and/or by contributing to or inducing such infringement;

(b) Defendants' infringement of the '491, '503, '095, '944, '537 and '999 patents is willful;

(c) Defendants and their affiliates, subsidiaries, officers, directors, employees, agents, representatives, licensees, successors, assigns, and all those acting for any of them or on their behalf, or acting in concert with them, be preliminarily and permanently enjoined from further infringement of Belden's patent rights;

(d) Plaintiffs be awarded compensatory damages and costs, with prejudgment interest;

(e) Plaintiffs be award treble damages for the willful patent infringement;

(f). This case be declared to be exceptional in favor of Plaintiffs under 35 U.S.C. § 285, and that Plaintiffs be awarded their costs, attorneys' fees, and other expenses incurred in connection with this action; and

(g) Plaintiffs be awarded such other relief as the Court deems just and proper.

JURY DEMAND

Belden demands a trial by jury on all issues so triable.

YOUNG CONAWAY STARGATT & TAYLOR, LLP

John W. Shaw (#3362)
Karen E. Keller (#4489)
The Brandywine Building, 17th Floor
1000 West Street
Wilmington, DE 19801
kkeller@ycst.com
(302) 571-6554

Attorneys for Plaintiffs Belden Technologies, Inc. and Belden CDT (Canada) Inc.

Of Counsel:

Matthew B. Lowrie
Robert J. Silverman
LOWRIE, LANDO & ANASTASI, LLP
Riverfront Office Park
One Main Street - 11th Floor
Cambridge, MA 02142
(617) 395-7000

EXHIBIT A

US005424491A

United States Patent [19]

Walling et al.

[11] Patent Number: 5,424,491

[45] Date of Patent: Jun. 13, 1995

[54] TELECOMMUNICATIONS CABLE

[75] Inventors: Jorg-Hein Walling, Beaconsfield; Clement Gagnon, Pierrefonds; Paul P. Kish, St. Lazare; Martin L. Belanger, Montreal, all of Canada

[73] Assignee: Northern Telecom Limited, Montreal, Canada

[21] Appl. No.: 133,392

[22] Filed: Oct. 8, 1993

[51] Int. Cl.[6] H01B 11/04

[52] U.S. Cl. ..... 174/113 R; 174/34

[58] Field of Search ..... 174/113 R, 34

[56] References Cited

U.S. PATENT DOCUMENTS

3,271,508	9/1966	Burr	174/34
3,489,844	1/1970	Motley	174/34
4,408,443	10/1983	Brown et al.	174/34
4,697,051	9/1987	Beggs et al.	174/34
4,873,393	10/1989	Friesen et al.	174/34
5,010,210	4/1991	Sidi et al.	174/34
5,162,609	11/1992	Adriaenssens et al.	174/34

FOREIGN PATENT DOCUMENTS

1265877	5/1961	France	174/34
197808	6/1978	Germany	174/34
1059343	2/1967	United Kingdom	174/34

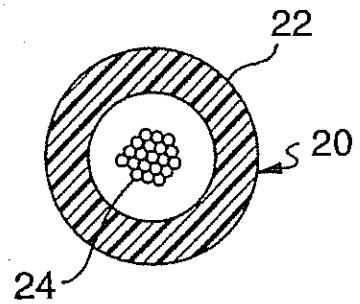
Primary Examiner—Morris H. Nimmo

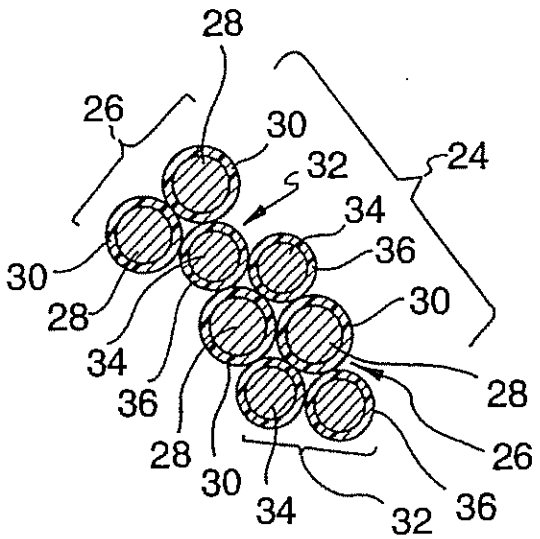
Attorney, Agent, or Firm—R. J. Austin

[57] ABSTRACT

High frequency cable with short twist lays with the insulation thickness of conductors being different from that of others, the thickness of insulation being dependent upon twist lay length so as to achieve a desired characteristic impedance and signal attenuation.

5 Claims, 1 Drawing Sheet





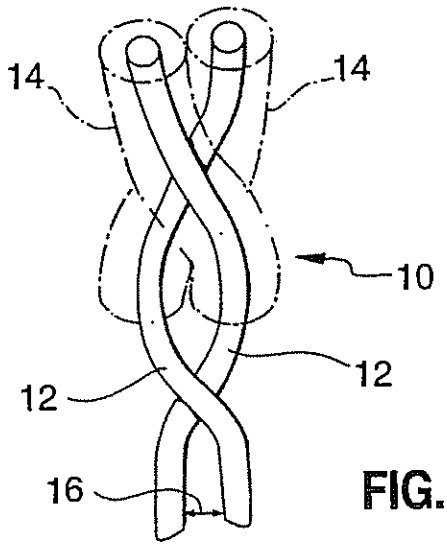


FIG.1

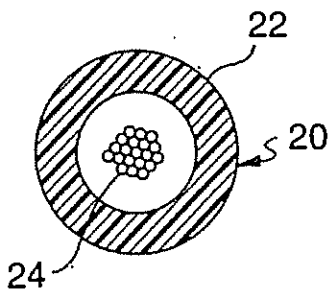


FIG.2

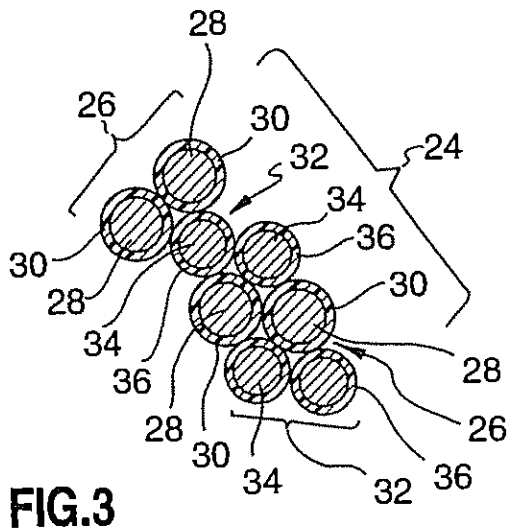


FIG.3

TELECOMMUNICATIONS CABLE

This invention relates to telecommunications cable.

In the telecommunications cable industry, specific designs of cable have conventionally been used for inside buildings. A conventional cable design, which has been employed for voice frequency ranges and low speed data, e.g., up to about 4 or 4.5 megabytes, is one in which the conductors are all of the same gauge and the conductors of each conductor pair are twisted together with a twist length, referred to as a "twist lay", of between 3.7 and 5.7 inches. While the above design of cable operates satisfactorily within the voice frequency range, it has been found to be unsatisfactory for various reasons above this range and has limitations for use with digital systems and local area networks using much higher frequencies. In particular, attenuation of signals at around 16 megabytes is undesirably high as is the amount of crosstalk experienced. For high frequency data transmission, e.g. up to about 100 megabytes, a conventional cable design for all voice frequency range use is entirely unsatisfactory.

In U.S. Pat. No. 5,010,210 to S. Sidi, et al and entitled "Telecommunications Cable", an unshielded telecommunications cable is described of special design in which it is recognized that the use of small twist lays for twisted conductor pairs in a particular cable provides the surprising result that electromagnetic interference is reduced to commercially acceptable levels even through the cable is unshielded, to provide minimization in crosstalk.

Capacitance in a conductor is dependent, in part, upon the length of the conductor. On the other hand, inductance is proportional to the "physical spacing area" between conductors that is the distance between the conductors taken along the lengths of the conductors. The nominal characteristic impedance of a twisted pair in telecommunications cable is commercially acceptable if it has a value of 100 ohms±15 ohms. With a cable designed for voice frequency range use, the twist lays in adjacent pairs are designed to be different from one another for the purpose of minimizing crosstalk. Although for a unitary length of cable, these twist lays differ, the nominal characteristic impedance for any one pair is easily controlled within the required limits, because any change in the normal large twist lays, e.g. between 3.70 and 6.00 inches, results in similar changes in the conductor length and in the physical spacing area between conductors, whereby changes in inductance and capacitance are substantially proportionate and the nominal characteristic impedance thus remains substantially unchanged. However, when a cable is provided with small twist lays to its twisted pairs and these twist lays differ from pair to pair so as to minimize crosstalk, the changes in twist lay from pair to pair are accompanied by large variations in the physical spacing area which provide large variations in inductance, but the helical lengths of the conductors from pair to pair vary more widely whereby change in capacitance is significantly larger than change in inductance. As a result, the nominal characteristic impedance is uncontrollable from pair to pair and it is found that in any cable there is a tendency for the nominal characteristic impedance of at least some pairs to be at or beyond the acceptable nominal characteristic impedance value in the telecommunications industry. Certainly for a cable having twenty-five pairs of twisted conductors, conventional

cable design cannot provide an acceptable nominal characteristic impedance for each pair where all pairs have small, but different twist lays.

The present invention seeks to provide a telecommunications cable which minimizes or avoids the above problems.

Accordingly, the present invention provides a telecommunications cable comprising a core having a plurality of pairs of twisted together individually insulated conductors, the maximum twist lay length being 2.00 inches, the twist lay length of at least some conductor pairs being different from that of others, and the insulation thickness of the conductors of at least some pairs being different from that of other pairs with the conductors of each pair having a thickness of insulation which provides the pair with a characteristic impedance which is within desirable limits and an acceptable signal attenuation.

With the above structure of the invention the insulation thicknesses of the conductors are matched to the twist lay lengths so as to provide in each case a nominal characteristic impedance for each twisted pair which lies within the normal acceptable commercial range. In practice, and within the scope of the invention, the pairs of conductors with the smallest twist lays necessarily have thicker insulations on the conductors than the pairs of conductors with the largest twist lays. The increase in thickness of the insulation provides for a larger physical spacing area increase than could be obtained using thinner insulation so as to be comparable more closely to the necessary increase in the lengths of the conductors to provide the small twist lays. Accordingly, changes in inductance and capacitance from one twisted pair to another are more closely aligned whereby the impedance can be more closely controlled within acceptable limits.

In principle, the present invention includes a structure of cable in which the twist lay length of each pair is different from that of each other pair and also in which the conductor insulation thicknesses are different from one pair to another. In a practical sense having completely different thicknesses of insulation from pair to pair may be highly inconvenient, impractical and may be expensive. Accordingly, in a preferred cable structure, less thicknesses of insulation may be used than the number of twist lays in the twisted pairs. Conveniently, the same thickness of insulation may be used over a range of twist lay lengths while still providing a nominal characteristic impedance which is within the desirable limits, and another thickness of insulation may be used for a different range of twist lays to provide similar results. In particular, therefore, it is preferable for a first plurality of conductor pairs having twist lays within a first range and have the same conductor insulation thickness which is consistent with providing a nominal characteristic impedance for each conductor pair of the first plurality within desirable limits and an acceptable signal attenuation, and at least a second plurality of conductor pairs is provided and which have twist lays within a second range. The conductors of the second plurality of conductor pairs each has substantially the same conductor thickness which is different from that of the first plurality of pairs to provide a nominal characteristic impedance for each conductor pair of the second plurality which is within the desirable limits and also an acceptable signal attenuation.

The inventive concept may be used in telecommunication cables with different numbers of conductor pairs

and in a particular case using twenty-five conductor pairs, a plurality of thicknesses of insulation may be employed to extend over different limits of twist lay lengths to provide the desired results. In a practical arrangement having twenty-five conductor pairs, it has been found that two insulation thicknesses may be provided, each insulation thickness applicable to an individual plurality of pairs of conductors lying within a certain range of twist lays while providing the acceptable nominal characteristic impedance and attenuation values.

The invention is applicable both to cables with and without a shield surrounding the core.

One embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is an isometric diagrammatic view of part of a conventional twisted pair of individually insulated conductors;

FIG. 2 is a cross-sectional view through a telecommunications cable for high frequency use and according to the embodiment; and

FIG. 3 is a cross-sectional view through part of a core of the cable of FIG. 2 and to a much larger scale.

In telecommunication cable constructions, as shown by FIG. 1, pairs 10 of conductors are normally used, the pairs 10 comprising two individually insulated conductors 12 each having a layer of insulation 14 (chain-dotted) which maintains the conductors apart. Each pair of conductors is twisted to have a particular twist lay, that is the twist length produced between them, and the distance between the conductors is controlled by the thickness of the layers of insulation 14. The signal attenuation in the conductors is partly dependent upon the length of the conductors and also upon the distance between them. As a result, if over a unitary length of cable the twist lay of a certain pair is shorter than for other pairs, then each conductor length in this pair is longer than in the other pairs which would tend to increase the attenuation of the short twist lay pair. In addition, conductors of the pairs with short twist lay tend to be crushed closer together than other pairs with the result that the insulation is more compressed thereby bringing the conductors slightly closer together. This is also a factor in increasing the attenuation while at the same time lowering impedance. In fact, the impedance decreases rapidly from twisted pair to twisted pair as twist lay reduces. Also the attenuation increase caused by the closing together of the conductors and the longer length of conductors for shorter twist lays results in unacceptable attenuation values at high frequencies. This is exemplified as follows.

The attenuation is inversely proportional to the nominal characteristic impedance of each pair. The impedance is proportional to the square root of the inductance and inversely proportional to the square root of the capacitance. For normal considerations in telecommunications cable design, for normal voice frequency cables with a long twist lay, e.g. between 3.7 and 6 inches, the square roots of the inductance and capacitance change substantially proportionately from twisted pair to twisted pair having different twist lays. As a result of this, for normal voice frequency use cable designs the nominal characteristic impedance changes only slightly from pair to pair and is easily contained within the acceptable design limits of 100 ohms±15 ohms. However, when a telecommunications cable is designed to operate at high frequencies, perhaps up to 100 megabytes, it is desirable for this purpose to have each twisted pair with a relatively low twist lay, i.e. below 2 inches in lengtb. Problems arise in this case with maintaining the nominal characteristic impedance within the desirable limits. One of the parameters for impedance, i.e. inductance, is proportional to the "physical spacing area" between the conductors of each pair, that is the distance between the conductors taken along the lengths of the conductors. In the example shown by FIG. 1, the physical spacing area is considered to bc that area which is generated by a spatial distance line 16 extending between the conductors 12, the spatial distance line 16 being moved from end to end of the pair of conductors. The physical spacing area increases from pair to pair as the twist lay decreases while the length of each conductor also increases as the twist lay decreases. However, the capacitance depends primarily upon the helical length of each conductor. For high twist lay lengths of cable for voice frequencies, the change in the physical spacing area is substantially proportional to the change of helical length of the conductors for variation in twist lay and results in the substantially proportional change in inductance and capacitance discussed above which results in little or no change to impedance. However, when small twist lays are being considered, e.g. below 2 inches, this effects substantial increases in capacitance compared to increases in inductance. As a result of this, the impedance is known to decrease rapidly from twisted pair to twisted pair as twist lay reduces. If nominal characteristic impedance values are to be maintained within acceptable limits, this places a limit on the number of twisted pairs which may be placed in the core of a high frequency telecommunications cable having a large range of twist lays which are all below 2 inches. In addition, the change in nominal characteristic impedance has drastic effects upon the attenuation which reaches high attenuation levels which are also completely unacceptable.

The present invention provides a telecommunications cable structure which, as described in the following embodiment, enables the nominal characteristic impedance to be more closely controlled between its acceptable limits while also placing a control upon signal attenuation. It also enables telecommunications cable employing large numbers of pairs, i.e. twenty-five pairs or above, to be employed with a range of low twist lays while also avoiding the above-discussed problems.

As shown by the embodiment (FIGS. 2 and 3), a shieldless telecommunications cable 20 comprises a jacket 22 of any suitable material for inside building use, the jacket surrounding a cable core 24.

The cable core 24 comprises twenty-five pairs of individually insulated conductors all of 24 AWG. Each pair has a different twist lay from all of the other pairs to minimize crosstalk. The lowest twist lay is 0.25 inches and the highest twist lay is 0.86 inches, the twist lays increasing incrementally between these two limits. As shown by FIG. 3, certain pairs 26 of the conductors have twist lays within a range of lower limits i.e. between 0.25 and 0.35 inches. There are ten of these conductor pairs with twist lays varying from 0.25 to 0.35 inches. Each of the conductors 28 in these pairs is individually insulated with a layer 30 of a chosen insulating material, the layer 30 having a thickness of 0.0095 inches to result in a total outside insulated diameter of 0.0391 inches. The other fifteen pairs 32 of conductors 34 having different twist lay lengths within a higher limiting range, each have an insulation layer 36 also of

chosen insulating material, the insulation layer being 0.0085 inches in thickness to provide a total overall insulated thickness of 0.0361 inches.

With this construction as shown by the accompanying Table, the nominal characteristic impedance of each conductor pair lies within the limits which are acceptable in the telecommunications cable industry, i.e. 100 ohms±15 ohms. In addition, the attenuation as shown by the Table lies within acceptable limits. As may be seen from the accompanying Table, the ten twisted pairs within the lower range of twist lays, i.e. within 0.25 and 0.35 inches have a nominal characteristic impedances at 1 MHZ between 102.5 and 109.5 ohms and at 100 MHZ between 99.6 and 106.1 ohms. The fifteen twisted pairs lying within the upper twist lay range have nominal characteristic impedances which are comparable to those at the lower end of the range as may be seen from the Table.

As may be seen from the embodiment and from the accompanying Table, the nominal characteristic impedance may be controlled for twist lay lengths below 2 inches (and in this case below 0.86 inches) to enable a relatively large pair content cable to be made for use at high frequencies while producing acceptable nominal characteristic impedance and attenuation values. The embodiment as described uses twenty-five pairs all of which have acceptable values between the defined limits. As may be realized, the inventive concept may easily be used upon cables having more or lesser pairs than those described in the embodiment, any increase in limit differential between the lay lengths of extra pairs being easily accommodated by thicknesses of insulation which are different from those described in the embodiment and which are calculated to produce the desired nominal characteristic impedance and accompanying attenuation values.

In effect therefore, as may be seen from the above description and from the Table and also with particular reference to FIG. 1, for shorter twist lays, in which it is normally expected that the helical length of the conductor increases more rapidly than the physical spacing area, the thicker insulation provided upon the conductors of these pairs results in further spacing apart of the conductors. This effects an increase in the conductor length which is greater than increase in the physical spacing area so that the capacitance value increases more than the inductance value thereby controlling the nominal characteristic impedance values within the desirable limits. The change in insulation thickness therefore results in control of spacing between the conductors of the pairs dependent upon the twist lay lengths of the pairs so as to provide a balancing effect between capacitance and inductance to produce the desirable nominal characteristic impedance.

TABLE

	ATTENUATION		NOMINAL CHARACTERISTIC IMPEDANCE		O.D.
	1 MHz	100 MHz	1 MHz	100 MHz	
LAY	(dB per 100 m)		(ohm)		DIAMETER INCHES
0.25	2.2	21.5	102.5	99.6	0.0391
0.26	2.1	20.7	105.7	101.8	0.0391
0.27	2.1	20.0	106.1	102.7	0.0391
0.28	2.1	20.0	106.3	103.4	0.0391
0.29	2.0	19.8	106.4	103.9	0.0391
0.3	2.0	19.7	107.7	104.5	0.0391
0.31	2.0	19.2	108.2	105.0	0.0391
0.33	2.0	19.3	107.9	105.9	0.0391
0.34	2.0	19.2	108.6	106.6	0.0391
0.35	2.10	19.1	109.5	1.06.1	0.0391
0.36	2.1	20.8	103.2	98.4	0.0361
0.38	2.1	20.4	103.0	98.8	0.0361
0.41	2.0	20.0	104.8	101.1	0.0361
0.44	2.0	20.0	105.0	100.0	0.0361
0.46	2.0	20.0	104.6	102.5	0.0361
0.48	2.0	19.5	105.0	101.4	0.0361
0.52	1.8	18.8	107.9	103.6	0.0361
0.53	2.0	19.9	106.1	100.7	0.0361
0.58	2.0	19.5	107.1	102.1	0.0361
0.64	2.0	19.7	106.4	102.5	0.0361
0.66	1.8	18.8	108.2	99.1	0.0361
0.71	1.8	19.5	106.3	100.9	0.0361
0.75	1.8	19.5	107.1	102.9	0.0361
0.8	1.8	19.2	108.4	101.6	0.0361
0.86	1.8	18.7	108.2	100.7	0.0361

What is claimed is:

1. A telecommunications cable comprising a core having a plurality of pairs of twisted together individually insulated conductors with all of the conductors being of the same gauge and the maximum twist lay of the plurality of pairs being 2.00 inches with a first group of the plurality of conductor pairs having twist lays within a first range, the conductors of the first group having the same insulation thickness which is consistent with providing a nominal characteristic impedance for each conductor pair of the first group within desirable limits and an acceptable signal attenuation, and at least a second group of the plurality of conductor pairs having twist lays within a second range, the conductors of the second group having the same insulation thickness which is different from that for the first group and which is consistent with providing a nominal characteristic impedance for each conductor pair of the second group which is also within the desirable limits and an acceptable signal attenuation.

2. A telecommunications cable according to claim 1 wherein the twist lay of each conductor pair is different from each other pair.

3. A telecommunications cable according to claim 1 wherein there are twenty-five conductor pairs including two groups of conductor pairs in each of which the conductor insulations are of substantially equal thickness, the thickness being different from one group to the other.

4. A telecommunications cable according to claim 1 wherein the conductors are each of 24 AWG and have different twist lays from 0.25 to 0.86 inches with the conductors in a plurality of conductor pairs with twist lays within a lower range each having an insulation thickness which is greater than an insulation thickness of the other conductor pairs with twist lays within an upper range.

5. A telecommunications cable according to claim 4 wherein each conductor of a pair within the lower range of twist lays has an insulation thickness of 0.0095 inches, the lower range being from 0.25 to 0.35 inches, and each conductor of a pair within the upper range of twist lays has an insulation thickness of 0.0085 inches.

* * * * *

EXHIBIT B

US006074503A

United States Patent [19]

Clark et al.

[11] Patent Number: 6,074,503

[45] Date of Patent: Jun. 13, 2000

[54] MAKING ENHANCED DATA CABLE WITH CROSS-TWIST CABLED CORE PROFILE

[75] Inventors: William T. Clark, Lancaster; Peter D. MacDonald, Gardner; Joseph Dellagala, Shrewsbury, all of Mass.

[73] Assignee: Cable Design Technologies, Inc., Leominster, Mass.

[21] Appl. No.: 08/841,440

[22] Filed: Apr. 22, 1997

[51] Int. Cl.[7] H01B 13/00

[52] U.S. Cl. ..... 156/50; 156/47; 156/55; 174/131 A

[58] Field of Search ..... 156/47, 50, 55, 156/52, 244.15; 174/70 C, 34, 36, 99 R, 116, 113 A, 131 R, 131 A; 385/105, 107, 110, 112; 264/1.28; 57/6, 12, 13

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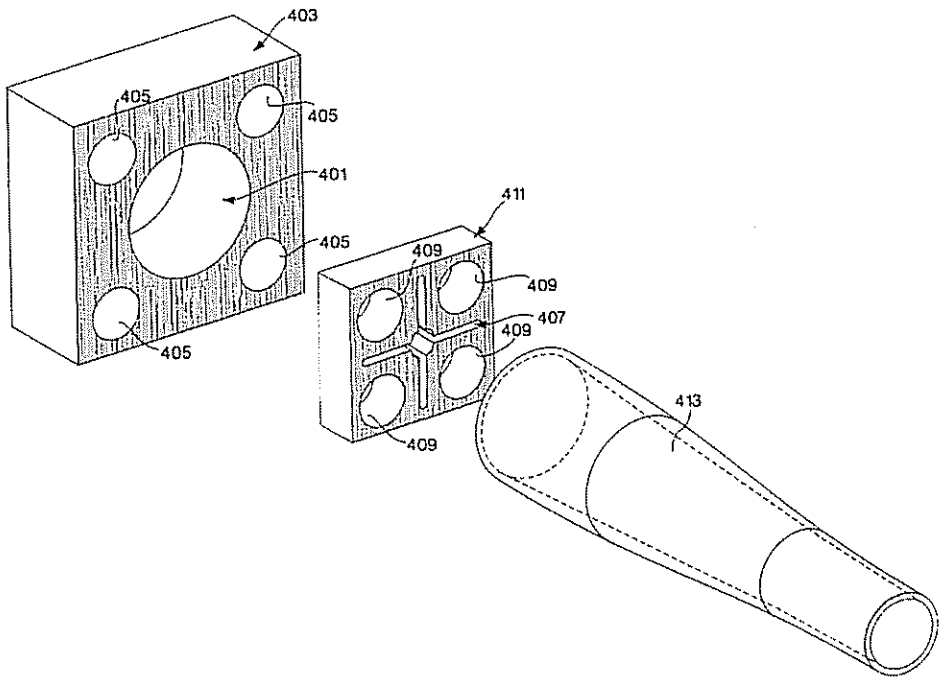
images of Belden 1711A Datatwist 300 4PR23 shielded cable, Sep. 11, 1995.

Primary Examiner—Geoffrey L. Knable
Attorney, Agent, or Firm—Wolf, Greenfield & Sacks, P.C.

[57] ABSTRACT

A cable exhibiting reduced crosstalk between transmission media includes a core having a profile with a shape which defines spaces or channels to maintain a spacing between transmission media in a finished cable. The core is formed of a conductive material to further reduce crosstalk. A method of producing a cable introduces a core as described above into the cable assembly and imparts a cable closing twist to the assembly.

4 Claims, 2 Drawing Sheets



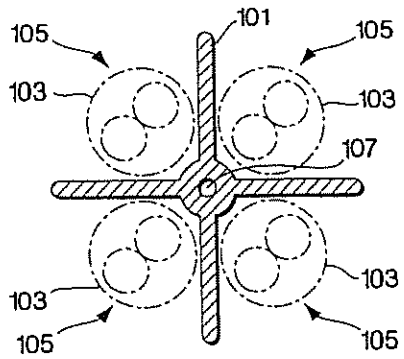


Fig. 1

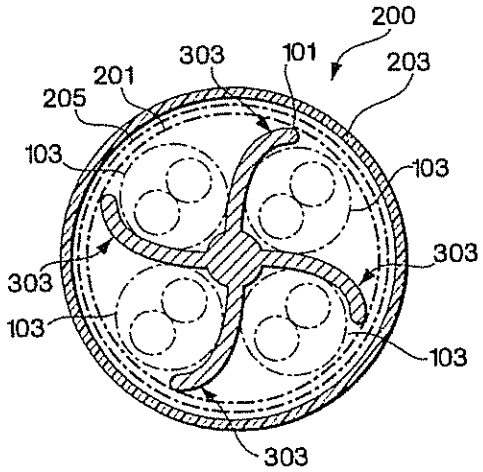


Fig. 2

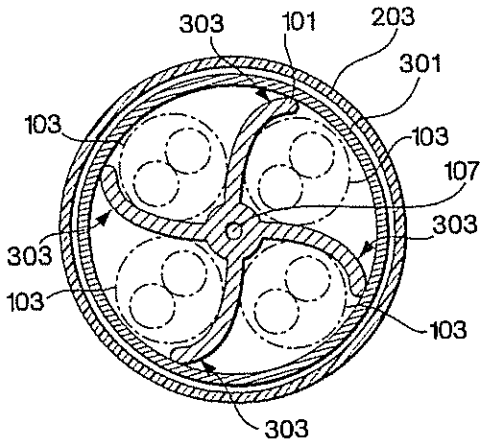


Fig. 3

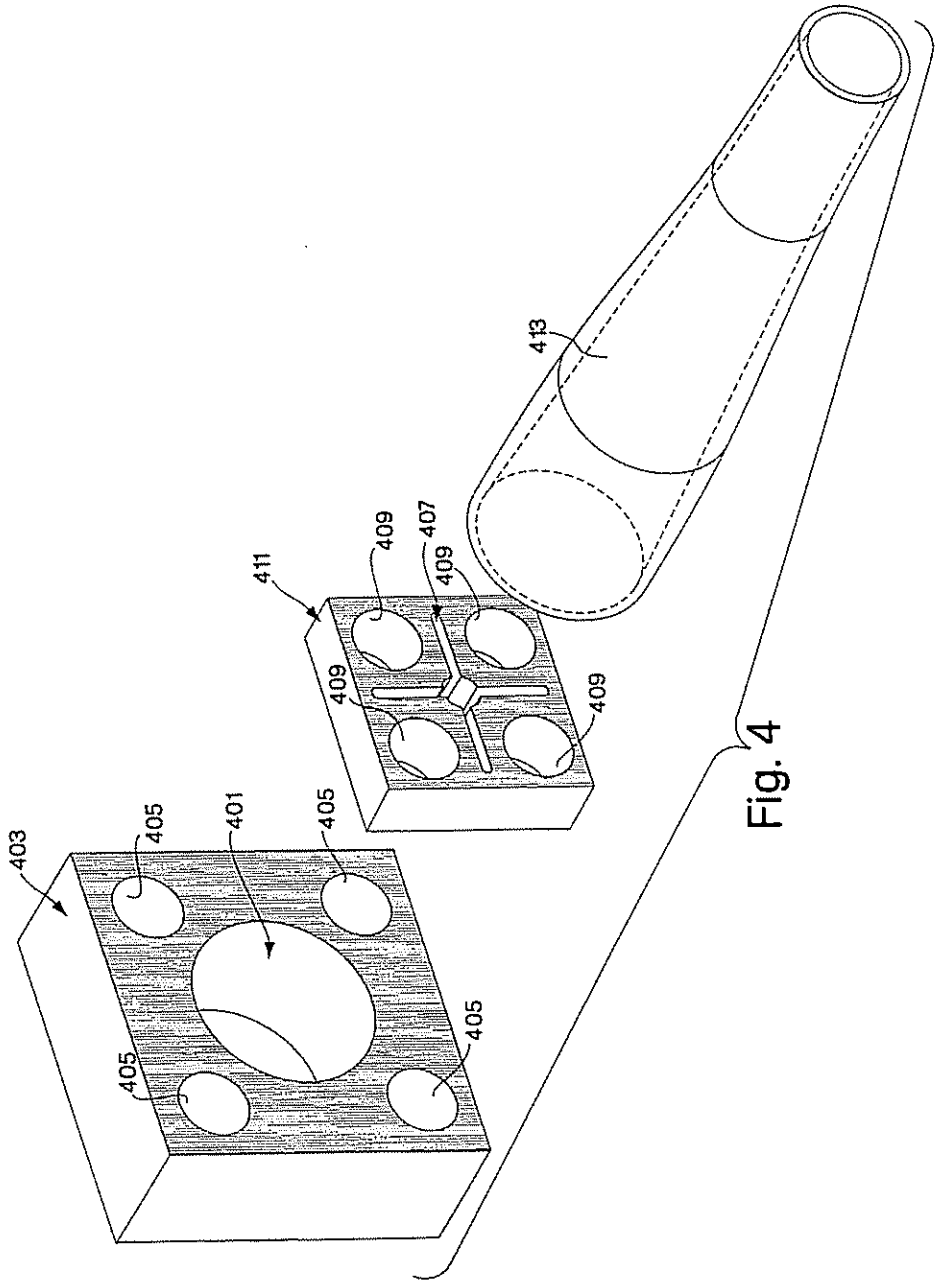


Fig. 4

MAKING ENHANCED DATA CABLE WITH CROSS-TWIST CABLED CORE PROFILE

BACKGROUND

1. Field of the Invention

The present invention relates to high-speed data communications cables using at least two twisted pairs of wires. More particularly, it relates to cables having a central core defining plural individual pair channels.

2. Related Art

High-speed data communications media in current usage include pairs of wire twisted together to form a balanced transmission line. Such pairs of wire are referred to as twisted pairs.

One common type of conventional cable for high-speed data communications includes multiple twisted pairs. When twisted pairs are closely placed, such as in a cable, electrical energy may be transferred from one pair of a cable to another. Such energy transferred between pairs is undesirable and referred to as crosstalk. The Telecommunications Industry Association and Electronics Industry Association have defined standards for crosstalk, including TIA/EIA-568A. The International Electrotechnical Commission has also defined standards for data communication cable crosstalk, including ISO/IEC 11801. One high-performance standard for 100Ω cable is ISO/IEC 11801, Category 5.

In conventional cable, each twisted pair of a cable has a specified distance between twists along the longitudinal direction, that distance being referred to as the pair lay. When adjacent twisted pairs have the same pair lay and/or twist direction, they tend to lie within a cable more closely spaced than when they have different pair lays and/or twist direction. Such close spacing increases the amount of undesirable crosstalk which occurs. Therefore, in some conventional cables, each twisted pair within the cable has a unique pair lay in order to increase the spacing between pairs and thereby to reduce the crosstalk between twisted pairs of a cable. Twist direction may also be varied. Along with varying pair lays and twist directions, individual solid metal or woven metal pair shields are sometimes used to electromagnetically isolate pairs.

Shielded cable, although exhibiting better crosstalk isolation, is more difficult and time consuming to install and terminate. Shield conductors are generally terminated using special tools, devices and techniques adapted for the job.

One popular cable type meeting the above specifications is Unshielded Twisted Pair (UTP) cable. Because it does not include shield conductors, UTP is preferred by installers and plant managers, as it is easily installed and terminated. However, UTP fails to achieve superior crosstalk isolation, as required by state of the art transmission systems, even when varying pair lays are used.

Another solution to the problem of twisted pairs lying too closely together within a cable is embodied in a cable manufactured by Belden Wire & Cable Company as product number 1711 A. This cable includes four twisted pair media radially disposed about a "+"-shaped core. Each twisted pair nests between two fins of the "+"-shaped core, being separated from adjacent twisted pairs by the core. This helps reduce and stabilize crosstalk between the twisted pair media. However, the core adds substantial cost to the cable, as well as material which forms a potential fire hazard, as explained below, while achieving a crosstalk reduction of only about 5dB.

In building design, many precautions are taken to resist the spread of flame and the generation of and spread of smoke throughout a building in case of an outbreak of fire. Clearly, it is desired to protect against loss of life and also to minimize the costs of a fire due to the destruction of electrical and other equipment. Therefore, wires and cables for in building installations are required to comply with the various flammability requirements of the National Electrical Code (NEC) and/or the Canadian Electrical Code (CEC).

Cables intended for installation in the air handling spaces (ie. plenums, ducts, etc.) of buildings are specifically required by NEC or CEC to pass the flame test specified by Underwriters Laboratories Inc. (UL), UL-910, or it's Canadian Standards Association (CSA) equivalent, the FT6. The UL-910 and the FT6 represent the top of the fire rating hierarchy established by the NEC and CEC respectively. Cables possessing this rating, generically known as "plenum" or "plenum rated", may be substituted for cables having a lower rating (ie. CMR, CM, CMX, FT4, FT1 or their equivalents), while lower rated cables may not be used where plenum rated cable is required.

Cables conforming to NEC or CEC requirements are characterized as possessing superior resistance to ignitability, greater resistant to contribute to flame spread and generate lower levels of smoke during fires than cables having a lower fire rating. Conventional designs of data grade telecommunications cables for installation in plenum chambers have a low smoke generating jacket material, e.g. of a PVC formulation or a fluoropolymer material, surrounding a core of twisted conductor pairs, each conductor individually insulated with a fluorinated ethylene propylene (FEP) insulation layer. Cable produced as described above satisfies recognized plenum test requirements such as the "peak smoke" and "average smoke" requirements of the Underwriters Laboratories, Inc., UL910 Steiner test and/or Canadian Standards Association CSA-FT6 (Plenum Flame Test) while also achieving desired electrical performance in accordance with EIA/TIA-568A for high frequency signal transmission.

While the above-described conventional cable including the Belden 1711 A cable due in part to their use of FEP meets all of the above design criteria, the use of fluorinated ethylene propylene is extremely expensive and may account for up to 60% of the cost of a cable designed for plenum usage.

The solid core of the Belden 1711 A cable contributes a large volume of fuel to a cable fire. Forming the core of a fire resistant material, such as FEP, is very costly due to the volume of material used in the core.

Solid flame retardant/smoke suppressed polyolefin may also be used in connection with FEP. Solid flame retardant/smoke suppressed polyolefin compounds commercially available all possess dielectric properties inferior to that of FEP. In addition, they also exhibit inferior resistance to burning and generally produce more smoke than FEP under burning conditions than FEP.

SUMMARY OF THE INVENTION

This invention provides an improved data cable.

According to one embodiment, the cable includes a plurality of transmission media; a core having a surface defining recesses within which each of the plurality of transmission media are individually disposed; and an outer jacket maintaining the plurality of data transmission media in position with respect to the core.

According to another embodiment of the invention, a cable includes a plurality of transmission media radially disposed about a core having a surface with features which

maintain a separation between each of the plurality of transmission media.

Finally, according to yet another embodiment of the invention, there is a method of producing a cable. The method first passes a plurality of transmission media and a core through a first die which aligns the plurality of transmission media with surface features of the core and prevents twisting motion of the core. Next, the method bunches the aligned plurality of transmission media and core using a second die which forces each of the plurality of transmission media into contact with the surface features of the core which maintain a spatial relationship between each of the plurality of transmission media. Finally, the bunched plurality of transmission media and core are twisted to close the cable, and the closed cable is jacketed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, in which like reference numerals designate like elements:

FIG. **1** is a cross-sectional view of a cable core used in embodiments of the invention;

FIG. **2** is a cross-sectional view of one embodiment of a cable including the core of FIG. **1**;

FIG. **3** is a cross-sectional view of another embodiment of a cable including the core of FIG. **1**; and

FIG. **4** is a perspective view of a die system for practicing a method of making a cable in accordance with another embodiment of the invention.

DETAILED DESCRIPTION

An embodiment of the invention is now described in which a cable is constructed to include four twisted pairs of wire and a core having a unique profile. However, the invention is not limited to the number of pairs or the profile used in this embodiment. The inventive principles can be applied to cables including greater or fewer numbers of twisted pairs and different core profiles. Also, although this embodiment of the invention is described and illustrated in connection with twisted pair data communication media, other high-speed data communication media can be used in constructions of cable according to the invention.

This illustrative embodiment of the invention, as shown in FIG. **1**, includes an extruded core **101** having a profile described below cabled into the cable with four twisted pairs **103**. The extruded core profile has an initial shape of a "+", providing four spaces or channels **105** between each pair of fins of the core. Each channel **105** carries one twisted pair **103** placed within the channel **105** during the cabling operation. The illustrated core **101** and profile should not be considered limiting. The core **101** may be made by some other process than extrusion and may have a different initial shape or number of channels **105**. For example, there may be an optional central channel **107** provided to carry a fiber optic element.

The above-described embodiment can be constructed using a number of different materials. While the invention is not limited to the materials now given, the invention is advantageously practiced using these materials. The core material should be a conductive material or one containing a powdered ferrite, the core material being generally compatible with use in data communications cable applications, including any applicable fire safety standards. In non-plenum applications, the core can be formed of solid or foamed flame retardant polyolefin or similar materials. In plenum applications, the core can be any one or more of the following compounds: a solid low dielectric constant fluoropolymer, e.g., ethylene chlortrifluoroethylene (E-CTFE) or fluorinated ethylene propylene (FEP), a foamed fluoropolymer, e.g., foamed FEP, and polyvinyl chloride (PVC) in either solid, low dielectric constant form or foamed. A filler is added to the compound to render the extruded product conductive. Suitable fillers are those compatible with the compound into which they are mixed, including but not limited to powdered ferrite, semiconductive thermoplastic elastomers and carbon black. Conductivity of the core helps to further isolate the twisted pairs from each other.

A conventional four-pair cable including a non-conductive core, such as the Belden 1711 A cable, reduces nominal crosstalk by up to 5dB over similar, four-pair cable without the core. By making the core conductive, crosstalk is reduced a further 5dB. Since both loading and jacket construction can affect crosstalk, these figures compare cables with similar loading and jacket construction.

The cable may be finished in any one of several conventional ways, as shown in FIG. **2**. The combined core **101** and twisted pairs **103** may be optionally wrapped with a dielectric tape **201**, then jacketed **205** to form cable **200**. An overall conductive shield **205** can optionally be applied over the cable before jacketing to prevent the cable from causing or receiving electromagnetic interference. The jacket **203** may be PVC or another material as discussed above in relation to the core **101**. The dielectric tape **201** may be polyester, or another compound generally compatible with data communications cable applications, including any applicable fire safety standards.

Greater crosstalk isolation is achieved in the construction of FIG. **3**, by using a conductive shield **301**, for example a metal braid, a solid metal foil shield or a conductive plastic layer in contact with the ends of the fins **303** of the core **101**. Such a construction rivals individual shielding of twisted pairs for crosstalk isolation. This construction optionally can advantageously include a drain wire in a central channel **107**. In the constructions of both FIGS. **2** and **3** it is advantageous to have the fins **303** of the core **101** extend somewhat beyond a boundary defined by the outer dimension of the twisted pairs **103**. In the construction of FIG. **2** this ensures that he twisted pairs **103** do not escape their respective channels **105** prior to the cable being jacketed, while in that of FIG. **3** and good contact between the fins **303** and the shield **301** is ensured. In both constructions, closing and jacketing the cable may bend the tips of the fins **303** over slightly, as shown in the core material is relatively soft, such as PVC.

A method of making cable in accordance with the above-described embodiments is now described.

As is known in this art, when plural elements are cabled together, an overall twist is imparted to the assembly to improve geometric stability and help prevent separation. In embodiments of the present invention, twisting of the profile of the core along with the individual twisted pairs is controlled. The process allows the extruded core to maintain a physical spacing between the twisted pairs and maintains geometrical stability within the cable. Thus, the process assists in the achievement of and maintenance of high crosstalk isolation by placing a conductive core in the cable to maintain pair spacing.

Cables of the previously described embodiments, can be made by a three-part die system. However, methods of making such cables are not limited to a three-part die system, as more or fewer die elements can be constructed to incorporate the features of the invention.

The extruded core is drawn from a payoff reel (not shown) through the central opening **401** in die **403**. Four twisted pairs are initially aligned with the core by passing through openings **405** in die **403**. The core is next brought through opening **407** and brought together with the four twisted pairs which are passed through openings **409** in a second die **411**, then cabled with the twisted pairs which are pushed into the channels of the core by a third die **413**, in an operation called bunching. The second die **411** eliminates back twist, which is inherent in bunching operations, thus allowing the third die **413** to place the pairs in the channels prior to the twisting. The cable twist is imparted to the cable assembly after the second die **411**, which locates the twisted pairs relative to the extruded core profile.

Although the method of making cable has been described in connection with an extruded core delivered into the process from a payoff reel, the invention is not so limited. For example, the core could be extruded immediately prior to use and transferred directly from the extruder to the central opening **401** of the first die **403**. In another variation, the core could be extruded directly through a properly shaped central opening of either the first die **403** or the second die **411**.

The present invention has now been described in connection with a number of specific embodiments thereof. However, numerous modifications which are contemplated as falling within the scope of the present invention should now be apparent to those skilled in the art. Therefore, it is intended that the scope of the present invention be limited only by the scope of the claims appended hereto.

What is claimed is:

1. A method of producing a cable, comprising steps of:

passing a plurality of transmission media and a core through a first die which aligns the plurality of transmission media with surface features of the core and prevents twisting motion of the core;

bunching the aligned plurality of transmission media and core using a second die which forces each of the plurality of transmission media into contact with the surface features of the core which maintain a spatial relationship between each of the plurality of transmission media;

twisting the bunched plurality of transmission media and core to close the cable; and

jacketing the closed cable.

2. The method of claim **1**, further comprising the steps of:

before passing the transmission media and the core through the first die, passing the transmission media and the core through a third die which generally centers the core relative to the plurality of transmission media.

3. The method of claim **2** wherein the step of passing the transmission media and the core thorugh the third die further comprises:

extruding the core at a center position relative to the plurality of transmission media.

4. The method of claim **1**, wherein the step of passing further comprises:

extruding the core so that the surface features thereof align with the plurality of transmission media.

* * * * *

EXHIBIT C

US006570095B2

(12) **United States Patent**
Clark et al.

(10) **Patent No.: US 6,570,095 B2**
(45) **Date of Patent: *May 27, 2003**

(54) **MULTI-PAIR DATA CABLE WITH CONFIGURABLE CORE FILLING AND PAIR SEPARATION**

(75) Inventors: **William Clark**, Lancaster, MA (US); **Joseph Dellagala**, Shrewsbury, MA (US); **Kenneth Consalvo**, Leominster, MA (US)

(73) Assignee: **Cable Design Technologies, Inc.**, Leominster, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/853,512**

(22) Filed: **May 11, 2001**

(65) **Prior Publication Data**

US 2002/0050394 A1 May 2, 2002

Related U.S. Application Data

(63) Continuation of application No. 09/257,844, filed on Feb. 25, 1999, now Pat. No. 6,248,954.

(51) **Int. Cl.**[7] **H01B 1/02**
(52) **U.S. Cl.** ..... **174/113 R**; 174/113 C
(58) **Field of Search** ..... 174/113 R, 113 C, 174/131 A, 117 F, 36, 121 A

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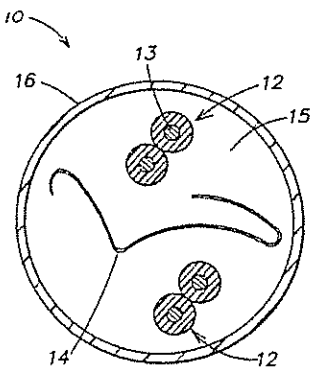
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Primary Examiner—Chau N. Nguyen
(74) *Attorney, Agent, or Firm*—Wolf, Greenfield & Sacks, P.C.

(57) **ABSTRACT**

An improved data telecommunications cable according to the invention includes a plurality of twisted pairs of insulated conductors, and a dielectric pair separator formed with a plurality of folds, to provide a plurality of grooves extending along a longitudinal length of the dielectric filler. Each twisted pair of insulated conductors is disposed within a groove of the dielectric pair separator. The data communications cable also includes a jacket assembly enclosing the plurality of twisted pairs of insulated conductors and the dielectric pair separator. The dielectric pair separator separates each twisted pair of insulated conductors from every other twisted pair of insulated conductors with a spacing sufficient to provide a desired crosstalk isolation between each of the plurality of twisted pairs of insulated conductors. With this arrangement, the data communications cable of the invention may be used in high speed data transmissions while maintaining a form factor that has desired flexibility and workability, and provides a cable that is compatible with industry standard hardware, such as plugs and jacks. The data communications cable of the invention also has the additional benefit of a reduced size.

33 Claims, 8 Drawing Sheets



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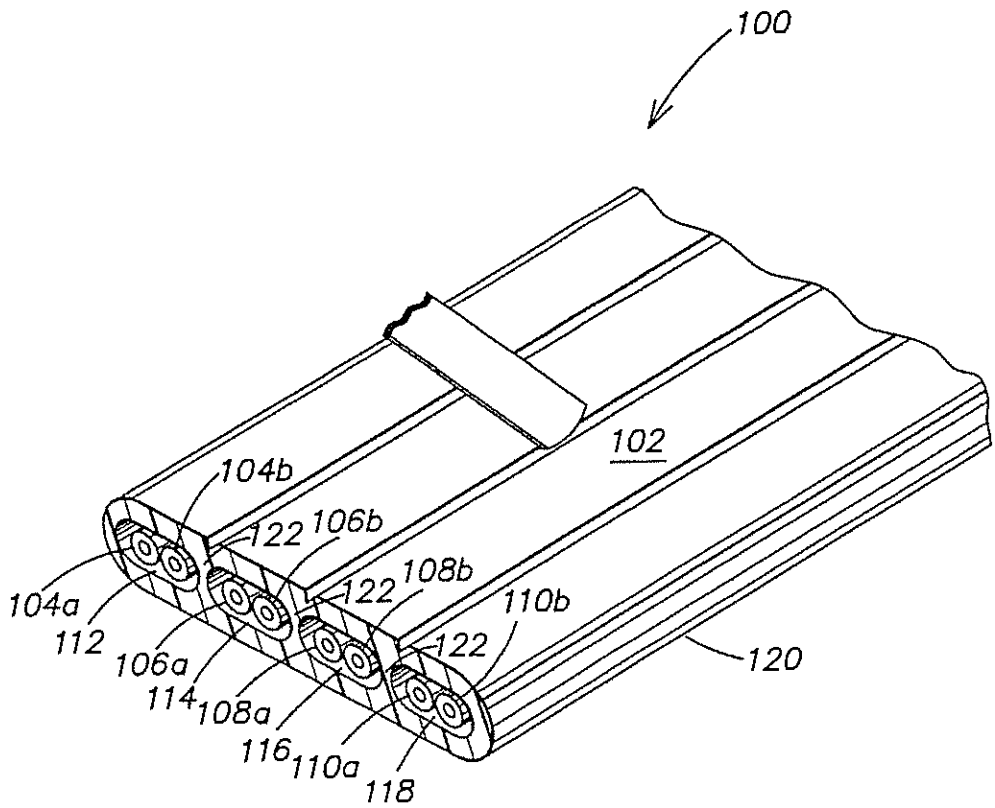


FIG. 1
(RELATED ART)

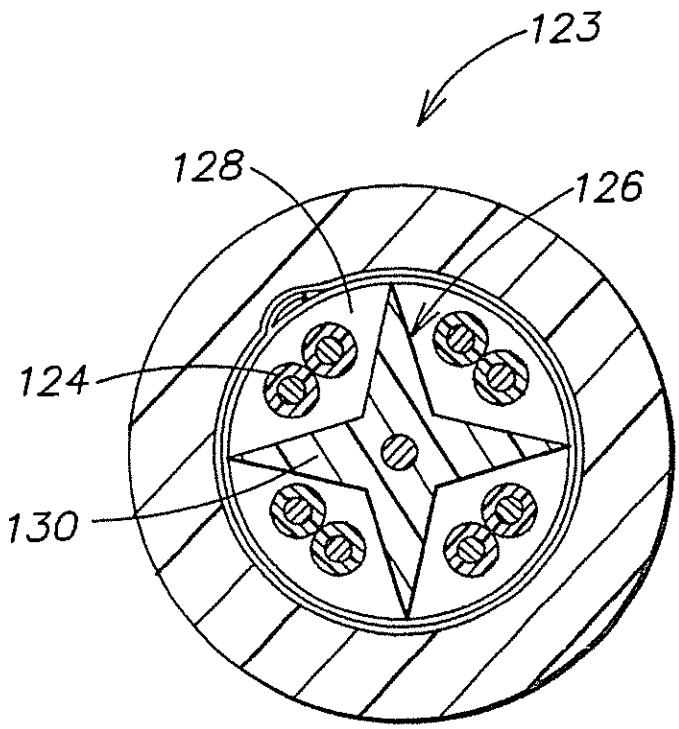


FIG. 2
(RELATED ART)

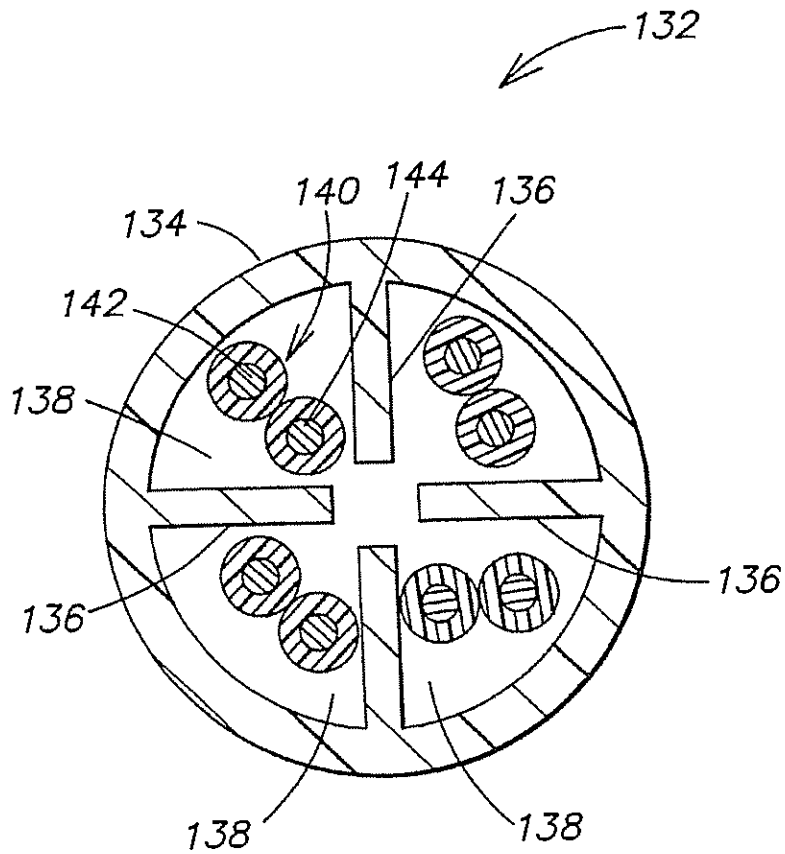


FIG. 3
(RELATED ART)

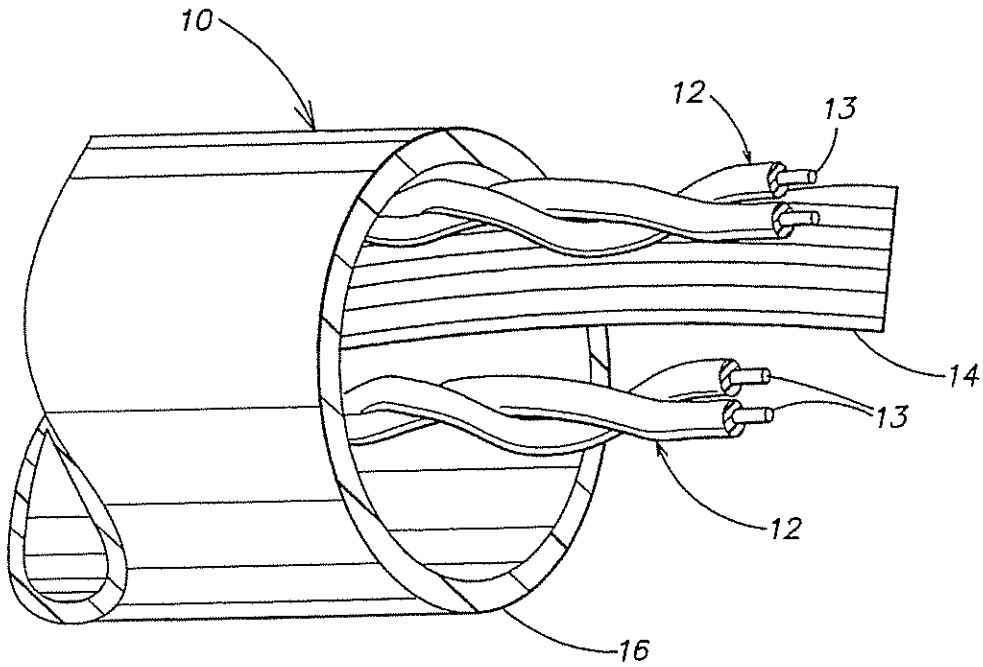


FIG. 4

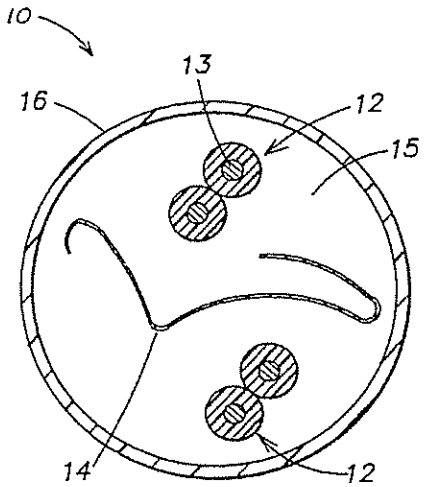


FIG. 5

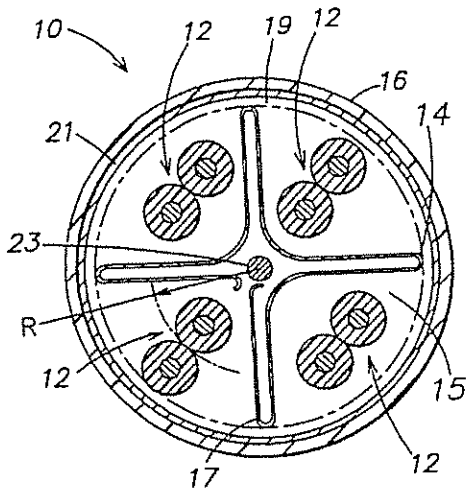


FIG. 6

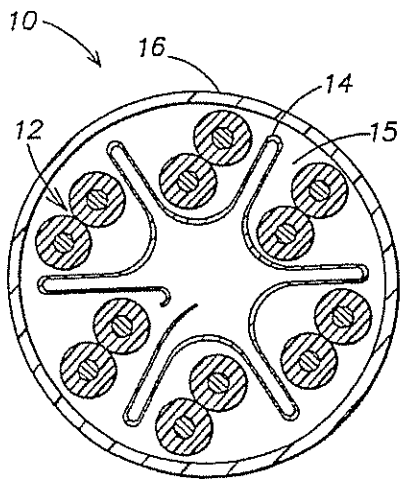


FIG. 7

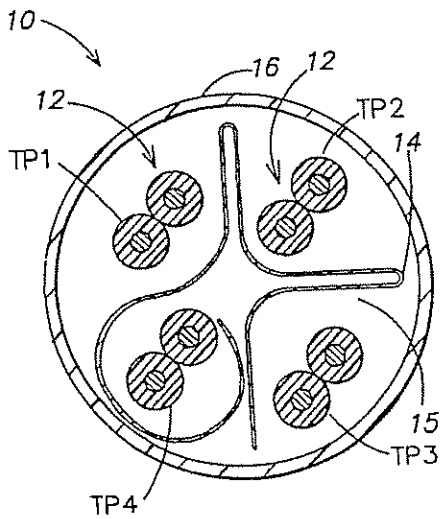


FIG. 8

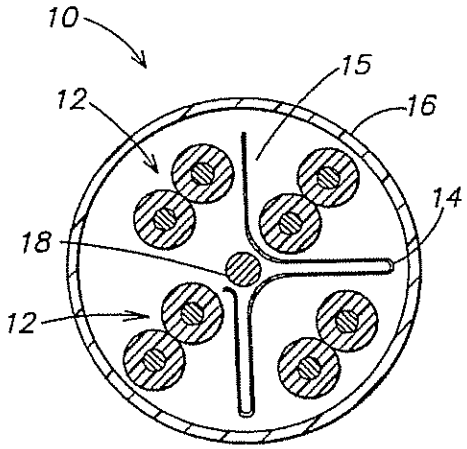


FIG. 9

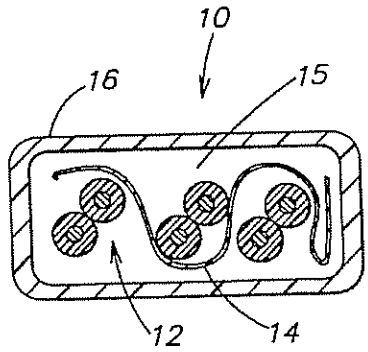


FIG. 10

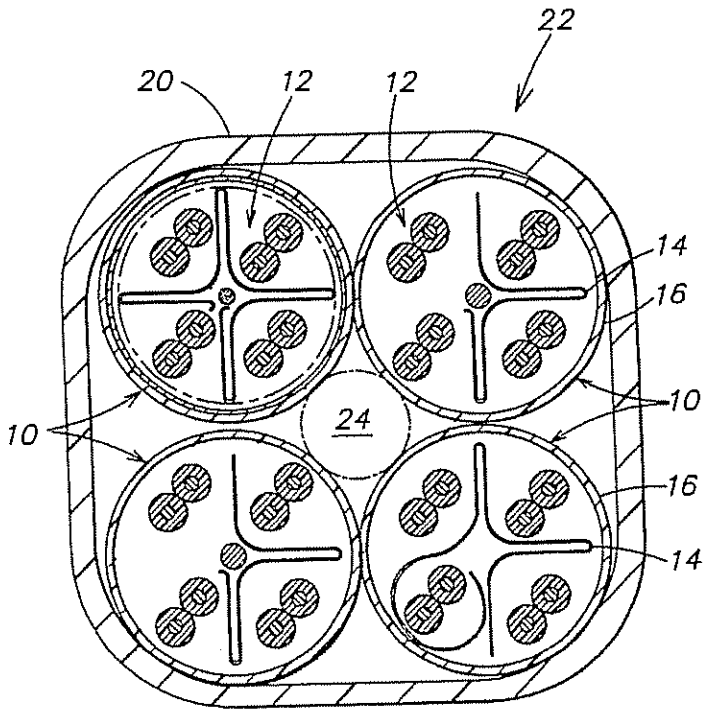


FIG. 11

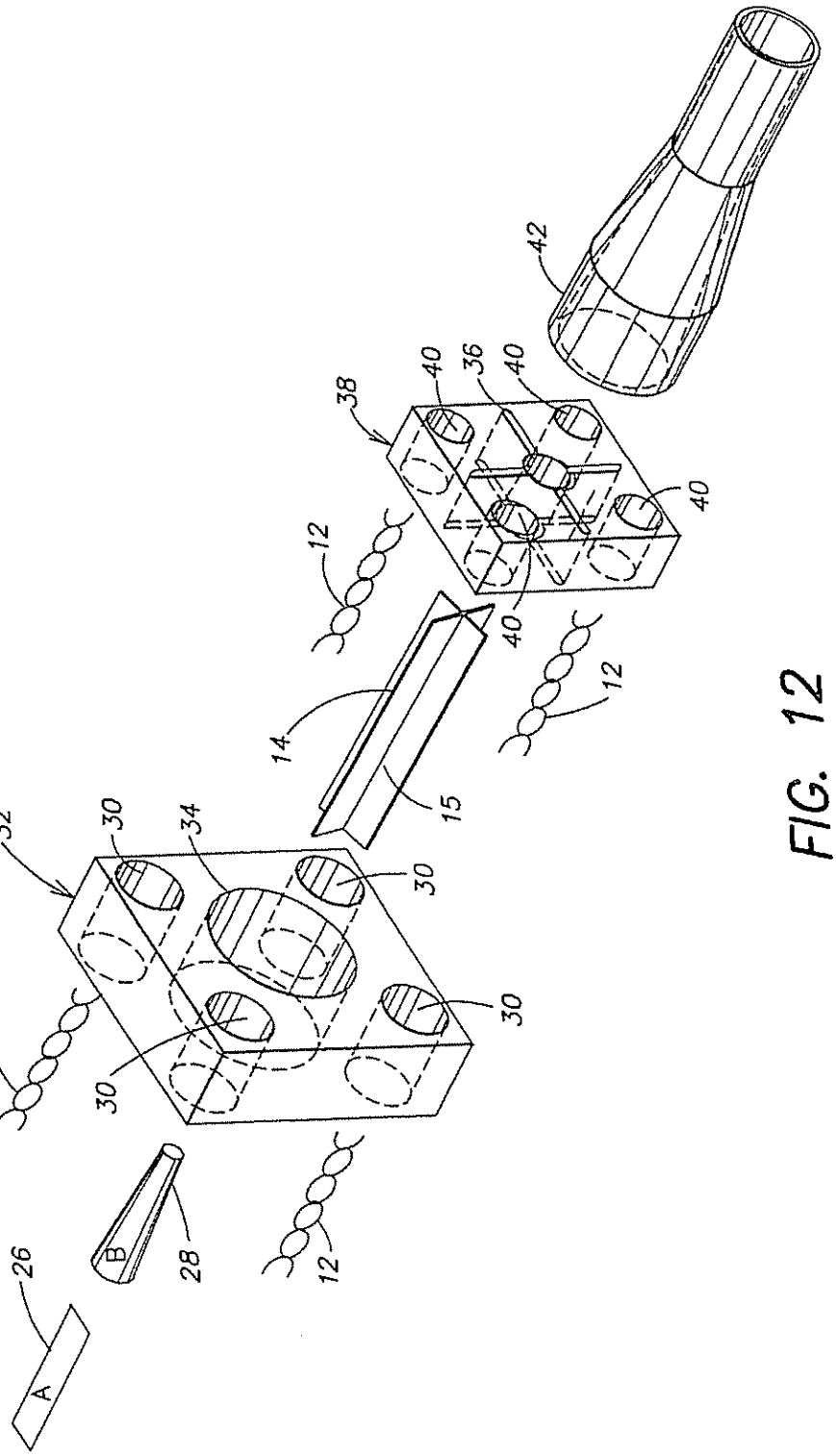


FIG. 12

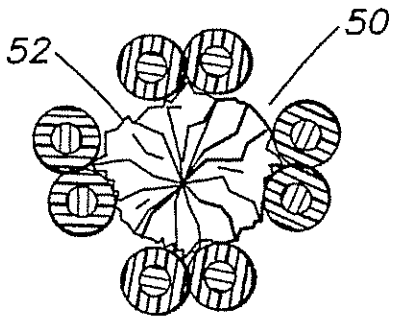


FIG. 13A

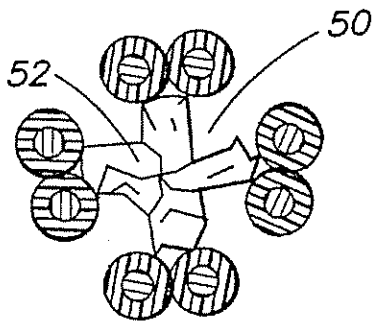


FIG. 13B

MULTI-PAIR DATA CABLE WITH CONFIGURABLE CORE FILLING AND PAIR SEPARATION

RELATED APPLICATION

This application is a Continuation of, and claims priority under 35 U.S.C. §119(e) to, commonly-owned, U.S. patent application Ser. No. 09/257,844, now U.S. Pat. No. 6,248,954 B1, entitled, "Multi-Pair Data Cable with Configurable Core Filling and Pair Separation," filed Feb. 25, 1999, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to high-speed data communications cables using at least two twisted pairs of insulated conductors. More particularly, the invention relates to high-speed data communications cables having a light-weight, configurable core-filling isolation pair separator that provides geometrical separation between the twisted pairs of insulated conductors.

DISCUSSION OF THE RELATED ART

High-speed data communications media in current usage include pairs of insulated conductors twisted together to form a balanced transmission line. Such pairs of insulated conductors are referred to herein as "twisted pairs." When twisted pairs are closely placed, such as in a cable, electrical energy may be transferred from one twisted pair of a cable to another twisted pair. Such energy transferred between twisted pairs is referred to as crosstalk. As operating frequencies increase, improved crosstalk isolation between the twisted pairs becomes more critical.

The Telecommunications Industry Association and the Electronics Industry Association (TIA/EIA) have developed standards which specify specific categories of performance for cable impedance, attenuation, skew and particularly crosstalk isolation. One standard for crosstalk or, in particular, crosstalk isolation, is TIA/EIA-568-A, wherein a category 5 cable is required to have 38 dB of isolation between the twisted pairs at 100 MHz and a category 6 cable is required to have 42 dB of isolation between the twisted pairs at 100 MHz. Various cable design techniques have been used to date in order to try to reduce crosstalk and to attempt to meet the industry standards.

For example, one cable implementation known in the industry that has been manufactured and sold as a high-speed data communications cable, includes the twisted pairs formed with relatively tight twists, and the cable is formed into a round construction. In this conventional cable, each twisted pair has a specified distance between twists along a longitudinal direction of the twisted pair, that distance being referred to as the "twist lay." When adjacent twisted pairs have the same twist lay and/or twist direction, they tend to lie within a cable more closely spaced than when the twisted pairs have different twist lays and/or a different twist direction. Such close spacing increases the amount of undesirable crosstalk which occurs between the twisted pairs. In some conventional cables, each twisted pair within the cable has a unique twist lay in order to increase the spacing between pairs and thereby to reduce the crosstalk between twisted pairs of the cable. In addition, the twist direction of the twisted pairs may also be varied. However, this industry standard configuration can only achieve limited crosstalk isolation.

Another cable implementation **100** disclosed in U.S. Pat. No. 4,777,325, is illustrated in FIG. **1**, wherein the twisted

pairs are enclosed within a jacket **102** that has a wide, flat configuration. In particular, aplurality of twisted pairs **104***a*–**104***b*, **106***a*–**106***b*, **108***a*–**108***b*, and **110***a*–**110***b* are positioned side-by-side, each in separate compartments **112**, **114**, **116**, and **118** formed within a flat hollow envelope of an extruded outer sheath **120**. The cable is provided with separator ribs **122** between a top and a bottom of the sheath to divide the outer sheath into the separate compartments and to prevent lateral movement of the twisted pairs out of their respective compartments. However, one problem with this flat configuration for a cable is that it has limited flexibility as compared to that of a round cable, which hinders installation of the cable in conduits and around bends.

Another cable implementation which addresses the problem of twisted pairs lying too closely together within the cable is described, for example, in U.S. Pat. No. 5,789,711 and is illustrated in FIG. **2**. In particular, the cable includes, for example, four twisted pairs **124** disposed about a central pre-shaped support **126**, wherein the support positions a twisted pair within grooves or channels **128** formed by the support. In particular, the support provides the grooves or channels which keep the twisted pairs at fixed positions with respect to each other. The support can have any of a number of shapes, including, for example, a standard "X", a "+", or the separator as is illustrated in FIG. **2**. The prongs or protrusions **130** of the support preserve the geometry of the pairs relative to each other, which helps reduce and stabilize crosstalk between the twisted pairs. However, some problems with the support is that the support adds cost to the cable, may limit the flexibility of the cable and increases the size; e.g., the diameter, of the cable. Another problem may be that the material which forms the support may result in the overall cable being a potential fire and/or smoke hazard.

Still another known industry cable implementation **132** is illustrated in FIG. **3**. The cable utilizes a jacket **134** with inward protrusions **136** that form channels **138** within the cable. A twisted pair **140** of conductors **142**, **144** is disposed within each channel. The protrusions are used to provide adequate pair separation. However, one problem with these protrusions is that they can be difficult to manufacture. In addition, the protrusions may not provide adequate separation between the twisted pairs where the stability of the protrusions is difficult to provide, and thus performance repeatability of the cable is an issue. Further, another problem is that the jacket is not easily strippable. When the cable is to be stripped by removing the outer jacket, which is often done with a sharp device such as, for example, a razor, the protrusions will not be cut by the incision around the circumference of the jacket and will have to be broken off separately in order to remove the jacket.

Accordingly, some of the problems with the above known configurations are that they are expensive, difficult to use, are generally undesirably large, and have decreased flexibility of the cables and workability of the twisted pairs of wires.

SUMMARY OF THE INVENTION

Therefore, a need exists for a high-speed data cable having multiple twisted pair wires with desired crosstalk performance, improved handling and termination capabilities, that is inexpensive, flexible and has a desired size. This invention provides an improved data cable.

According to the invention, a data communications cable has been developed so as to better facilitate the cable for its the intended use of high speed data transmission, yet main-

tain a form factor that has desired flexibility and workability, and that is compatible with industry standard hardware, such as plugs and jacks. The data communications cable of the invention has the additional benefit of a reduced cabled size relative to other known cables within its performance class.

In particular, the present invention provides these advantages by utilizing a configurable, highly flexible, core-filling, dielectric pair separator to provide pair separation for the cable.

One embodiment of a data communications cable of the invention includes a first twisted pair of insulated conductors, a second twisted pair of insulated conductors, and the dielectric pair separator. The dielectric pair separator is disposed between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors and is folded and arranged to provide a sufficient spacing between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors so as to provide a desired crosstalk isolation between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors. The data communications cable also includes a jacket assembly enclosing the first twisted pair of insulated conductors, the second twisted pair of insulated conductors, and the dielectric pair separator. With this arrangement, the data communications cable can be made with desired crosstalk isolation between the twisted pairs of insulated conductors. In addition, due to the conforming nature and the desired thickness of the dielectric pair separator, the cable has desired flexibility, workability and size. Moreover, these advantages do not come at the expense of other properties of the cable such as, for example, size or reduced impedance stability. The pair separator also facilitates termination of the data communications cable to known industry standard hardware.

Another embodiment of a data communications cable of the invention includes a plurality of twisted pairs of insulated conductors and the dielectric pair separator, having a plurality of folds in the dielectric pair separator to provide a plurality of grooves extending along a longitudinal length of the dielectric pair separator. Each of a twisted pair of insulated conductors is disposed within a groove of the dielectric pair separator. The data communications cable also includes a jacket assembly enclosing the plurality of twisted pairs of insulated conductors and the dielectric pair separator. This arrangement of the communications cable also has the above-described advantages.

According to the invention, one embodiment of a method of manufacturing the data communications cable of the invention includes forming the pair separator around a round cob to form a shaped pair separator such as a cylinder, and passing a plurality of twisted pairs of insulated conductors and the shaped pair separator through a first die which aligns the plurality of twisted pairs of insulated conductors with the shaped pair separator. The shaped pair separator is then further shaped or formed with a plurality of folds to provide a plurality of grooves along a longitudinal length of the formed pair separator. The formed pair separator and the plurality of twisted pairs of insulated conductors are then passed through corresponding apertures in a second die to align the plurality of twisted pairs with the grooves of the formed pair separator. The plurality of twisted pairs of insulated conductors and the formed pair separator are then passed through a third die which forces the plurality of twisted pairs of insulated conductors into contact with the grooves of the formed pair separator, and a jacket is provided around the plurality of twisted pairs of insulated conductors and the formed pair separator, to form the data communications cable.

BRIEF DESCRIPTION OF DRAWINGS

The objects, features and advantages of the present invention will become more apparent in view of the following detailed description of the invention when taken in conjunction with the figures, in which:

FIG 1 is a perspective view of an embodiment of a communications cable according to the related art;

FIG. 2 is a cross-sectional view of another embodiment of a communications cable according to the related art;

FIG. 3 is a cross-sectional view of another embodiment of a communications cable according to the related art;

FIG. 4 is a perspective view of a data communications cable according to one embodiment of the invention;

FIG. 5 is a cross-sectional view of the embodiment of the data communications cable of FIG. 4;

FIG. 6 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 7 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 8 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 9 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 10 is a cross-sectional view of a data communications cable according to embodiment of the invention;

FIG. 11 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 12 is a perspective view of a system for practicing a method of making a cable in accordance with an embodiment of the invention;

FIG. 13A illustrates a core of a four twisted pair cable; and

FIG. 13B is an exploded view of the core of the cable of FIG. 13A, having a filler material according to the invention.

DETAILED DESCRIPTION

A number of embodiments of a data communications cable according to the invention will now be described in which the cable is constructed with a plurality of twisted pairs of insulated conductors and a core made from a configurable, dielectric pair separator. However, it is to be appreciated that the invention is not limited to any number of twisted pairs or any profile for the configurable, dielectric pair separator illustrated in any of these embodiments. The inventive principles can be applied to cables including greater or fewer numbers of twisted pairs and having different core profiles of the configurable dielectric pair separator. In addition, although these embodiments of the invention are described and illustrated in connection with twisted pair data communication media, it is to be appreciated that other high-speed data communication media can be used instead of twisted pairs of conductors in the constructions of the cable according to the invention, such as, for example, fiber optic media.

FIG. 4 depicts an embodiment of a data communications cable 10 according to the present invention. The cable 10 includes two twisted pairs 12 of insulated conductors 13. The twisted pairs 12 are separated by a low dielectric constant, low dissipation factor, polymer "pair separator" 14. The twisted pairs 12 and the pair separator 14 are encased within a jacket assembly 16. The outer jacket can be a PVC, a low-smoke, low-flame PVC, or any plenum or non-plenum rated thermoplastic.

FIG. 5 depicts a cross-sectional view of an embodiment of the cable of FIG. 4. The configurable pair separator **14** runs along a longitudinal length of the cable, and is configured such that the twisted pairs are disposed within channels or grooves **15** of the pair separator along the length of the cable. As illustrated, the grooves **15** do not form completely enclosed channels. Some of the advantages of this cable according to the invention are that the pair separator provides structural stability during manufacture and use of the data communications cable, yet does not degrade the flexibility and workability of the cable, and does not substantially increase the size of the cable. In addition, the pair separator improves the crosstalk isolation between the twisted pairs by providing desired spacing between the twisted pairs. Therefore, the configurable pair separator of the invention lessens the need for complex and hard to control twist lay procedures, core filling arrangements and jacket embodiments described above with respect to the related art.

The above-described embodiment of the data communications cable can be constructed using a number of different materials as the pair separator **14**. While the invention is not limited to the materials described herein, the invention is advantageously practiced using these materials. In particular, the configurable pair separator is preferably a flame-retardant, low-dielectric constant, low-dissipation factor, foamed polymer tape, such as, for example, a foamed flame retardant, cellular polyolefin or fluoropolymer like NEPTC PP500 "SuperBulk", a foamed fluorinated ethylene propylene (FEP) or a foamed polyvinyl chloride (PVC). The above-described pair separators are preferably used in a non-plenum rated application where the cable is not required to pass industry standard flame and smoke tests such as the Underwriters Laboratories (UL) 910 test. Another preferable configurable pair separator is a woven fiberglass tape normally used as a binder for cables, such as, for example, Allied Fluoroglass CTX3X50. This woven fiberglass binder is preferably used in a plenum rated application where the cable must satisfy the UL 910 test.

Still another pair separator material that may be used in the cable of the invention is a bulk filling material such as a polyolefin or glass fiber filler that is flame-retardant and is typically shredded or fibrulated, but may also be solid, such as, for example, Chadwick AFT 033 Fiberglass. Such a bulk filling material is typically twisted up and used as a filling material in a core of the cable, with no other purpose. In particular, referring to FIG. 13A, the bulk filler is typically used as a core filling material that fills 100% of the core area **50** between the illustrated four twisted pair, that is used to keep the cable in a more or less round construction. However, referring to FIG. 13B, according to the present invention it is preferable to provide less than 100% of the core area **50** with the filling material; and it is more preferable us use less than 42% of the core with the filler material **52** for providing isolation between the twisted pairs. In a preferred embodiment, approximately 32% of the overall core area between the four twisted pairs of the cable is filled with such a filler and shaped as described herein. Therefore, one aspect of the present invention is the recognition that the filler or tape described above can be used to prevent physical contact between opposite and adjacent twisted pairs, thereby increasing the isolation between the twisted pairs, while not requiring the entire core area be filled, and therefore not sacrificing the size, cost or flexibility of the overall cable.

FIG. 6 depicts a cross-sectional view of a preferred embodiment of the data cable **10** of this invention. The cable includes the low-dielectric constant, low-dissipation factor polymer pair separator **14** formed into a cable core in such a way as to physically separate the four twisted pairs **12**, thereby decreasing field coupling between the twisted pairs, providing a desired opposite twisted pair-to-pair physical distance, as well as providing a desired adjacent pair separation. It is to be appreciated that like components of the data communications cable illustrated in FIGS. **4–5** have been provided with like reference numbers and the description of these components applies with respect to each of the cable embodiments to be described herein.

In the embodiment of the cable of FIG. **6**, the pair separator **14** is a flat configurable tape used as a core filler, that is shaped to have the illustrated profile and that is provided in the cable between the four twisted pairs **12**. In particular, in this embodiment, the configured pair separator has a shape somewhat like a "+", providing four channels **15** between each pair of protrusions **17** formed by the pair separator. Each channel carries one twisted pair **12** that is placed within the channel during a process of manufacturing the cable that will be described in further detail below. As is discussed above, the illustrated configurable core profile should not be considered limiting. In particular, although it is preferred that the pair separator is supplied as a flat extruded tape, the configurable pair separator may be made by a process other than extrusion and may have a number of different shapes or provide a number of different channels, as is illustrated by some of the embodiments described in further detail below.

Referring again to FIG. **6**, the data communications cable may also be provided with a binder **19**, as illustrated in phantom, that is wrapped around the configurable core pair separator **14** and the plurality of twisted pairs **12**. For this embodiment, it is preferable that the configurable core pair separator be an aluminum/mylar tape, with an aluminum layer on a side of the tape facing the plurality of twisted pairs. In addition, it is preferred that the binder be made of the aluminum/mylar tape, with the aluminum layer of the tape facing the plurality of the twisted pairs so that the combination of the binder and the configurable pair separator provide four electrically shielded, enclosed channels. With this embodiment, the four enclosed channels are isolated from one another to provide desired crosstalk isolation. In addition, another benefit of the embodiment of the cable is that a cable adjacent this cable will have reduced coupling with the cable of the invention, or in other words, reduced alien cross talk as it is known in the industry.

The embodiment of FIG. **6** further illustrates a shield **21** may also be laterally wrapped around the binder **19**; the shield is preferably made from a foil or metal. The shield may be applied over the cable before jacketing the cable with the jacket **16**, and is also used to help reduce crosstalk between the twisted pairs, to reduce alien crosstalk, and prevent the cable from causing or receiving electromagnetic interference. It is to be appreciated that the shield can also be provided in lieu of the binder. In particular, greater crosstalk isolation between the twisted pairs of the cable, and reduced alien crosstalk may also be achieved by using a conductive shield **21** that is, for example, a metal braid, a solid metal foil, or a conductive plastic that is in contact with ends of the protrusions **17** of the configurable filler **14**. If the configurable pair separator is also conductive or semi-conductive as described above for the aluminum/mylar tape, then the combination of the pair separator and the shield forms conductive compartments that shield each twisted pair from the other twisted pairs. Referring to FIG. **6**, the cable can advantageously include a metal drain wire **23** exposed,

for example, within the middle of the configurable pair separator **14**. The metal drain wire runs the length of the cable and acts as a ground. However, it is to be appreciated that the metal drain wire need not be so placed and may also be arranged in arrangements known to those of skill in the art such as, for example, spirally wrapped around the binder **19** or the shield **21**.

It is preferable in the embodiments described herein that the protrusions **17** of the configurable pair separator extend at least beyond a center axis of each twisted pair, known in the art as a pitch radius. The pitch radius is illustrated in FIG. **6** as the radius R between the center of the cable core and the center axis of the twisted pairs **12** of conductors. This preferred configuration of the configurable pair separator ensures that the twisted pairs do not escape their respective spaces or channels. It is also to be appreciated that the process of jacketing of the cable, to be described in detail below, may bend the ends of the protrusions **17** over slightly (not illustrated), since the configurable pair separator is relatively formable.

As discussed above, it is to be appreciated that the twisted pairs of insulated conductors and configurable pair separator of the communications data cable of the invention, can be configured in a variety of ways. FIGS. **7–12** depict cross-sectional views of various embodiments of the data communications cable of the invention. As illustrated, for example, in FIGS. **7**, **9** and **10**, the configurable pair separator may be configured such that the grooves **15** do not form completely enclosed channels. FIG. **7** depicts a cable **10** wherein six twisted pairs **12** are encased within the jacket assembly **16**, and are separated from each other by the configurable pair separator **14**. The pair separator **14** is configured in a somewhat "*" shape that provides support and placement of the twisted pairs so that the twisted pairs **12** have a desired spacial arrangement and do not come into direct physical contact with each other.

FIG. **8** depicts still another embodiment of the data communications cable **10** having multiple twisted pairs **12** encased within the jacket assembly **16** and having at least one of the twisted pairs isolated by the pair separator **14**, from the remainder of the twisted pairs. In particular, referring to FIG. **8**, the twisted pairs have been labeled TP1, TP2, TP3 and TP4, wherein twisted pair TP4 is isolated from twisted pairs TP1, TP2 and TP3 by the pair separator **14**. It is an advantage of this embodiment, that the pair separator **14** can be provided with an appropriate number of twists or wrappings around the twisted pair TP4, so as to provide selective isolation between twisted pair TP4 and twisted pairs TP1, TP2 and TP3. This embodiment of the cable according to the invention can be used, for example, to provide better isolation between a weakest one or a weakest combination of twisted pairs of cables, in an environment where there is known to be a low amount of isolation between a particular twisted pair and another twisted pair, or a plurality of twisted pairs. Accordingly, with this embodiment of the cable of the invention, there can be selective enhancement of isolation between twisted pairs TP1–TP4, TP2–TP4, and TP3–TP4. It is to be appreciated that although the twisted pair TP4 has been illustrated as being isolated from the remainder of the twisted pairs, that any of the twisted pairs can be so wrapped with the filler and isolated. This embodiment of the invention may also be used in conjunction with a lessening of the twist lays requirements for the twisted pairs, to provide cable having a same amount of isolation between twisted pairs as a cable with tighter twist lays. Accordingly, this embodiment of the cable according to the invention allows for selective design of isolation between particular twisted pairs of the cable and lessening of the twist lay requirements for the cable.

FIG. **9** depicts still another embodiment of the data communications cable **10** having multiple twisted pairs **12** encased within the jacket assembly **16** and physically separated from each other by the configurable pair separator **14**, and also including a central core filler **18** positioned at the middle of the cable and that runs along the longitudinal length of the cable, provided less than 100% of the core is filled with the filler. The configurable pair separator provides desired separation between the individual twisted pairs **12** as discussed above. The central core **18** provides additional support or structure and may be formed of, for example, a solid or foamed flame retardant polyolefin or other materials that are known in the industry. For plenum rated cables, it is preferable that the core be any of one or more of the following compounds: a solid low-dielectric constant fluoropolymer, e.g. ethylene chlorotrifluoroethylene (E-CTFE), is FEP, a foamed fluoropolymer, e.g. foamed FEP, and PVC in either solid, low dielectric constant form or foamed. The central core filling **18** may also be constructed of the same materials as the configurable pair separator **14** discussed above.

FIG. **10** depicts yet another embodiment of a data communications cable **10**, having a substantially flat configuration. Twisted pairs **12** are encased within a substantially flat jacket assembly **16** and physically separated from each other by the configurable pair separator **14**. The cable of FIG. **10** is an alternative to the cable of the related art as illustrated in FIG. **1**, and other known flat cables. It is to be understood, that although this embodiment is illustrated with a single fold of the pair separator material between each twisted pair, that the number of folds can be increased to further adjust the distance between each of the twisted pairs and thereby increase the isolation between each of the twisted pairs. Other variations known to those of skill in the art are also intended to be within the scope of the invention and this embodiment. For example, the pair separator may also be disposed at a bottom of the cable with folds directed upwardly towards the top of the cable, in contrast to at the top of the cable with the folds directed towards the bottom of the cable as illustrated in FIG. **10**, or the pair separator may be disposed at both the bottom and top.

FIG. **11** depicts an embodiment of a data communications cable **22** including a plurality of data communications cables **10** according to any of the embodiments described above. In particular, each data cable **10** contains multiple twisted pairs **12** separated by the configurable pair separator **14** according to any of the above-described configurations, and encased in the jacket assembly **16**. The plurality of data cables are enclosed within outer casing **20**. The cable **22** may also have a central core filler **24**, as illustrated in phantom, that may be formed from any of the above-described materials and may be used to, for example, to keep the data cables in a desired arrangement so as to, for example, minimize crosstalk between each of the data cables **10**.

Referring now to FIG. **12**, there is illustrated a perspective view of a system for practicing a method of making a cable in accordance with an embodiment of the invention. The pair separator **26** is drawn from a reel or pad (not shown), and is formed around a round cob **28** into a shaped pair separator such as, for example, in the shape of a cylinder. The shaped pair separator is aligned with four twisted pairs **12** by passing the four twisted pairs through openings **30** in first die **32**, and the shaped pair separator through central opening **34**. The shaped pair separator is then further configured into a desired shape (formed pair separator) as illustrated in FIG.

12. It is to be appreciated, as discussed above, that this shape can be varied. The formed pair separator **15** is then passed through opening **36** in second die **38** and brought together with the four twisted pairs **12** which are passed through corresponding openings **40** in the second die. The plurality of twisted pairs are then cabled with the formed pair separator by a third die **42**, in an operation referred to as "bunching". The third die places the twisted pairs in the channels **15** (see FIGS. **5–10**) of the formed pair separator prior to twisting of the cable. It is to be appreciated that the cable can be twisted with any known twisting arrangement such as a helix, or an S-Z configuration. It is also to be appreciated that this method can be varied to include any of the components illustrated and discussed above, such as, for example, to include a drain wire, a binder, a shield, or central core filler.

Accordingly, some of the advantages of the various embodiments of the data communications cable of the invention are crosstalk performance and isolation enhancement can be configured and provided as customized cable solutions for hardware manufactures who request special requirements. For example, specific twisted pair combinations can receive a dedicated amount of isolation tape folds, thereby enhancing separation of selected twisted pairs and enhancing crosstalk isolation between the selected twisted pairs where an end user, for example, needs more crosstalk isolation. The data communications cable can also be made with a desired crosstalk isolation between the opposing twisted pairs of insulated conductors. In addition, due to the conforming nature and the thickness of the pair separator material, this advantage does not come at the expense of, for example, the size of the data communications cable, and does not result in a reduced impedance stability of the data communications cable. Another advantage is that the amorphous nature of the pair separator yields a desired cable that better facilitates termination of the data communications cable to known industry hardware, than larger diameter cables of the related art.

The present invention has now been described in connection with a number of specific embodiments thereof. However, numerous modifications which are contemplated as falling within the scope of the present invention should now be apparent to those skilled in the art. Therefore, it is intended that the scope of the present invention be limited only by the scope of the claims appended hereto.

What is claimed is:

1. A data communications cable comprising:

a first twisted pair of insulated conductors;

a second twisted pair of insulated conductors;

a dielectric pair separator consisting of a dielectric layer disposed between the first twisted pair and the second twisted pair of insulated conductors, the dielectric pair separator being folded and arranged to provide a plurality of grooves extending along a longitudinal length of the dielectric pair separator, the dielectric pair separator providing a sufficient spacing between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors so as to provide a desired crosstalk isolation between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors;

a jacket assembly enclosing the first twisted pair of insulated conductors, the second twisted pair of insulated conductors and the dielectric pair separator; and

wherein the plurality of grooves do not form completely enclosed channels.

2. The data communications cable according to claim **1**, wherein the dielectric pair separator is made of a foamed polymer.

3. The data communications cable according to claim **1**, wherein the dielectric pair separator is a woven fiberglass tape.

4. The data communications cable according to claim **1**, wherein the dielectric pair separator is a flame-retardant, low-dielectric constant, foamed polymer tape.

5. The data communications cable according to claim **1**, wherein the dielectric pair separator is a foamed fluorinated ethylene propylene material.

6. The data communications cable according to claim **1**, further comprising a central core filling material disposed in a core of the data communications cable between the first and second twisted pairs of insulated conductors.

7. The data communications cable according to claim **6**, wherein the central core filling is made of a same material as the dielectric pair separator.

8. The data communications cable according to claim **1**, wherein the cable is substantially flat.

9. The data communications cable according to claim **1**, further comprising a conductive shield surrounding the combination of the first twisted pair of insulated conductors, the second twisted pair of insulated conductors, and the dielectric pair separator.

10. A data communications cable comprising:

a plurality of twisted pairs of insulated conductors,

a dielectric pair separator consisting of a dielectric layer formed with a plurality of folds to provide a plurality of grooves extending along a longitudinal length of the dielectric pair separator;

each twisted pair of insulated conductors of the plurality of twisted pairs of insulated conductors, being disposed within a corresponding groove of the dielectric pair separator;

a jacket assembly enclosing the plurality of the twisted pairs of insulated conductors and the dielectric pair separator; and

wherein the plurality of grooves do not form completely enclosed channels.

11. The data communications cable according to claim **10**, wherein the dielectric pair separator is folded so as to separate each twisted pair of insulated conductors from every other twisted pair of insulated conductors, with a sufficient spacing to provide a desired crosstalk isolation between each of the plurality of twisted pairs of insulated conductors.

12. The data communications cable according to claim **10**, wherein the dielectric pair separator is wrapped around a first twisted pair of insulated conductors of the plurality of twisted pairs of insulated conductors, so as to separate the first twisted pair of insulated conductors from a remainder of the plurality of twisted pairs of insulated conductors, with a sufficient spacing to provide a desired crosstalk isolation between the first twisted pair of insulated conductors and the remainder of the twisted pair of insulated conductors.

13. The data communications cable according to claim **10**, wherein the plurality of folds of the dielectric pair separator extend from a center of the data communications cable to at least a pitch radius of the data communications cable.

14. The data communications cable according to claim **10**, wherein the dielectric pair separator is a flame-retardant, foamed polymer tape.

15. The data communications cable according to claim **12**, wherein the dielectric pair separator is a woven fiberglass tape.

16. The data communications cable according to claim 10, wherein the dielectric pair separator is a foamed fluorinated ethylene propylene material disposed in a core of the data communications cable between the first and second twisted pairs of insulated conductors.

17. The data communications cable according to claim 10, the cable further comprising a central core filling material disposed in a core of the data communications cable between the first and second twisted pairs of insulated conductors.

18. The data communications cable according to claim 17, wherein the central core filling is made of a same material as the dielectric pair separator.

19. The data communications cable according to claim 10, wherein the data cable is substantially flat.

20. The data communications cable according to claim 10, further comprising a conductive shield surrounding the plurality of twisted pairs of insulated conductors and the dielectric pair separator.

21. The data communications cable according to claim 10, wherein the plurality of twisted pairs of insulated conductors and the dielectric pair separator are twisted together in a helical manner along the longitudinal length of the data communications cable.

22. The data communications cable according to claim 10, further comprising a drain wire disposed within a center of the dielectric pair separator between the plurality of folds of the dielectric pair separator, and extending along the longitudinal length of the data communications cable.

23. The data communications cable according to claim 10, wherein a plurality of the data communications cables are disposed within an outer casing to form an overall data cable.

24. A data communications cable comprising:

a plurality of twisted pairs of insulated conductors;

a dielectric pair separator consisting of a dielectric layer and a conductive layer formed with a plurality of folds to provide a plurality of grooves extending along a longitudinal length of the dielectric pair separator, wherein the plurality of grooves do not form completely enclosed channels;

a jacket assembly enclosing the plurality of twisted pairs of insulated conductors and the dielectric pair separator;

each twisted pair of insulated conductors of the plurality of twisted pairs of insulated conductors being disposed within a corresponding groove of the dielectric pair separator; and

a binder enclosing the plurality of twisted pairs of insulated conductors and the dielectric pair separator, the binder having a conductive layer that faces each of the plurality of twisted pairs of insulated conductors so that the binder in combination with the dielectric pair separator provides a plurality of enclosed channels extending along a longitudinal length of the data communications cable, each enclosed channel providing crosstalk isolation between a corresponding twisted pair of insulated conductors enclosed within the channel and a remainder of the plurality of twisted pairs of insulated conductors, and providing reduced susceptibility of the twisted pair of insulated conductors to electromagnetic interference.

25. The data communications cable according to claim 24, wherein the dielectric pair separator is folded and arranged so that the conductive layer faces each of the plurality of twisted pairs of insulated conductors.

26. The data communications cable according to claim 25 wherein the binder and the dielectric pair separator are made of an aluminum/mylar tape, an aluminum layer of the tape being the conductive layer facing the plurality of twisted pairs of insulated conductors.

27. A data communications cable comprising:

a first twisted pair of insulated conductors;

a second twisted pair of insulated conductors;

a configurable dielectric pair separator that separates the first and second twisted pairs of conductors, the configurable dielectric pair separator being substantially flat;

a jacket enclosing the first and second twisted pairs of insulated conductors and the dielectric pair separator; and

wherein the configurable dielectric pair separator, the first twisted pair of insulated conductors and the second twisted pair of insulated conductors are twisted about a common central axis to form a twisted pair cable; and wherein the configurable dielectric pair separator is arranged within the jacket to form at least two grooves.

28. The data communications cable as claimed in claim 27, wherein the configurable dielectric pair separator is arranged to provide a sufficient spacing between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors so as to provide a desired crosstalk isolation between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors.

29. The data communications cable as claimed in claim 27, wherein the at least two grooves do not form completely enclosed channels.

30. The data communications cable as claimed in claim 27, wherein the configurable dielectric pair separator comprises a foamed polymer tape.

31. A data communications cable comprising:

a plurality of twisted pairs of insulated conductors;

a configurable dielectric pair separator disposed between at least two of the plurality of twisted pairs of insulated conductors, the configurable dielectric pair separator including a substantially flat dielectric tape formed of a foamed polymer;

a jacket enclosing the plurality of twisted pairs of insulated conductors and the configurable dielectric pair separator; and

wherein the plurality of twisted pairs of insulated conductors and the configurable dielectric pair separator are twisted about a common axis to formn a twisted pair cable.

32. The data communications cable as claimed in claim 31, wherein the configurable dielectric pair separator is arranged to provide a sufficient spacing between the at least two twisted pairs of insulated conductors so as to provide a desired crosstalk isolation between the at least two twisted pairs of insulated conductors.

33. The data communications cable as claimed in claim 31, wherein the configurable dielectric pair separator is arranged within the jacket to provide at least two grooves, at least one twisted pair of conductors being disposed within each of the at least two grooves.

* * * * *

EXHIBIT D

US006596944B1

(12) **United States Patent**
Clark et al.

(10) **Patent No.: US 6,596,944 B1**
(45) **Date of Patent: Jul. 22, 2003**

(54) **ENHANCED DATA CABLE WITH CROSS-TWIST CABLED CORE PROFILE**

(75) Inventors: **William T. Clark**, Lancaster, MA (US); **Peter D. MacDonald**, Gardner, MA (US); **Joseph Dellagala**, Shrewsbury, MA (US)

(73) Assignee: **Cable Design Technologies, Inc.**, Leominster, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/532,837**

(22) Filed: **Mar. 21, 2000**

Related U.S. Application Data

(63) Continuation of application No. 08/841,440, filed on Apr. 22, 1997, now Pat. No. 6,074,503.

(51) **Int. Cl.**[7] **H01B 11/02**
(52) **U.S. Cl.** ..... **174/113 C**
(58) **Field of Search** ..... 174/113 R, 113 C, 174/131 A, 27; 385/101, 103, 105

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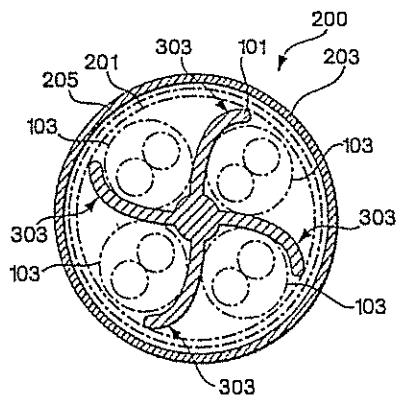
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Primary Examiner—Chau N. Nguyen
(74) *Attorney, Agent, or Firm*—Wolf, Greenfield & Sacks, P.C.

(57) **ABSTRACT**

A cable exhibiting reduced crosstalk between transmission media includes a core having a profile with a shape which defines spaces or channels to maintain a spacing between transmission media in a finished cable. The core is formed of a conductive material to further reduce crosstalk. A method of producing a cable introduces a core as described above into the cable assembly and imparts a cable closing twist to the assembly.

12 Claims, 3 Drawing Sheets



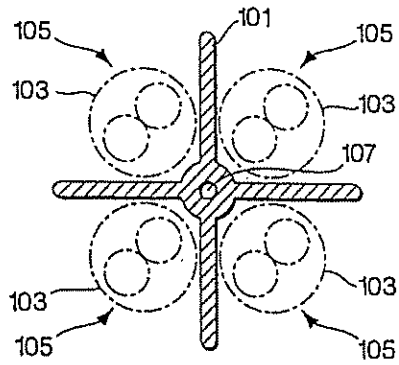


Fig. 1

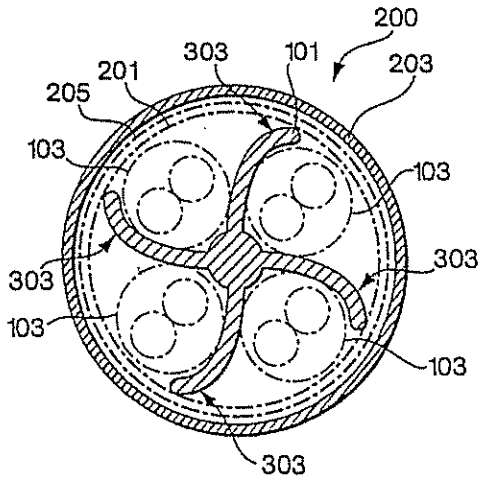


Fig. 2

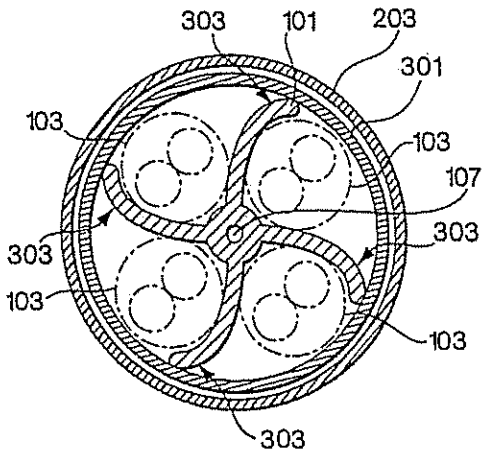


Fig. 3

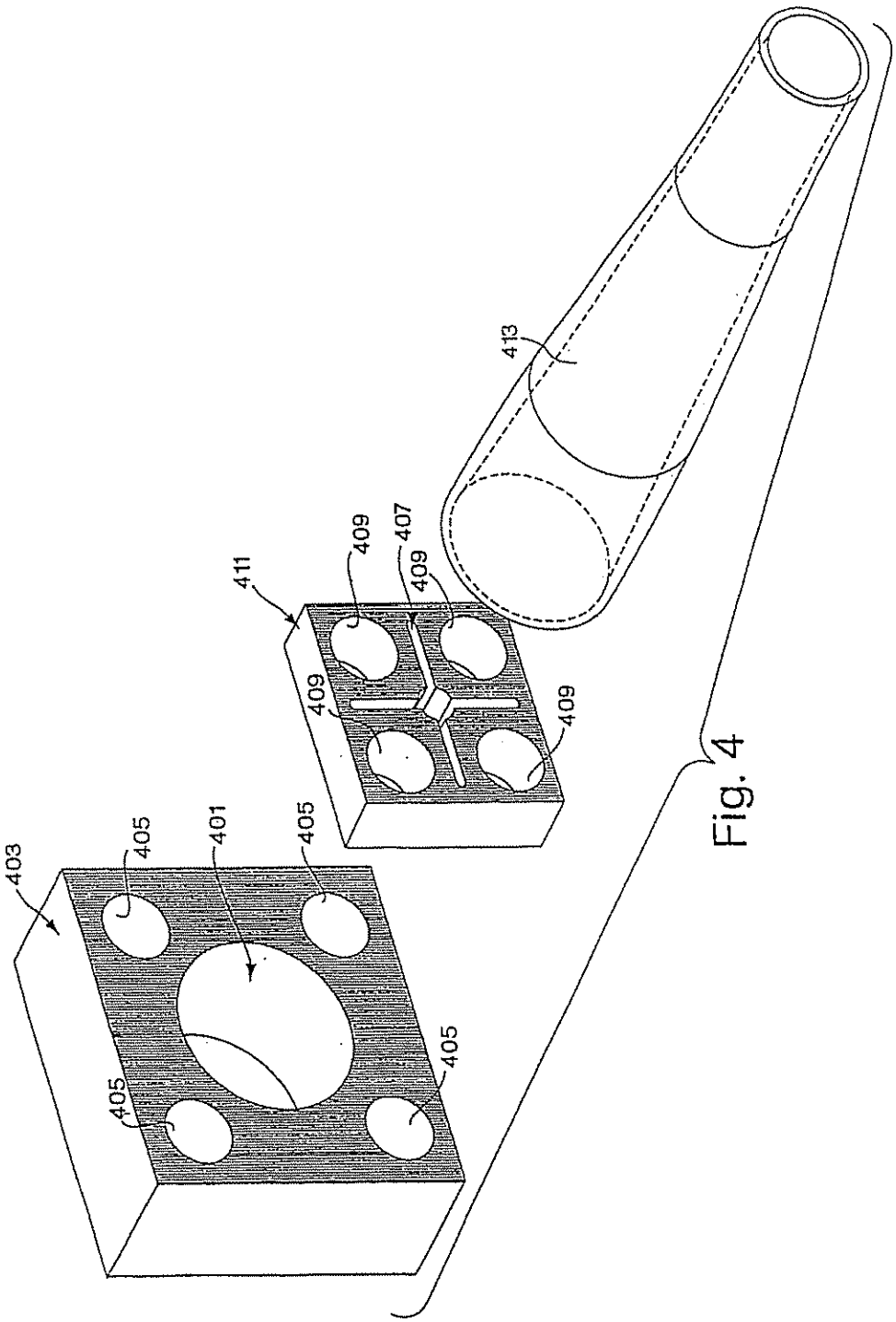


Fig. 4

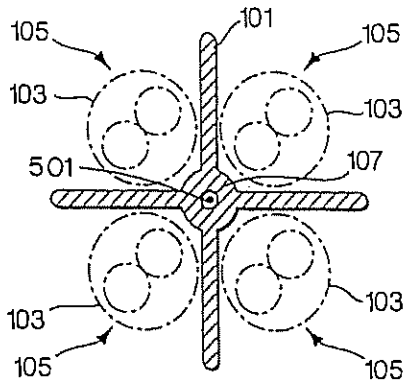

101
105
105
103
103
501
107
103
103
105
105

Fig. 5

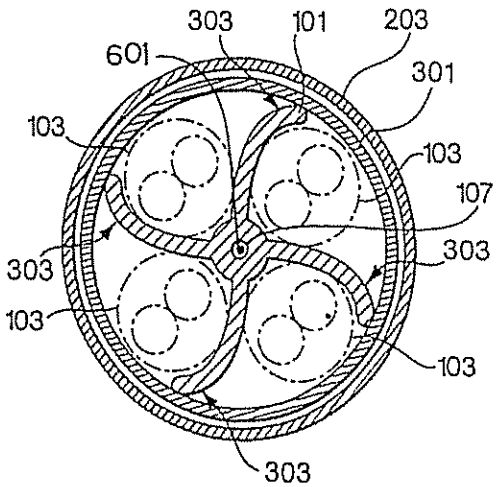

303
101
203
601
301
103
103
107
303
303
103
103
303

Fig. 6

ENHANCED DATA CABLE WITH CROSS-TWIST CABLED CORE PROFILE

BACKGROUND

This application is a continuation of application Ser. No. 08/841,440, filed Apr. 22, 1997 entitled Making Enhanced Data Cable with Cross-Twist Cabled Core Profile (as amended) now U.S. Pat. No. 6,074,503.

FIELD OF THE INVENTION

The present invention relates to high-speed data communications cables using at least two twisted pairs of wires. More particularly, it relates to cables having a central core defining plural individual pair channels.

RELATED ART

High-speed data communications media in current usage include pairs of wire twisted together to form a balanced transmission line. Such pairs of wire are referred to as twisted pairs. One common type of conventional cable for high-speed data communications includes multiple twisted pairs. When twisted pairs are closely placed, such as in a cable, electrical energy may be transferred from one pair of a cable to another. Such energy transferred between pairs is undesirable and referred to as crosstalk. The Telecommunications Industry Association and Electronics Industry Association have defined standards for crosstalk, including TIA/EIA-568A. The International Electrotechnical Commission has also defined standards for data communication cable crosstalk, including ISO/IEC 11801. One high-performance standard for 100Ω cable is ISO/IEC 11801, Category 5.

In conventional cable, each twisted pair of a cable has a specified distance between twists along the longitudinal direction, that distance being referred to as the pair lay. When adjacent twisted pairs have the same pair lay and/or twist direction, they tend to lie within a cable more closely spaced than when they have different pair lays and/or twist direction. Such close spacing increases the amount of undesirable crosstalk which occurs. Therefore, in some conventional cables, each twisted pair within the cable has a unique pair lay in order to increase the spacing between pairs and thereby to reduce the crosstalk between twisted pairs of a cable. Twist direction may also be varied. Along with varying pair lays and twist directions, individual solid metal or woven metal pair shields are sometimes used to electromagnetically isolate pairs.

Shielded cable, although exhibiting better crosstalk isolation, is more difficult and time consuming to install and terminate. Shield conductors are generally terminated using special tools, devices and techniques adapted for the job.

One popular cable type meeting the above specifications is Unshielded Twisted Pair (UTP) cable. Because it does not include shield conductors, UTP is preferred by installers and plant managers, as it is easily installed and terminated. However, UTP fails to achieve superior crosstalk isolation, as required by state of the art transmission systems, even when varying pair lays are used.

Another solution to the problem of twisted pairs lying too closely together within a cable is embodied in a cable manufactured by Belden Wire & Cable Company as product number 1711A. This cable includes four twisted pair media radially disposed about a "+"-shaped core. Each twisted pair nests between two fins of the "+"-shaped core, being separated from adjacent twisted pairs by the core. This helps reduce and stabilize crosstalk between the twisted pair media. However, the core adds substantial cost to the cable, as well as material which forms a potential fire hazard, as explained below, while achieving a crosstalk reduction of only about 5 dB.

In building design, many precautions are taken to resist the spread of flame and the generation of and spread of smoke throughout a building in case of an outbreak of fire. Clearly, it is desired to protect against loss of life and also to minimize the costs of a fire due to the destruction of electrical and other equipment. Therefore, wires and cables for in building installations are required to comply with the various flammability requirements of the National Electrical Code (NEC) and/or the Canadian Electrical Code (CEC).

Cables intended for installation in the air handling spaces (ie. plenums, ducts, etc.) of buildings are specifically required by NEC or CEC to pass the flame test specified by Underwriters Laboratories Inc. (UL), UL-910, or it's Canadian Standards Association (CSA) equivalent, the FT6. The UL-910 and the FT6 represent the top of the fire rating hierarchy established by the NEC and CEC respectively. Cables possessing this rating, generically known as "plenum" or "plenum rated", may be substituted for cables having a lower rating (ie. CMR, CM, CMX, FT4, FT1 or their equivalents), while lower rated cables may not be used where plenum rated cable is required.

Cables conforming to NEC or CEC requirements are characterized as possessing superior resistance to ignitability, greater resistant to contribute to flame spread and generate lower levels of smoke during fires than cables having a lower fire rating. Conventional designs of data grade telecommunications cables for installation in plenum chambers have a low smoke generating jacket material, e.g. of a PVC formulation or a fluoropolymer material, surrounding a core of twisted conductor pairs, each conductor individually insulated with a fluorinated ethylene propylene (FEP) insulation layer. Cable produced as described above satisfies recognized plenum test requirements such as the "peak smoke" and "average smoke" requirements of the Underwriters Laboratories, Inc., UL910 Steiner test and/or Canadian Standards Association CSA-FT6 (Plenum Flame Test) while also achieving desired electrical performance in accordance with EIA/TIA-568A for high frequency signal transmission.

While the above-described conventional cable including the Belden 1711A cable due in part to their use of FEP meets all of the above design criteria, the use of fluorinated ethylene propylene is extremely expensive and may account for up to 60% of the cost of a cable designed for plenum usage.

The solid core of the Belden 1711A cable contributes a large volume of fuel to a cable fire. Forming the core of a fire resistant material, such as FEP, is very costly due to the volume of material used in the core.

Solid flame retardant/smoke suppressed polyolefin may also be used in connection with FEP. Solid flame retardant/smoke suppressed polyolefin compounds commercially available all possess dielectric properties inferior to that of FEP. In addition, they also exhibit inferior resistance to burning and generally produce more smoke than FEP under burning conditions than FEP.

SUMMARY OF THE INVENTION

This invention provides an improved data cable.

According to one embodiment, the cable includes a plurality of transmission media; a core having a surface defining recesses within which each of the plurality of transmis-

sion media are individually disposed; and an outer jacket maintaining the plurality of data transmission media in position with respect to the core.

According to another embodiment of the invention, a cable includes a plurality of transmission media radially disposed about a core having a surface with features which maintain a separation between each of the plurality of transmission media.

Finally, according to yet another embodiment of the invention, there is a method of producing a cable. The method first passes a plurality of transmission media and a core through a first die which aligns the plurality of transmission media with surface features of the core and prevents twisting motion of the core. Next, the method bunches the aligned plurality of transmission media and core using a second die which forces each of the plurality of transmission media into contact with the surface features of the core which maintain a spatial relationship between each of the plurality of transmission media. Finally, the bunched plurality of transmission media and core are twisted to close the cable, and the closed cable is jacketed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, in which like reference numerals designate like elements:

FIG. **1** is a cross-sectional view of a cable core used in embodiments of the invention;

FIG. **2** is a cross-sectional view of one embodiment of a cable including the core of FIG. **1**;

FIG. **3** is a cross-sectional view of another embodiment of a cable including the core of FIG. **1**;

FIG. **4** is a perspective view of a die system for practicing a method of making a cable in accordance with another embodiment of the invention;

FIG. **5** is a cross-sectional view of another embodiment of a cable core used in some embodiments of the cable of the invention; and

FIG. **6** is a cross-sectional view of another embodiment of a cable core used in some embodiments of the cable of the invention.

DETAILED DESCRIPTION

An embodiment of the invention is now described in which a cable is constructed to include four twisted pairs of wire and a core having a unique profile. However, the invention is not limited to the number of pairs or the profile used in this embodiment. The inventive principles can be applied to cables including greater or fewer numbers of twisted pairs and different core profiles. Also, although this embodiment of the invention is described and illustrated in connection with twisted pair data communication media, other high-speed data communication media can be used in constructions of cable according to the invention.

This illustrative embodiment of the invention, as shown in FIG. **1**, includes an extruded core **101** having a profile described below cabled into the cable with four twisted pairs **103**. The extruded core profile has an initial shape of a "+", providing four spaces or channels **105** between each pair of fins of the core. Each channel **105** carries one twisted pair **103** placed within the channel **105** during the cabling operation. The illustrated core **101** and profile should not be considered limiting. The core **101** may be made by some other process than extrusion and may have a different initial shape or number of channels **105**. For example, as illustrated in FIG. **5**, there may be an optional central channel **107** provided to carry a fiber optic element **501**.

The above-described embodiment can be constructed using a number of different materials. While the invention is not limited to the materials now given, the invention is advantageously practiced using these materials. The core material should be a conductive material or one containing a powdered ferrite, the core material being generally compatible with use in data communications cable applications, including any applicable fire safety standards. In non-plenum applications, the core can be formed of solid or foamed flame retardant polyolefin or similar materials. In plenum applications, the core can be any one or more of the following compounds: a solid low dielectric constant fluoropolymer, e.g., ethylene chlortrifluoroethylene (E-CTFE) or fluorinated ethylene propylene (FEP), a foamed fluoropolymer, e.g., foamed FEP, and polyvinyl chloride (PVC) in either solid, low dielectric constant form or foamed. A filler is added to the compound to render the extruded product conductive. Suitable fillers are those compatible with the compound into which they are mixed, including but not limited to powdered ferrite, semiconductive thermoplastic elastomers and carbon black. Conductivity of the core helps to further isolate the twisted pairs from each other.

A conventional four-pair cable including a non-conductive core, such as the Belden 1711A cable, reduces nominal crosstalk by up to 5 dB over similar, four-pair cable without the core. By making the core conductive, crosstalk is reduced a further 5 dB. Since both loading and jacket construction can affect crosstalk, these figures compare cables with similar loading and jacket construction.

The cable may be finished in any one of several conventional ways, as shown in FIG. **2**. The combined core **101** and twisted pairs **103** may be optionally wrapped with a dielectric tape **201**, then jacketed **203** to form cable **200**. An overall conductive shield **205** can optionally be applied over the cable before jacketing to prevent the cable from causing or receiving electromagnetic interference. The jacket **203** may be PVC or another material as discussed above in relation to the core **101**. The dielectric tape **201** may be polyester, or another compound generally compatible with data communications cable applications, including any applicable fire safety standards.

Greater cross-talk isolation is achieved in the construction of FIG. **3**, by using a conductive shield **301**, for example a metal braid, a solid metal foil shield or a conductive plastic layer in contact with the ends of the fins **303** of the core **101**. Such a construction rivals individual shielding of twisted pairs for cross-talk isolation. This construction optionally can advantageously include a drain wire **601** in a central channel **107**, as illustrated in FIG. **6**. In the constructions of both FIGS. **2** and **3** it is advantageous to have the fins **303** of the core **101** extend somewhat beyond a boundary defined by the outer dimension of the twisted pairs **103**. In the construction of FIG. **2** this ensures that he twisted pairs **103** do not escape their respective channels **105** prior to the cable being jacketed, while in that of FIG. **3** and good contact between the fins **303** and the shield **301** is ensured. In both constructions, closing and jacketing the cable may bend the tips of the fins **303** over slightly, as shown in the core material is relatively soft, such as PVC.

A method of making cable in accordance with the above-described embodiments is now described.

As is known in this art, when plural elements are cabled together, an overall twist is imparted to the assembly to improve geometric stability and help prevent separation. In embodiments of the present invention, twisting of the profile

of the core along with the individual twisted pairs is controlled. The process allows the extruded core to maintain a physical spacing between the twisted pairs and maintains geometrical stability within the cable. Thus, the process assists in the achievement of and maintenance of high crosstalk isolation by placing a conductive core in the cable to maintain pair spacing.

Cables of the previously described embodiments, can be made by a three-part die system. However, methods of making such cables are not limited to a three-part die system, as more or fewer die elements can be constructed to incorporate the features of the invention.

The extruded core is drawn from a payoff reel (not shown) through the central opening **401** in die **403**. Four twisted pairs are initially aligned with the core by passing through openings **405** in die **403**. The core is next brought through opening **407** and brought together with the four twisted pairs which are passed through openings **409** in a second die **411**, then cabled with the twisted pairs which are pushed into the channels of the core by a third die **413**, in an operation called bunching. The second die **411** eliminates back twist, which is inherent in bunching operations, thus allowing the third die **413** to place the pairs in the channels prior to the twisting. The cable twist is imparted to the cable assembly after the second die **411**, which locates the twisted pairs relative to the extruded core profile.

Although the method of making cable has been described in connection with an extruded core delivered into the process from a payoff reel, the invention is not so limited. For example, the core could he extruded immediately prior to use and transferred directly from the extruder to the central opening **401** of the first die **403**. In another variation, the core could be extruded directly through a properly shaped central opening of either the first die **403** or the second die **411**.

The present invention has now been described in connection with a number of specific embodiments thereof. However, numerous modifications which are contemplated as falling within the scope of the present invention should now be apparent to those skilled in the art. Therefore, it is intended that the scope of the present invention be limited only by the scope of the claims appended hereto.

What is claimed is:

1. An unshielded data cable comprising:

a plurality of twisted pairs of conductors;

a non-conductive central core having a surface that defines a plurality of channels within which the plurality of twisted pairs of conductors are individually disposed;

an outer jacket that maintains the plurality of twisted pairs of conductors in position with respect to the non-conductive central core, the outer jacket being formed of a non-conductive material; and

wherein the unshielded data cable does not include a shield that encloses any of the plurality of conductors and the non-conductive central core.

2. The unshielded data cable of claim **1**, wherein the non-conductive central core comprises a plurality of fins extending radially outward from a center of the core to at least an outer boundary defined by an outer dimension of the twisted pairs of conductors.

3. The unshielded data cable of claim **2**, wherein each of the plurality of fins has substantially parallel sides.

4. The cable as claimed in claim **2**, wherein each of the fins is bent at a tip by the outer jacket.

5. The unshielded data cable of claim **2**, wherein the non-conductive central core comprising the plurality of fins is made of a fire resistant plastic.

6. The unshielded data cable of claim **2**, wherein the plurality of channels are defined by the plurality of fins.

7. The unshielded data cable of claim **2**, wherein the plurality of fins position the plurality of twisted pairs in a substantially 90° relationship.

8. The unshielded data cable of claim **1**, wherein the non-conductive central core comprises four fins, each fin extending radially outward from a center of the core at substantially right angles to at least one other of the four fins.

9. The unshielded data cable of claim **1**, wherein the non-conductive central core comprises:

at least one of a solid fluoropolymer, a foamed fluoropolymer, foamed polyvinyl chloride, and solid polyvinyl chloride.

10. The unshielded data cable of claim **1**, wherein the non-conductive central core comprises a cavity.

11. The unshielded data cable of claim **10**, further comprising a fiber optic element disposed within the cavity.

12. The unshielded data cable of claim **10**, further comprising a drain wire disposed within the cavity.

* * * * *

EXHIBIT E

US006998537B2

(12) **United States Patent**
Clark et al.

(10) **Patent No.: US 6,998,537 B2**
(45) **Date of Patent: Feb. 14, 2006**

(54) **MULTI-PAIR DATA CABLE WITH CONFIGURABLE CORE FILLING AND PAIR SEPARATION**

(75) Inventors: **William Clark**, Lancaster, MA (US); **Joseph Dellagala**, Shrewsbury, MA (US); **Kenneth Consalvo**, Leominster, MA (US)

(73) Assignee: **Belden CDT Networking, Inc.**, Fort Mills, SC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/336,535**

(22) Filed: **Jan. 3, 2003**

(65) **Prior Publication Data**

US 2003/0217863 A1 Nov. 27, 2003

Related U.S. Application Data

(63) Continuation of application No. 09/853,512, filed on May 11, 2001, now Pat. No. 6,570,095, which is a continuation of application No. 09/257,844, filed on Feb. 25, 1999, now Pat. No. 6,248,954.

(51) **Int. Cl.**
H01B 1/02 (2006.01)

(52) **U.S. Cl.** ..... **174/113 R**; 174/113 C
(58) **Field of Classification Search** ..... 174/113 R, 174/113 C, 131 A, 36, 117 F, 121 A
See application file for complete search history.

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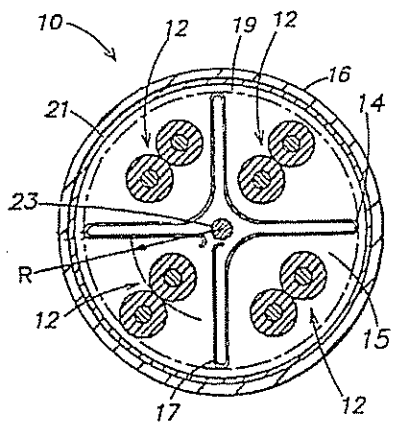
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Primary Examiner—Chau N. Nguyen
(74) *Attorney, Agent, or Firm*—Lowrie, Lando & Anastasi, LLP

(57) **ABSTRACT**

An improved data telecommunications cable according to the invention includes a plurality of twisted pairs of insulated conductors, and a substantially flat configurable dielectric separator disposed between the plurality of twisted pairs of insulated conductors along a longitudinal length of the telecommunications cable. The data communications cable also includes a jacket assembly enclosing the plurality of twisted pairs of insulated conductors and the substantially flat dielectric pair separator. The substantially flat dielectric pair separator separates each twisted pair of insulated conductors from every other twisted pair of insulated conductors with a spacing sufficient to provide a desired crosstalk isolation between each of the plurality of twisted pairs of insulated conductors.

22 Claims, 8 Drawing Sheets



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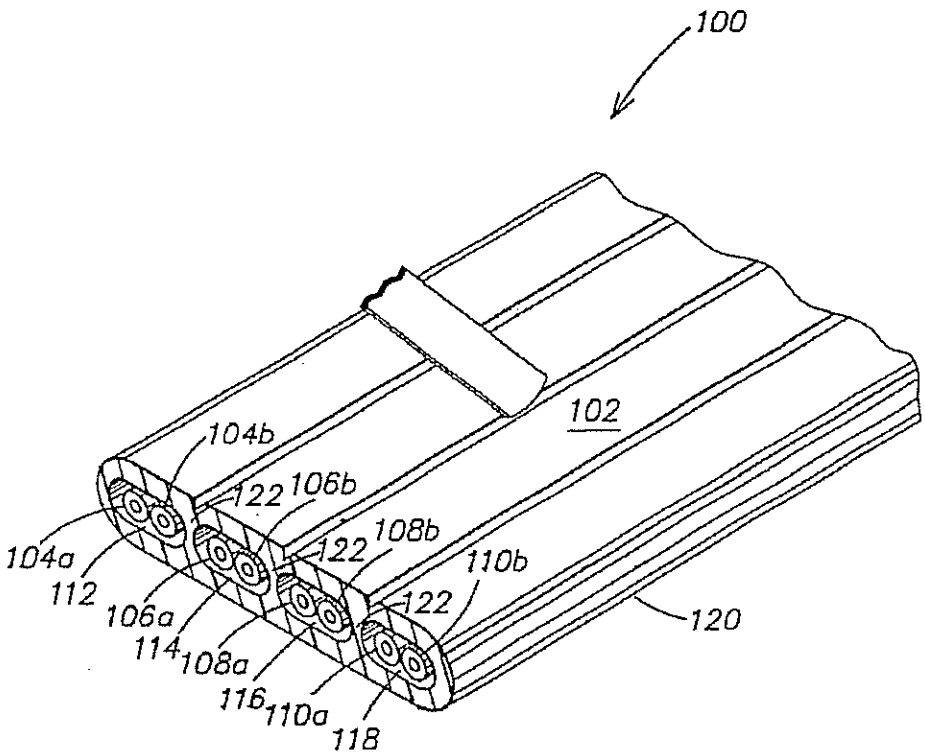


FIG. 1
(RELATED ART)

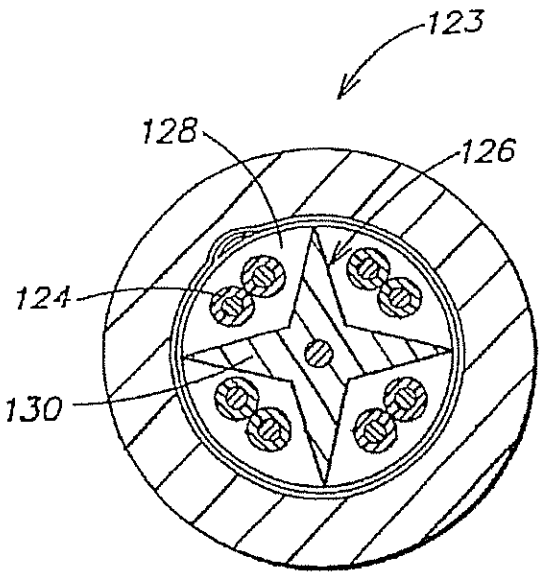


FIG. 2
(RELATED ART)

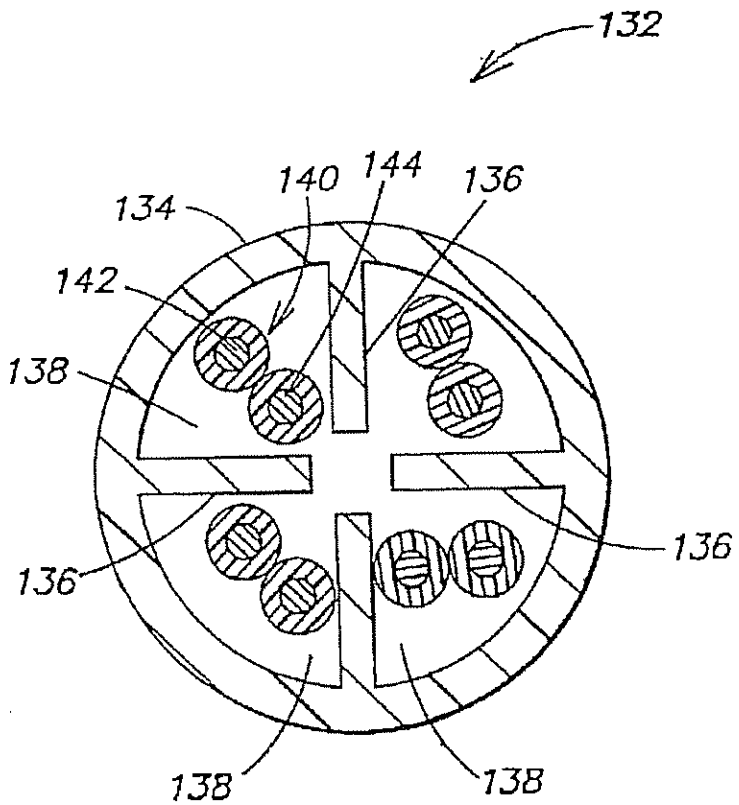


FIG. 3
(RELATED ART)

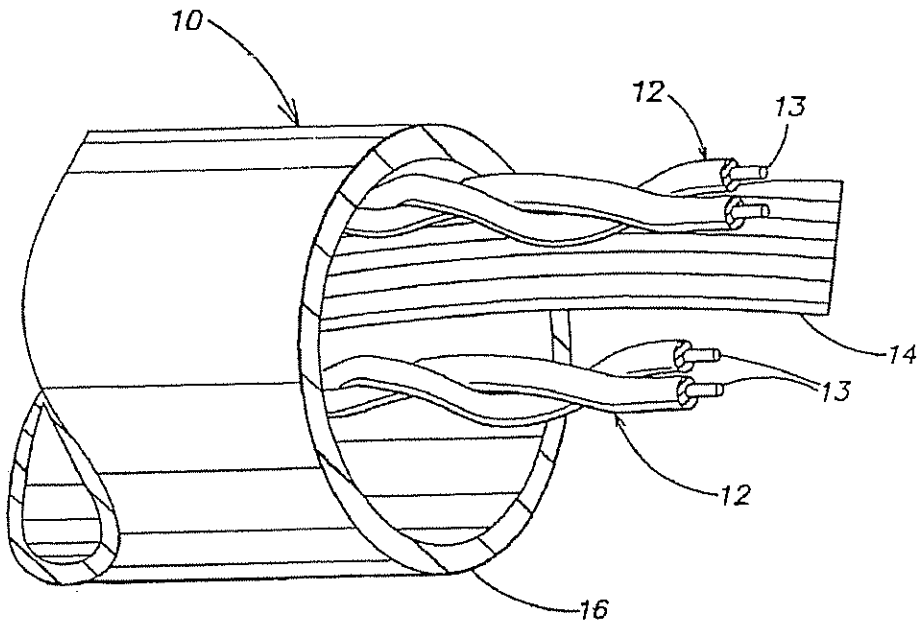


FIG. 4

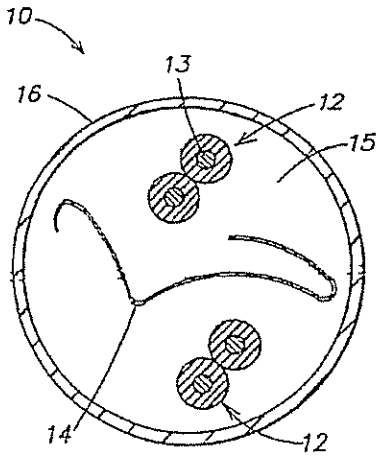


FIG. 5

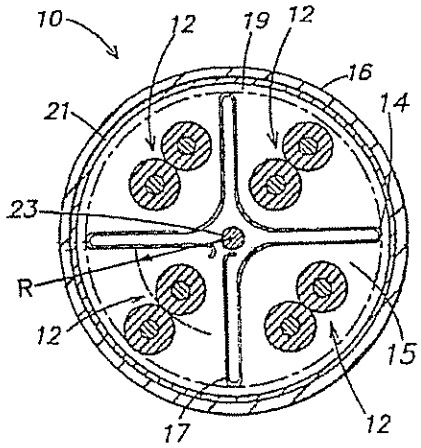


FIG. 6

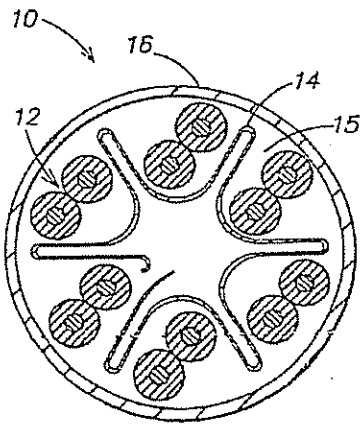


FIG. 7

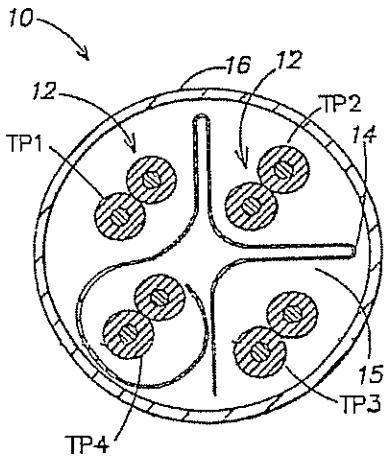


FIG. 8

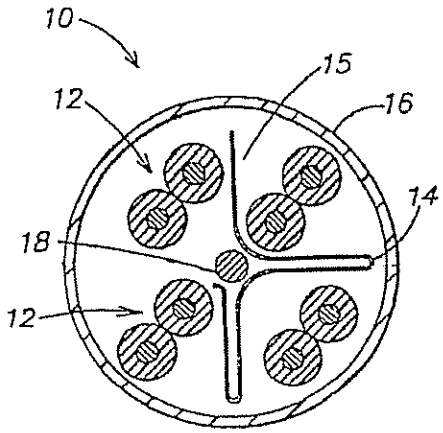


FIG. 9

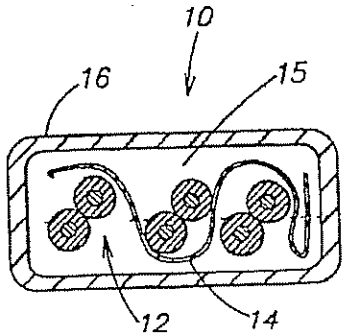


FIG. 10

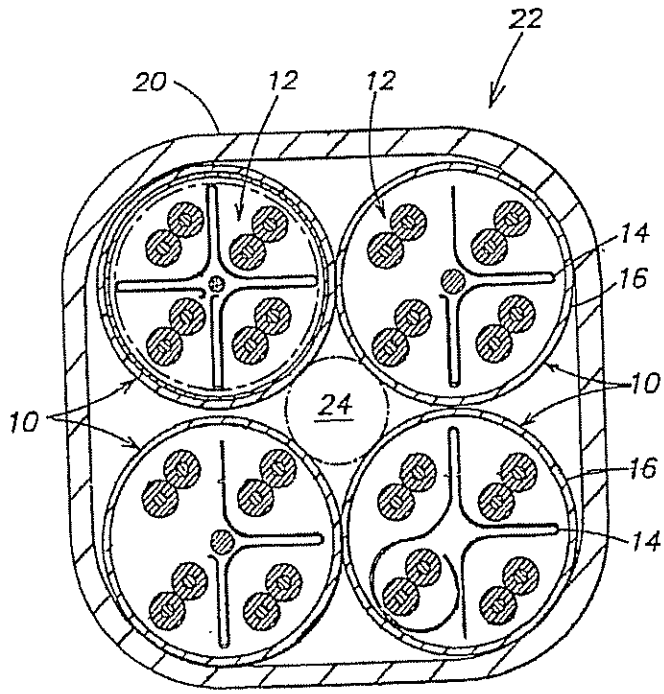


FIG. 11

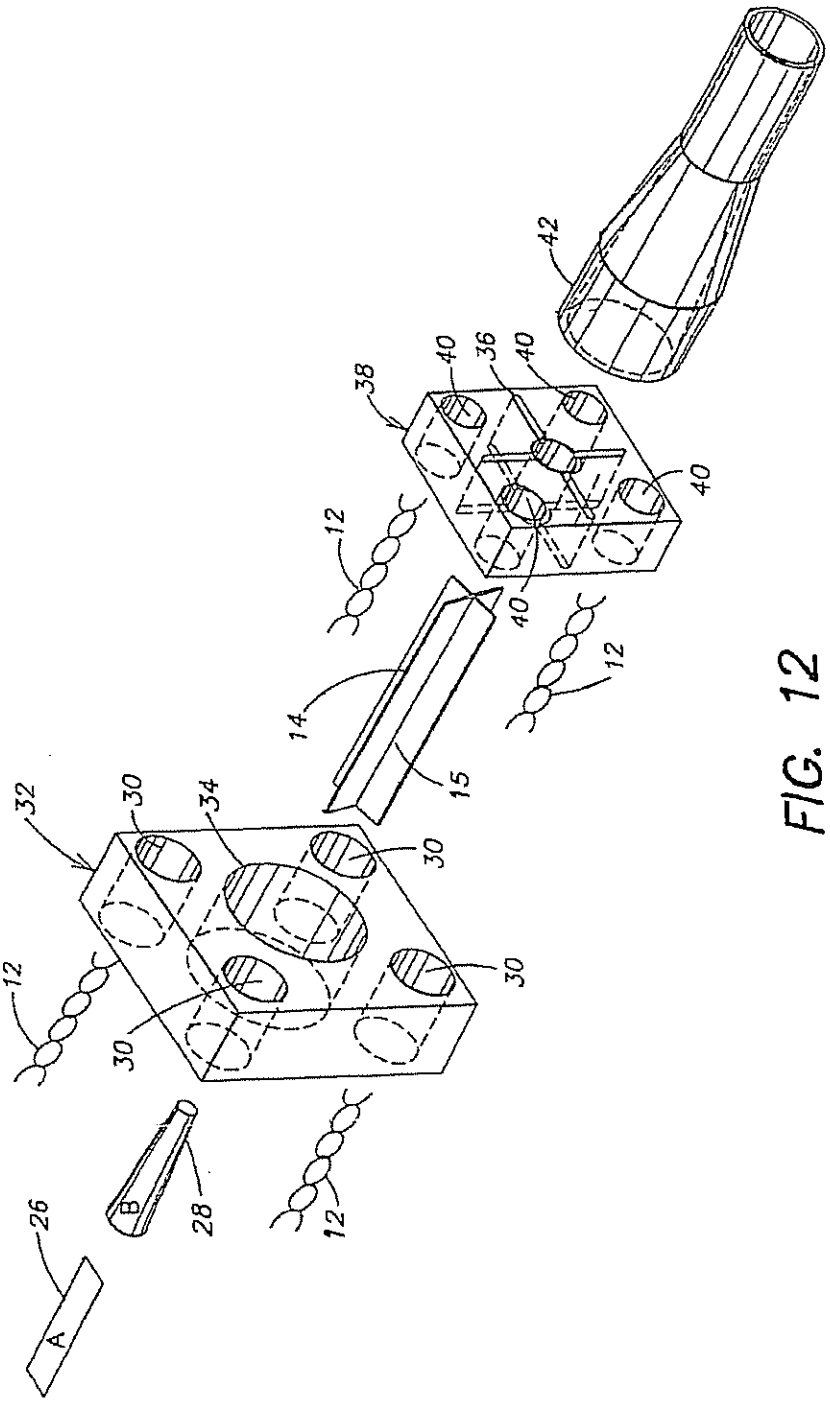


FIG. 12

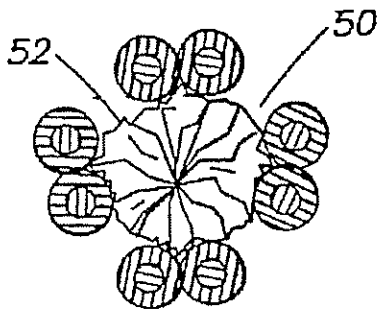
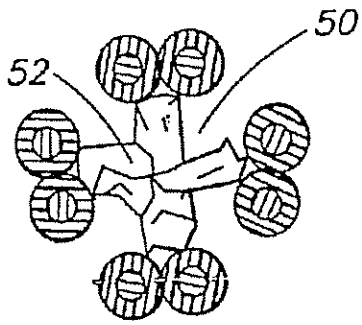


FIG. 13A



1 . 1

MULTI-PAIR DATA CABLE WITH CONFIGURABLE CORE FILLING AND PAIR SEPARATION

RELATED APPLICATION

This application is a Continuation of under 35 U.S.C. §120 to, commonly-owned, U.S. patent application Ser. No. 09/853,512, filed May 11, 2001 now U.S. Pat. No. 6,570,095, entitled Multi-Pair Data Cable with Configurable Core Filling and Pair Separation which is a continuation under 35 U.S.C. §120 of commonly-owned, U.S. patent application Ser. No. 09/257,844, now U.S. Pat. No. 6,248,954 B1, entitled, Multi-Pair Data Cable with Configurable Core Filling and Pair Separation, filed Feb. 25, 1999, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to high-speed data communications cables using at least two twisted pairs of insulated conductors. More particularly, the invention relates to high-speed data communications cables having a light-weight, configurable core-refilling isolation pair separator that provides geometrical separation between the twisted pairs of insulated conductors.

DISCUSSION OF THE RELATED ART

High-speed data communications media in current usage include pairs of insulated conductors twisted together to form a balanced transmission line. Such pairs of insulated conductors are referred to herein as "twisted pairs." When twisted pairs are closely placed, such as in a cable, electrical energy may be transferred from one twisted pair of a cable to another twisted pair. Such energy transferred between twisted pairs is referred to as crosstalk. As operating frequencies increase, improved crosstalk isolation between the twisted pairs becomes more critical.

The Telecommunications Industry Association and the Electronics Industry Association (TIA/EIA) have developed standards which specify specific categories of performance for cable impedance, attenuation, skew and particularly crosstalk isolation. One standard for crosstalk or, in particular, crosstalk isolation, is TIA/EIA-568-A, wherein a category 5 cable is required to have 38 dB of isolation between the twisted pairs at 100 MHz and a category 6 cable is required to have 42 dB of isolation between the twisted pairs at 100 MHz. Various cable design techniques have been used to date in order to try to reduce crosstalk and to attempt to meet the industry standards.

For example, one cable implementation known in the industry that has been manufactured and sold as a high-speed data communications cable, includes the twisted pairs formed with relatively tight twists, and the cable is formed into a round construction. In this conventional cable, each twisted pair has a specified distance between twists along a longitudinal direction of the twisted pair, that distance being referred to as the "twist lay." When adjacent twisted pairs have the same twist lay and/or twist direction, they tend to lie within a cable more closely spaced than when the twisted pairs have different twist lays and/or a different twist direction. Such close spacing increases the amount of undesirable crosstalk which occurs between the twisted pairs. In some conventional cables, each twisted pair within the cable has a unique twist lay in order to increase the spacing between pairs and thereby to reduce the crosstalk between twisted pairs of the cable. In addition, the twist direction of the twisted pairs may also be varied. However, this industry standard configuration can only achieve limited crosstalk isolation.

Another cable implementation **100** disclosed in U.S. Pat. No. 4,777,325, is illustrated in FIG. **1**, wherein the twisted pairs are enclosed within a jacket **102** that has a wide, flat configuration. In particular, a plurality of twisted pairs **104***a*–**104***b*, **106***a*–**106***b*, **108***a*–**108***b*, and **110***a*–**110***b* are positioned side-by-side, each in separate compartments **112**, **114**, **116**, and **118** formed within a flat hollow envelope of an extruded outer sheath **120**. The cable is provided with separator ribs **122** between a top and a bottom of the sheath to divide the outer sheath into the separate compartments and to prevent lateral movement of the twisted pairs out of their respective compartments. However, one problem with this flat configuration for a cable is that it has limited flexibility as compared to that of a round cable, which hinders installation of the cable in conduits and around bends.

Another cable implementation which addresses the problem of twisted pairs lying too closely together within the cable is described, for example, in U.S. Pat. No. 5,789,711 and is illustrated in FIG. **2**. In particular, the cable includes, for example, four twisted pairs **124** disposed about a central pre-shaped support **126**, wherein the support positions a twisted pair within grooves or channels **128** formed by the support. In particular, the support provides the grooves or channels which keep the twisted pairs at fixed positions with respect to each other. The support can have any of a number of shapes, including, for example, a standard "X", a "+", or the separator as is illustrated in FIG. **2**. The prongs or protrusions **130** of the support preserve the geometry of the pairs relative to each other, which helps reduce and stabilize crosstalk between the twisted pairs. However, some problems with the support is that the support adds cost to the cable, may limit the flexibility of the cable and increases the size; e.g., the diameter, of the cable. Another problem may be that the material which forms the support may result in the overall cable being a potential fire and/or smoke hazard.

Still another known industry cable implementation **132** is illustrated in FIG. **3**. The cable utilizes a jacket **134** with inward protrusions **136** that form channels **138** within the cable. A twisted pair **140** of conductors **142**, **144** is disposed within each channel. The protrusions are used to provide adequate pair separation. However, one problem with these protrusions is that they can be difficult to manufacture. In addition, the protrusions may not provide adequate separation between the twisted pairs where the stability of the protrusions is difficult to provide, and thus performance repeatability of the cable is an issue. Further, another problem is that the jacket is not easily strippable. When the cable is to be stripped by removing the outer jacket, which is often done with a sharp device such as, for example, a razor, the protrusions will not be cut by the incision around the circumference of the jacket and will have to be broken off separately in order to remove the jacket.

Accordingly, some of the problems with the above known configurations are that they are expensive, difficult to use, are generally undesirably large, and have decreased flexibility of the cables and workability of the twisted pairs of wires.

SUMMARY OF THE INVENTION

Therefore, a need exists for a high-speed data cable having multiple twisted pair wires with desired crosstalk performance, improved handling and termination

capabilities, that is inexpensive, flexible and has a desired size. This inveotion provides an improved data cable.

According to the inventioo, a data communications cable has been developed so as to better facilitate the cable for its the intended usc of high speed data transmission, yet maintain a form factor that has desired flexibility and workability, and that is compatible with industry standard hardware, such as plugs and jacks. The data communications cable of the invention has the additional benefit of a reduced cabled size relative to other known cables within its performance class.

In particular, the present invention provides these advantages by utilizing a substantially flat configurable, highly flexible, core-filling, dielectric separator to provide twisted pair separation for the cable.

One embodiment of a data communications cable of the invention includes a first twisted pair of insulated conductors, a second twisted pair of insulated conductors, and the substantially flat dielectric pair separator. The substantially flat configurable dielectric pair separator is disposed between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors The data communications cable also includes a jacket assembly enclosing the first twisted pair of insulated conductors, the second twisted pair of insulated conductors, and the substantially flat dielectric pair separator.

With this arrangement, the data communications cable can be made with desired crosstalk isolation between the twisted pairs of insulated conductors. In addition, due to the conforming nature and the desired thickness of the substantially flat configurable dielectric pair separator, the cable has desired flexibility, workability and size. Moreover, these advantages do not come at the expense of other properties of the cable such as, for example, size or reduced impedance stability. The substantially flat configurable dielectric pair separator also facilitates termination of the data communications cable to known industry standard hardware.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects, features and advantages of the present invention will become more apparent in view of the following detailed description of the invention when taken in conjunction with the figures, in which:

FIG. 1 is a perspective view of an embodiment of a communications cable according to the related art;

FIG. 2 is a cross-sectional view of another embodiment of a communications cable according to the related art;

FIG. 3 is a cross-sectional view of anotber embodiment of a communications cable according to the related art;

FIG. 4 is a perspective view of a data communications cable according to one embodiment of the invention;

FIG. 5 is a cross-sectional view of the embodiment of the data communications cable of FIG. 4;

FIG. 6 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 7 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 8 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 9 is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. 10 is a cross-sectional view of a data communications cable according to another embodiment of tbe invention;

FIG. 11 is a cross-sectional view of a data communications cable according to another embodiment of tbe invention;

FIG. 12 is a perspective view of a system for practicing a method of making a cable in accordance with an embodiment of the invention;

FIG. 13A illustrates a core of a four twisted pair cable; and

FIG. 13B is an exploded view of the core of tbe cable of FIG. 13A, having a filler material according to the invention.

DETAILED DESCRIPTION

A number of embodiments of a data communications cable according to the invention will now be described in which the cable is constructed with a plurality of twisted pairs of insulated conductors and a core made from a configurable, dielectric pair separator. However, it is to be appreciated that the invention is not limited to any number of twisted pairs or any profile for the configurable, dielectric pair separator illustrated in any of these embodiments. The inventive principles can be applied to cables including greater or fewer numbers of twisted pairs and having different core profiles of the configurable dielectric pair separator. In addition, although these embodiments of the invention are described and illustrated in connection with twisted pair data communication media, it is to be appreciated that other high-speed data communication media can be used instead of twisted pairs of conductors in the constructions of the cable according to the invention, such as, for example, fiber optic media.

FIG. 4 depicts an embodiment of a data communications cable **10** according to the present invention. The cable **10** includes two twisted pairs **12** of insulated conductors **13**. The twisted pairs **12** are separated by a low dielectric constant, low dissipation factor, polymer "pair separator" **14**. The twisted pairs **12** and the pair separator **14** are encased within a jacket assembly **16**. The outer jacket can be a PVC, a low-smoke, low-flame PVC, or any plenum or non-plenum rated thermoplastic.

FIG. 5 depicts a cross-sectional view of an embodiment of the cable of FIG. **4**. The configurable pair separator **14** runs along a longitudinal length of the cable, and is configured such that the twisted pairs are disposed within channels or grooves **15** of the pair separator along the length of the cable. As illustrated, the grooves **15** do not form completely enclosed channels. Some of the advantages of this cable according to the invention are that the pair separator provides structural stability during manufacture and use of the data communications cable, yet does not degrade the flexibility and workability of the cable, and does not substantially increase the size of the cable. In addition, the pair separator improves the crosstalk isolation between the twisted pairs by providing desired spacing between the twisted pairs. Therefore, the configurable pair separator of the invention lessens the need for complex and hard to control twist lay procedures, core filling arrangements and jacket embodiments described above with respect to the related art.

The above-described embodiment of the data communications cable can he constructed using a number of different materials as the pair separator **14**. While the invention is not limited to the materials described herein, the invention is advantageously practiced using tbese materials. In particular, the configurable pair separator is preferably a flame-retardant, low-dielectric constant, low-dissipation factor, foamed polymer tape, such as, for example, a foamed flame retardant, cellular polyolefin or fluoropolymer like NEPTC PP500 "SuperBulk", a foamed fluorinated ethylene propylene (FEP) or a foamed polyvinyl chloride (PVC). The above-described pair separators are preferably used in a

non-plenum rated application where the cable is not required to pass industry standard flame and smoke tests such as the Underwriters Laboratories (UL) 910 test. Another preferable configurable pair separator is a woven fiberglass tape normally used as a binder for cables, such as, for example, Allied Fluoroglass CTX3X50. This woven fiberglass binder is preferably used in a plenum rated application where the cable must satisfy the UL 910 test.

Still another pair separator material that may be used in the cable of the invention is a bulk filling material such as a polyolefin or glass fiber filler that is flame-retardant and is typically shredded or fibrulated, but may also be solid, such as, for example, Chadwick AFT 033 Fiberglass. Such a bulk filling material is typically twisted up and used as a filling material in a core of the cable, with no other purpose. In particular, referring to FIG. 13A, the bulk filler is typically used as a core filling material that fills 100% of the core area 50 between the illustrated four twisted pair, that is used to keep the cable in a more or less round construction. However, referring to FIG. 13B, according to the present invention it is preferable to provide less than 100% of the core area 50 with the filling material; and it is more preferable us use less than 42% of the core with the filler material 52 for providing isolation between the twisted pairs. In a preferred embodiment, approximately 32% of the overall core area between the four twisted pairs of the cable is filled with such a filler and shaped as described herein. Therefore, one aspect of the present invention is the recognition that the filler or tape described above can be used to prevent physical contact between opposite and adjacent twisted pairs, thereby increasing the isolation between the twisted pairs, while not requiring the entire core area be filled, and therefore not sacrificing the size, cost or flexibility of the overall cable.

FIG. 6 depicts a cross-sectional view of a preferred embodiment of the data cable 10 of this invention. The cable includes the low-dielectric constant, low-dissipation factor polymer pair separator 14 formed into a cable core in such a way as to physically separate the four twisted pairs 12, thereby decreasing field coupling between the twisted pairs, providing a desired opposite twisted pair-to-pair physical distance, as well as providing a desired adjacent pair separation. It is to be appreciated that like components of the data communications cable illustrated in FIGS. 4–5 have been provided with like reference numbers and the description of these components applies with respect to each of the cable embodiments to be described herein.

In the embodiment of the cable of FIG. 6, the pair separator 14 is a flat configurable tape used as a core filler, that is shaped to have the illustrated profile and that is provided in the cable between the four twisted pairs 12. In particular, in this embodiment, the configured pair separator has a shape somewhat like a "+", providing four channels 15 between each pair of protrusions 17 formed by the pair separator. Each channel carries one twisted pair 12 that is placed within the channel during a process of manufacturing the cable that will be described in further detail below. As is discussed above, the illustrated configurable core profile should not be considered limiting. In particular, although it is preferred that the pair separator is supplied as a flat extruded tape, the configurable pair separator may be made by a process other than extrusion and may have a number of differeot shapes or provide a number of different channels, as is illustrated by some of the embodiments described in further detail below.

Referring again to FIG. 6, the data communications cable may also be provided with a binder 19, as illustrated in phantom, that is wrapped around the configurable core pair separator 14 and the plurality of twisted pairs 12. For this embodiment, it is preferable that the configurable core pair separator be an aluminum/mylar tape, with an aluminum layer on a side of the tape facing the plurality of twisted pairs. In addition, it is preferred that the binder be made of the aluminum/mylar tape, with the aluminum layer of the tape facing the plurality of the twisted pairs so that the combination of the binder and the configurable pair separator provide four electrically shielded, enclosed channels. With this embodiment, the four enclosed channels are isolated from one another to provide desired crosstalk isolation. In addition, another benefit of the embodiment of the cable is that a cable adjacent this cable will have reduced coupling with the cable of the invention, or in other words, reduced alien cross talk as it is known in the industry.

The embodiment of FIG. 6 further illustrates a shield 21 may also be laterally wrapped around the binder 19; the shield is preferably made from a foil or metal. The shield may be applied over the cable before jacketing the cable with the jacket 16, and is also used to help reduce crosstalk between the twisted pairs, to reduce alien crosstalk, and prevent the cable from causing or receiving electromagnetic interference. It is to be appreciated that the shield can also be provided in lieu of the binder. In particular, greater crosstalk isolation between the twisted pairs of the cable, and reduced alien crosstalk may also be achieved by using a conductive shield 21 that is, for example, a metal braid, a solid metal foil, or a conductive plastic that is in contact with ends of the protrusions 17 of the configurable filler 14. If the configurable pair separator is also conductive or semi-conductive as described above for the aluminum/mylar tape, then the combination of the pair separator and the shield forms conductive compartments that shield each twisted pair from the other twisted pairs. Referring to FIG. 6, the cable can advantageously include a metal drain wire 23 exposed, for example, within the middle of the configurable pair separator 14. The metal drain wire runs the length of the cable and acts as a ground. However, it is to be appreciated that the metal drain wire need not be so placed and may also be arranged in arrangements known to those of skill in the art such as, for example, spirally wrapped around the binder 19 or the shield 21.

It is preferable in the embodiments described herein that the protrusions 17 of the configurable pair separator extend at least beyond a center axis of each twisted pair, known in the art as a pitch radius. The pitch radius is illustrated in FIG. 6 as the radius R between the center of the cable core and the center axis of the twisted pairs 12 of conductors. This preferred configuration of the configurable pair separator ensures that the twisted pairs do not escape their respective spaces or channels. It is also to be appreciated that the process of jacketing of the cable, to be described in detail below, may bend the ends of the protrusions 17 over slightly (not illustrated), since the configurable pair separator is relatively formable.

As discussed above, it is to be appreciated that the twisted pairs of insulated conductors and configurable pair separator of the communications data cable of the invention, can be configured in a variety of ways. FIGS. 7–12 depict cross-sectional views of various embodiments of the data communications cable of the invention. As illustrated, for example, in FIGS. 7, 9 and 10, the configurable pair separator may be configured such that the grooves 15 do not form completely enclosed channels. FIG. 7 depicts a cable 10 wherein six twisted pairs 12 are encased within the jacket assembly 16, and are separated from each other by the

configurable pair separator **14**. The pair separator **14** is configured in a somewhat "*" shape that provides support and placement of the twisted pairs so that the twisted pairs **12** have a desired spacial arrangement and do not come into direct physical contact with each other.

FIG. **8** depicts still another embodiment of the data communications cable **10** having multiple twisted pairs **12** encased within the jacket assembly **16** and having at least one of the twisted pairs isolated by the pair separator **14**, from the remainder of the twisted pairs. In particular, referring to FIG. **8**, the twisted pairs have been labeled TP1, TP2, TP3 and TP4, wherein twisted pair TP4 is isolated from twisted pairs TP1, TP2 and TP3 by the pair separator **14**. It is an advantage of this embodiment, that the pair separator **14** can be provided with an appropriate number of twists or wrappings around the twisted pair TP4, so as to provide selective isolation between twisted pair TP4 and twisted pairs TP1, TP2 and TP3. This embodiment of the cable according to the invention can be used, for example, to provide better isolation between a weakest one or a weakest combination of twisted pairs of cables, in an environment where there is known to be a low amount of isolation between a particular twisted pair and another twisted pair, or a plurality of twisted pairs. Accordingly, with this embodiment of the cable of the invention, there can be selective enhancement of isolation between twisted pairs TP1–TP4, TP2–TP4, and TP3–TP4. It is to be appreciated that although the twisted pair TP4 has been illustrated as being isolated from the remainder of the twisted pairs, that any of the twisted pairs can be so wrapped with the filler and isolated. This embodiment of the invention may also be used in conjunction with a lessening of the twist lays requirements for the twisted pairs, to provide cable having a same amount of isolation between twisted pairs as a cable with tighter twist lays. Accordingly, this embodiment of the cable according to the invention allows for selective design of isolation between particular twisted pairs of the cable and lessening of the twist lay requirements for the cable.

FIG. **9** depicts still another embodiment of the data communications cable **10** having multiple twisted pairs **12** encased within the jacket assembly **16** and physically separated from each other by the configurable pair separator **14**, and also including a central core filler **18** positioned at the middle of the cable and that runs along the longitudinal length of the cable, provided less than 100% of the core is filled with the filler. The configurable pair separator provides desired separation between the individual twisted pairs **12** as discussed above. The central core **18** provides additional support or structure and may be formed of, for example, a solid or foamed flame retardant polyolefin or other materials that are known in the industry. For plenum rated cables, it is preferable that the core be any of one or more of the following compounds: a solid low-dielectric constant fluoropolymer, e.g. ethylene chlorotrifluoroethylene (E-CTFE), FEP, a foamed fluoropolymer, e.g. foamed FEP, and PVC in either solid, low dielectric constant form or foamed. The central core filling **18** may also be constructed of the same materials as the configurable pair separator **14** discussed above.

FIG. **10** depicts yet another embodiment of a data communications cable **10**, having a substantially flat configuration. Twisted pairs **12** are encased within a substantially flat jacket assembly **16** and physically separated from each other by the configurable pair separator **14**. The cable of FIG. **10** is an alternative to the cable of the related art as illustrated in FIG. **1**, and other known flat cables. It is to be understood, that although this embodiment is illustrated with a single fold of the pair separator material between each twisted pair, that the number of folds can be increased to further adjust the distance between each of the twisted pairs and thereby increase the isolation between each of the twisted pairs. Other variations known to those of skill in the art are also intended to be within the scope of the invention and this embodiment. For example, the pair separator may also be disposed at a bottom of the cable with folds directed upwardly towards the top of the cable, in contrast to at the top of the cable with the folds directed towards the bottom of the cable as illustrated in FIG. **10**, or the pair separator may be disposed at both the bottom and top.

FIG. **11** depicts an embodiment of a data communications cable **22** including a plurality of data communications cables **10** according to any of the embodiments described above. In particular, each data cable **10** contains multiple twisted pairs **12** separated by the configurable pair separator **14** according to any of the above-described configurations, and encased in the jacket assembly **16**. The plurality of data cables are enclosed within outer casing **20**. The cable **22** may also have a central core filler **24**, as illustrated in phantom, that may be formed from any of the above-described materials and may be used to, for example, to keep the data cables in a desired arrangement so as to, for example, minimize crosstalk between each of the data cables **10**.

Referring now to FIG. **12**, there is illustrated a perspective view of a system for practicing a method of making a cable in accordance with an embodiment of the invention. The pair separator **26** is drawn from a reel or pad (not shown), and is formed around a round cob **28** into a shaped pair separator such as, for example, in the shape of a cylinder. The shaped pair separator is aligned with four twisted pairs **12** by passing the four twisted pairs through openings **30** in first die **32**, and the shaped pair separator through central opening **34**. The shaped pair separator is then further configured into a desired shape (formed pair separator) as illustrated in FIG. **12**. It is to be appreciated, as discussed above, that this shape can be varied. The formed pair separator **15** is then passed through opening **36** in second die **38** and brought together with the four twisted pairs **12** which are passed through corresponding openings **40** in the second die. The plurality of twisted pairs are then cabled with the formed pair separator by a third die **42**, in an operation referred to as "bunching". The third die places the twisted pairs in the channels **15** (see FIGS. **5–10**) of the formed pair separator prior to twisting of the cable. It is to be appreciated that the cable can be twisted with any known twisting arrangement such as a helix, or an S-Z configuration. It is also to be appreciated that this method can be varied to include any of the components illustrated and discussed above, such as, for example, to include a drain wire, a binder, a shield, or central core filler.

Accordingly, some of the advantages of the various embodiments of the data communications cable of the invention are crosstalk performance and isolation enhancement can be configured and provided as customized cable solutions for hardware manufactures who request special requirements. For example, specific twisted pair combinations can receive a dedicated amount of isolation tape folds, thereby enhancing separation of selected twisted pairs and enhancing crosstalk isolation between the selected twisted pairs where an end user, for example, needs more crosstalk isolation. The data communications cable can also be made with a desired crosstalk isolation between the opposing twisted pairs of insulated conductors. In addition, due to the conforming nature and the thickness of the pair separator material, this advantage does not come at the expense of, for

example, the size of the data communications cable, and does not result in a reduced impedance stability of the data communications cable. Another advantage is that the amorphous nature of the pair separator yields a desired cable that better facilitates termination of the data communications cable to known industry hardware, than larger diameter cables of the related art.

The present invention has now been described in connection with a number of specific embodiments thereof. However, numerous modifications which are contemplated as falling within the scope of the present invention should now be apparent to those skilled in the art. Therefore, it is intended that the scope of the present invention be limited only by the scope of the claims appended hereto.

What is claimed is:

1. A finished communications cable comprising:

a plurality of twisted pairs of insulated conductors comprising a first twisted pair of insulated conductors and a second twisted pair of insulated conductors;

a substantially flat configurable dielectric separator disposed between the plurality of twisted pairs of conductors in the finished communications cable, that separates the first twisted pair of insulated conductors from the second twisted pair of insulated conductors; and

a jacket enclosing the plurality of twisted pairs of insulated conductors and the configurable dielectric separator;

wherein the plurality of twisted pairs of insulated conductors and the substantially flat configurable dielectric separator are twisted about a common axis to form the finished communications cable.

2. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator is arranged to have no more than one concave surface to provide a groove extending along a longitudinal length of the communications cable.

3. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator is arranged within the jacket to provide at least two grooves, at least one twisted pair of insulated conductors being disposed within each of the at least two grooves.

4. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator includes a foamed polymer.

5. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator includes a woven fiberglass tape.

6. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator includes a flame-retardant, low-dielectric constant, foamed polymer tape.

7. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator includes a foamed fluorinated ethylene propylene material.

8. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator is a flame-retardant, foamed polymer tape.

9. The communications cable as claimed in claim 1, further comprising a central core filling material disposed in a core of the communications cable between the first and second twisted pairs of insulated conductors.

10. The communications cable as claimed in claim 9, wherein the central core filling is made of a same material as the substantially flat configurable dielectric separator.

11. The communicatioos cable as claimed in claim 1, further comprising a conductive shield substantially surrounding the plurality of twisted pairs of insulated conductors and the substantially flat configurable dielectric separator.

12. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator is arranged so as to separate each twisted pair of insulated conductors from every other twisted pair of insulated conductors.

13. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator comprises a conductive layer and is arranged so that the conductive layer faces each of the plurality of twisted pairs of insulated conductors.

14. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator comprises an aluminum/mylar tape, an aluminum layer of the aluminum/mylar tape facing the plurality of twisted pairs of insulated conductors.

15. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator is arranged to provide a sufficient spacing between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors so as to provide a desired crosstalk isolation between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors.

16. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator is arranged so as to prevent the first twisted pair from contacting the jacket.

17. The communications cable as claimed in claim 1, wherein the substantially flat configurable dielectric separator has a concave shape.

18. The communication cable as claimed in claim 17, wherein the substantially flat configurable dielectric separator does not extend more than 180 around any one of the plurality of twisted pairs of insulated conductors.

19. An unshielded communications cable comprising:

a plurality of twisted pairs of insulated conductors comprising a first twisted pair of insulated conductors and a second twisted pair of insulated conductors;

a substantially flat configurable dielectric separator that consists of non-conductive, dielectric materials disposed between the plurality of twisted pairs of conductors that separates the first twisted pair of insulated conductors from the second twisted pair of insulated conductors; and

a jacket enclosing the plurality of twisted pairs of insulated conductors and the configurable dielectric separator;

wherein the substantially flat configurable dielectric separator includes a foamed polymer.

20. The communications cable as claimed in claim 19, wherein the substantially flat configurable dielectric separator includes a flame-retardant, low-dielectric constant, foamed polymer tape.

21. The communications cable as claimed in claim 19, wherein the substantially flat configurable dielectric separator includes a foamed fluorinated ethylene propylene material.

22. The communications cable as claimed in claim 19, wherein the substantially flat configurable dielectric separator is a flame-retardant, foamed polymer tape.

* * * * *

EXHIBIT F

US007179999B2

(12) **United States Patent**
Clark et al.

(10) **Patent No.: US 7,179,999 B2**
(45) **Date of Patent: *Feb. 20, 2007**

(54) **MULTI-PAIR DATA CABLE WITH CONFIGURABLE CORE FILLING AND PAIR SEPARATION**

(75) Inventors: **William T. Clark**, Lancaster, MA (US); **Joseph Dellagala**, Shrewsbury, MA (US); **Kenneth Consalvo**, Leominster, MA (US)

(73) Assignee: **Belden Technologies, Inc.**, St. Louis, MO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/352,850**

(22) Filed: **Feb. 13, 2006**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 10/336,535, filed on Jan. 3, 2003, now Pat. No. 6,998,537, which is a continuation of application No. 09/853,512, filed on May 11, 2001, now Pat. No. 6,570,095, which is a continuation of application No. 09/257,844, filed on Feb. 25, 1999, now Pat. No. 6,248,954.

(51) **Int. Cl.**
H01B 11/02 (2006.01)

(52) **U.S. Cl.** ..... **174/113 R**; 174/113 C

(58) **Field of Classification Search** ..... 174/113 R, 174/113 C, 131 A

See application file for complete search history.

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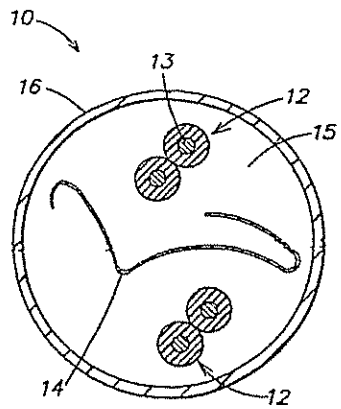
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Primary Examiner—Chau Nguyen N.
(74) *Attorney, Agent, or Firm*—Lowrie, Lando & Anastasi, LLP.

(57) **ABSTRACT**

An improved twisted pair telecommunications cable according to the invention includes a plurality of twisted pairs of insulated conductors, and a substantially flat configurable pair separator disposed between the plurality of twisted pairs of insulated conductors along a longitudinal length of the telecommunications cable. The twisted pair communications cable also includes a jacket assembly enclosing the plurality of twisted pairs of insulated conductors and the substantially flat pair separator. The substantially flat pair separator separates each twisted pair of insulated conductors from every other twisted pair of insulated conductors with a spacing sufficient to provide a desired crosstalk isolation between each of the plurality of twisted pairs of insulated conductors.

20 Claims, 8 Drawing Sheets



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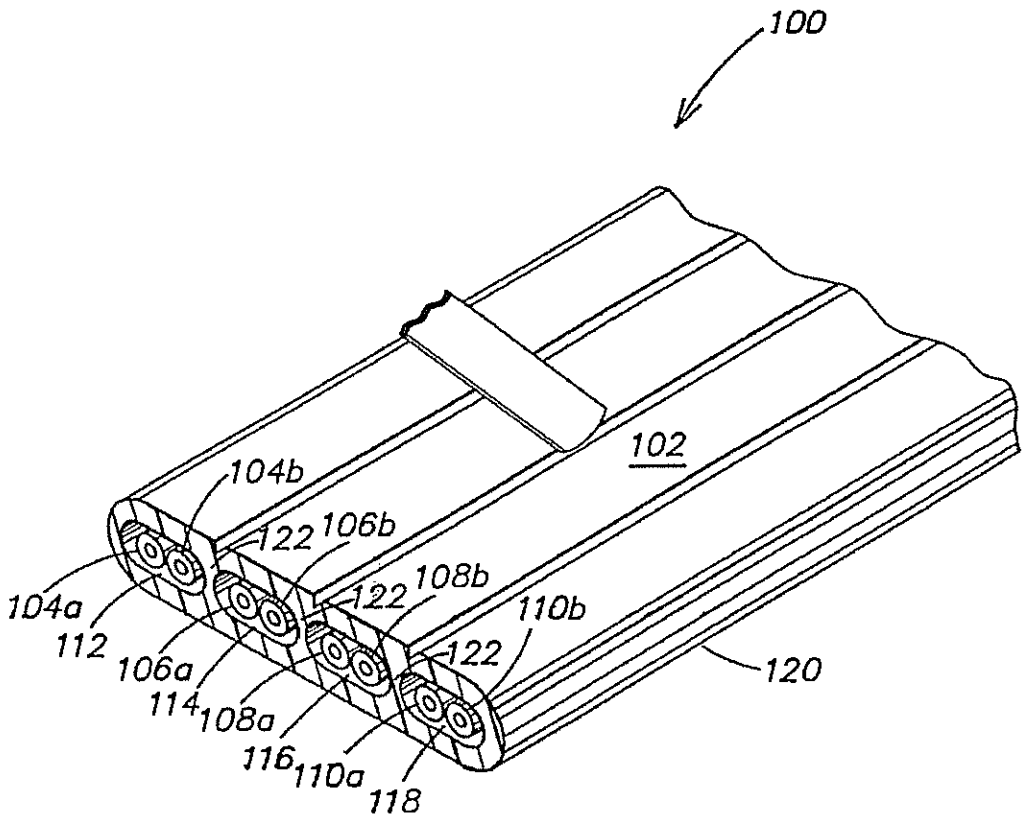
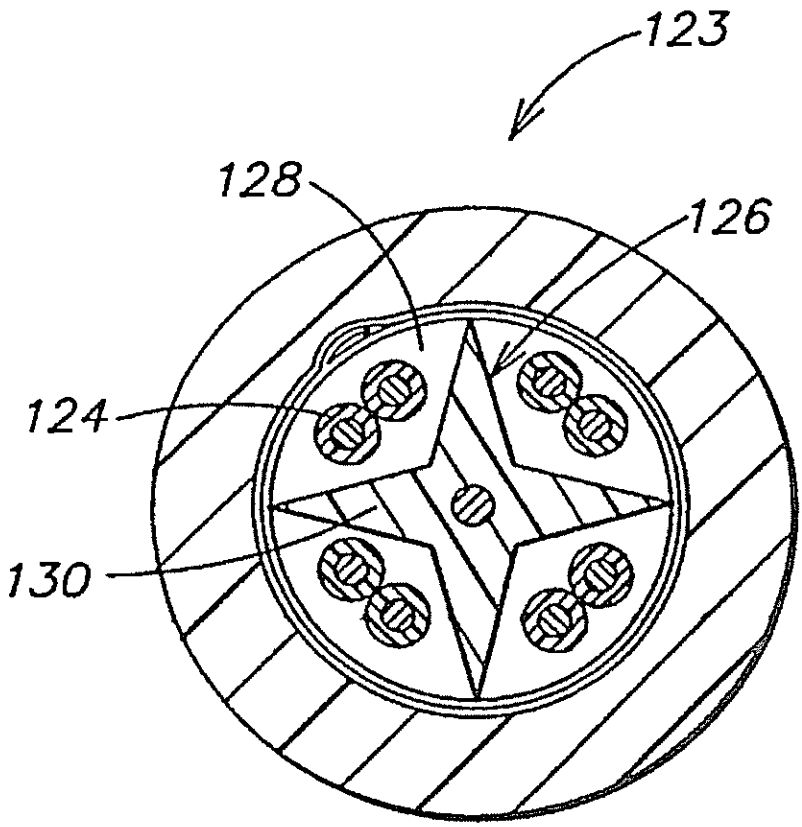
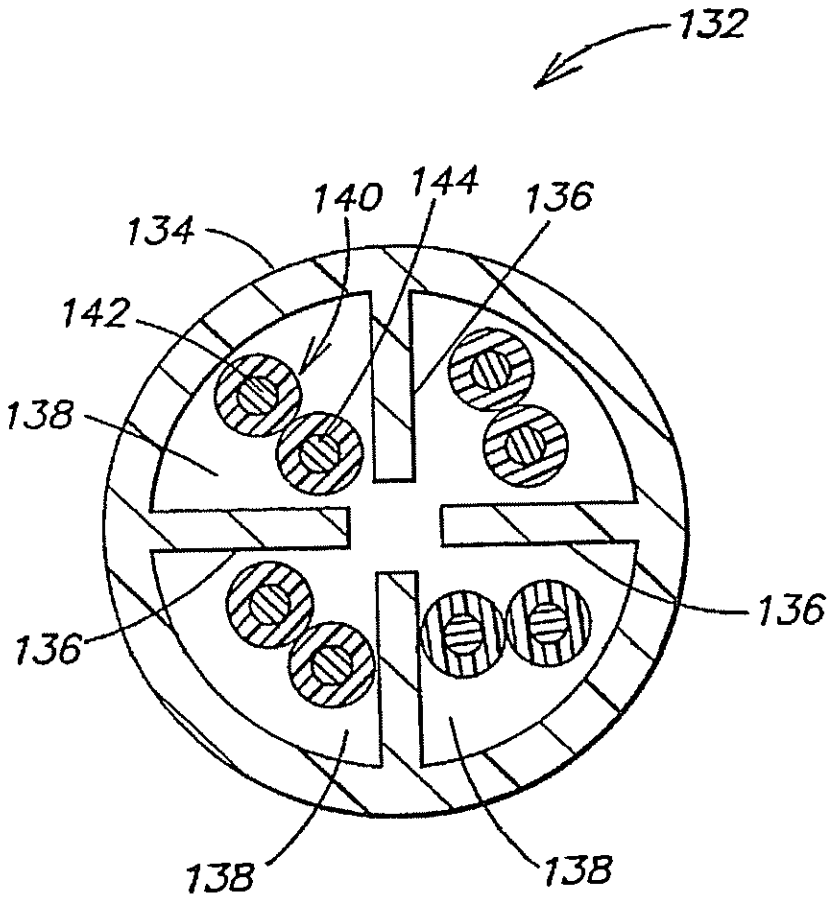


FIG. 1
(RELATED ART)



. 2
(RELATED ART)



1.

(RELA ART)

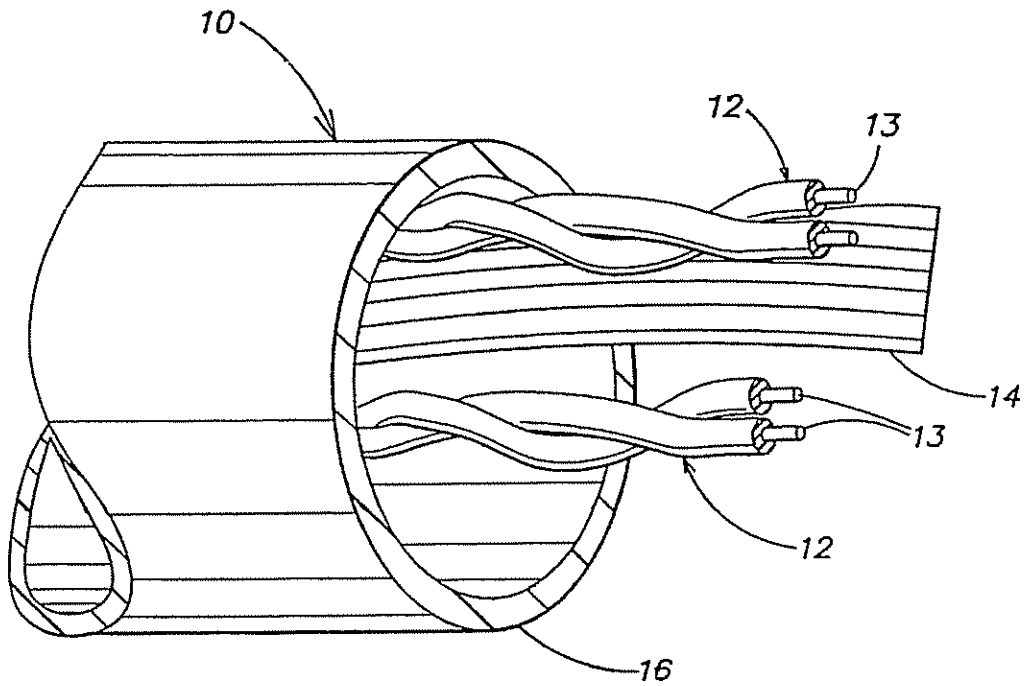


FIG. 4

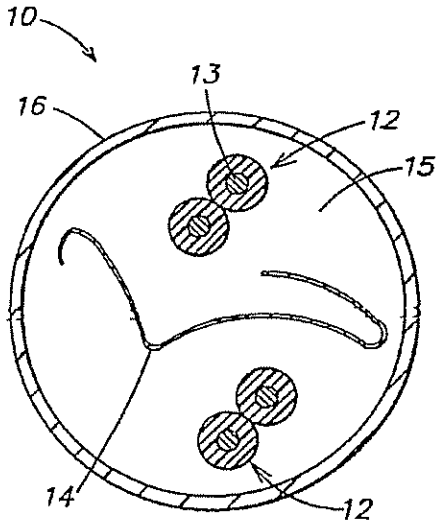


FIG. 5

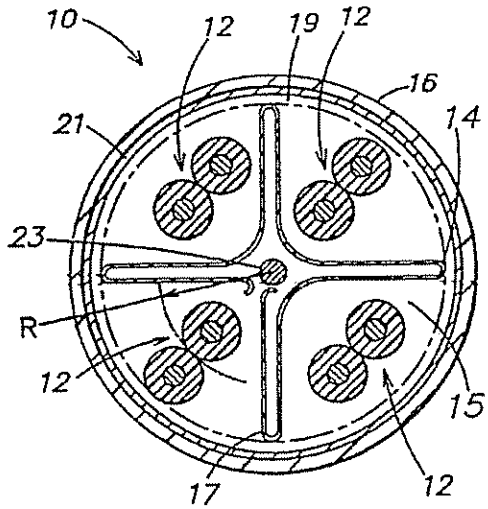


FIG. 6

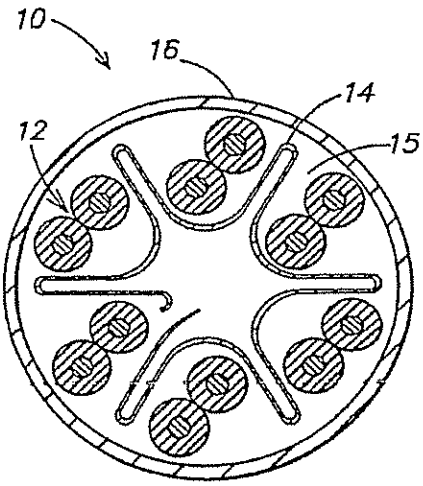


FIG. 7

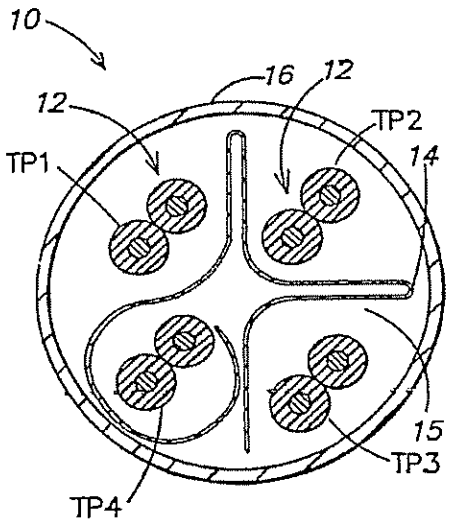


FIG. 8

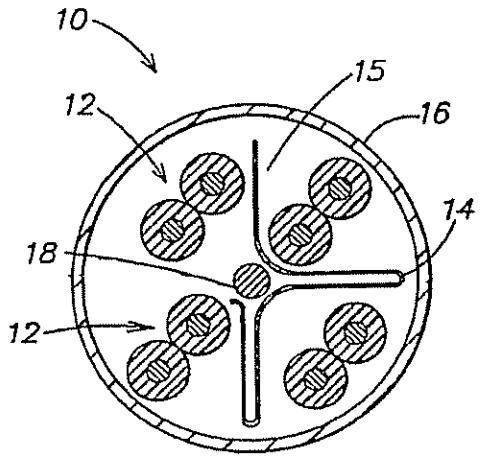


FIG. 9

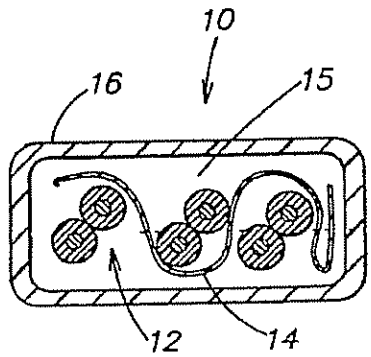


FIG. 10

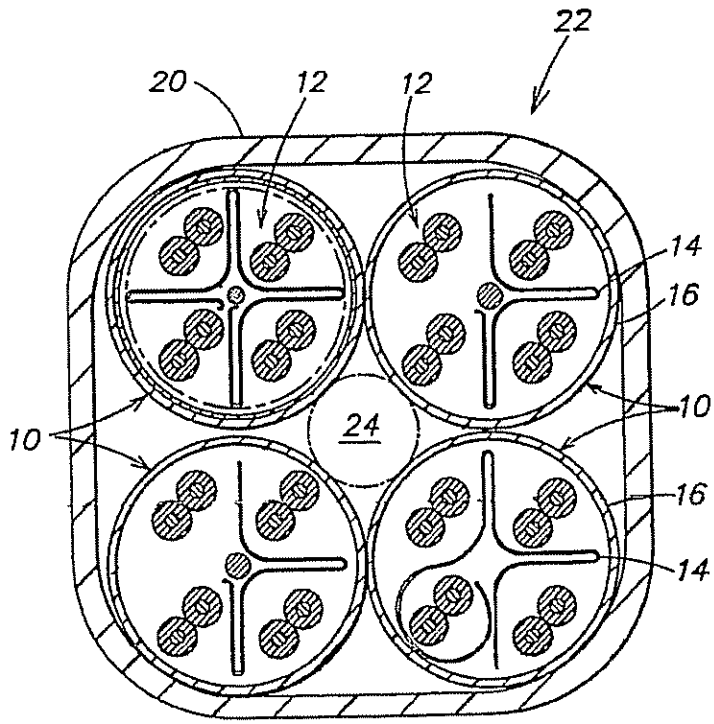


FIG. 11

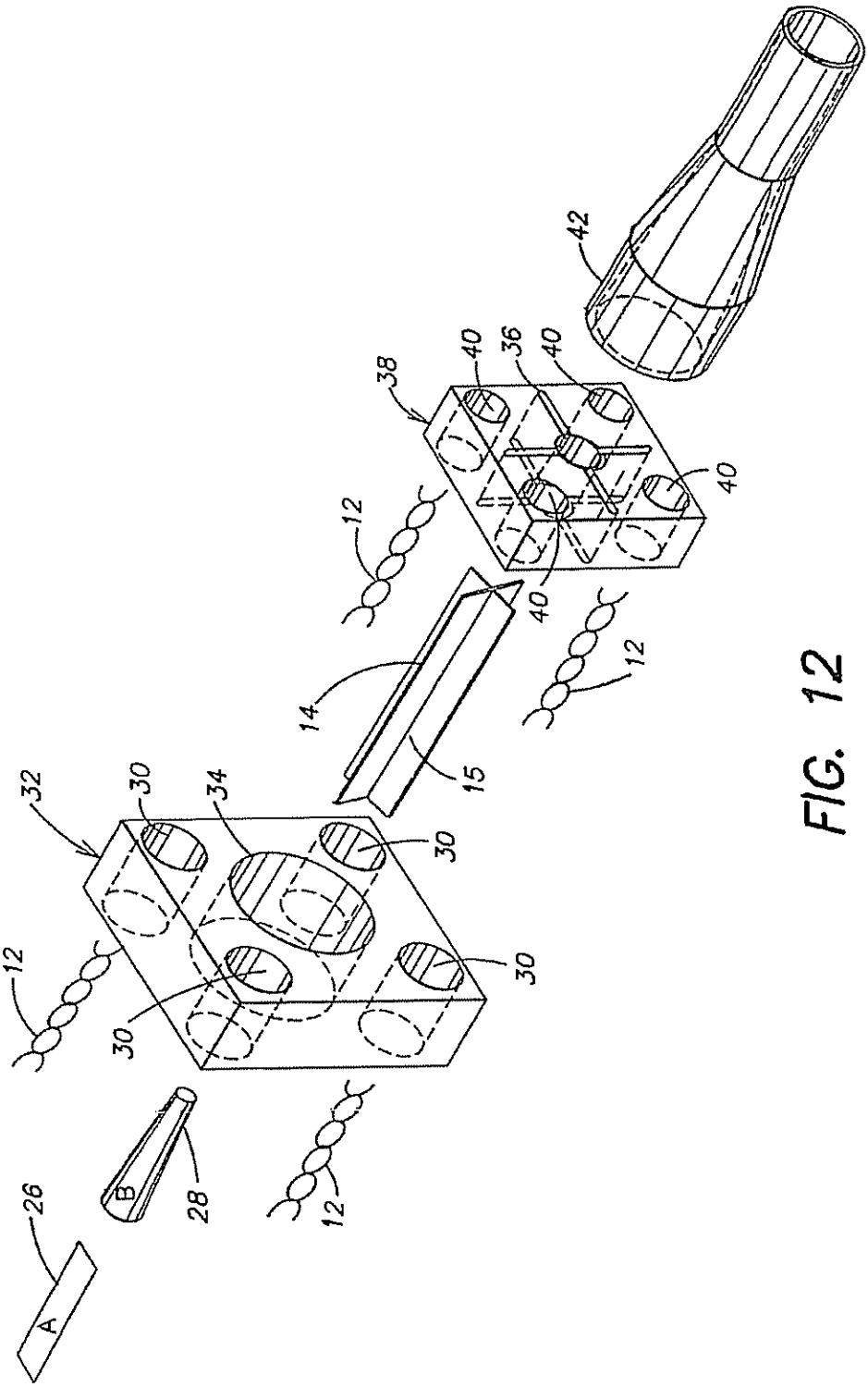


FIG. 12

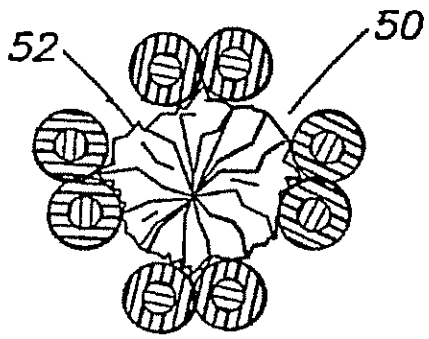
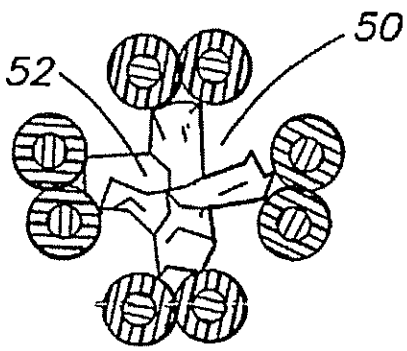


FIG. 13A



1 . 1

MULTI-PAIR DATA CABLE WITH CONFIGURABLE CORE FILLING AND PAIR SEPARATION

RELATED APPLICATIONS

This application is a continuation of and claims the benefit under 35 U.S.C. §120 to pending U.S. patent application Ser. No. 10/336,535, filed Jan. 3, 2003 now U.S. Pat. No. 6,998,537, entitled "Multi-Pair Data Cable with Configurable Core Filling and Pair Separation," which is a continuation of and claims the benefit under 35 U.S.C. §120 of U.S. patent application Ser. No. 09/853,512, filed May 11, 2001 now U.S. Pat. No. 6,570,095, entitled "Multi-Pair Data Cable with Configurable Core Filling and Pair Separation," which is a continuation of and claims the benefit under 35 U.S.C. §120 of U.S. patent application Ser. No. 09/257,844, now U.S. Pat. No. 6,248,954 B1, entitled, "Multi-Pair Data Cable with Configurable Core Filling and Pair Separation," filed Feb. 25, 1999, all of which which are hereby incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

The present invention relates to high-speed data communications cables using at least two twisted pairs of insulated conductors. More particularly, the invention relates to high-speed data communications cables having a light-weight, configurable core-filling isolation pair separator that provides geometrical separation between the twisted pairs of insulated conductors.

DISCUSSION OF THE RELATED ART

High-speed data communications media in current usage include pairs of insulated conductors twisted together to form a balanced transmission line. Such pairs of insulated conductors are referred to herein as "twisted pairs." When twisted pairs are closely placed, such as in a cable, electrical energy may be transferred from one twisted pair of a cable to another twisted pair. Such energy transferred between twisted pairs is referred to as crosstalk. As operating frequencies increase, improved crosstalk isolation between the twisted pairs becomes more critical.

The Telecommunications Industry Association and the Electronics Industry Association (TIA/EIA) have developed standards which specify specific categories of performance for cable impedance, attenuation, skew and particularly crosstalk isolation. One standard for crosstalk or, in particular, crosstalk isolation, is TIA/EIA-568-A, wherein a category 5 cable is required to have 38 dB of isolation between the twisted pairs at 100 MHz and a category 6 cable is required to have 42 dB of isolation between the twisted pairs at 100 MHz. Various cable design techniques have been used to date in order to try to reduce crosstalk and to attempt to meet the industry standards.

For example, one cable implementation known in the industry that has been manufactured and sold as a high-speed data communications cable, includes the twisted pairs formed with relatively tight twists, and the cable is formed into a round construction. In this conventional cable, each twisted pair has a specified distance between twists along a longitudinal direction of the twisted pair, that distance being referred to as the "twist lay." When adjacent twisted pairs have the same twist lay and/or twist direction, they tend to lie within a cable more closely spaced than when the twisted pairs have different twist lays and/or a different twist direction. Such close spacing increases the amount of undesirable crosstalk which occurs between the twisted pairs. In some conventional cables, each twisted pair within the cable has a unique twist lay in order to increase the spacing between pairs and thereby to reduce the crosstalk between twisted pairs of the cable. In addition, the twist direction of the twisted pairs may also be varied. However, this industry standard configuration can only achieve limited crosstalk isolation.

Another cable implementation **100** disclosed in U.S. Pat. No. 4,777,325, is illustrated in FIG. **1**, wherein the twisted pairs are enclosed within a jacket **102** that has a wide, flat configuration. In particular, a plurality of twisted pairs **104***a*–**104***b*, **106***a*–**106***b*, **108***a*–**108***b*, and **110***a*–**110***b* are positioned side-by-side, each in separate compartments **112**, **114**, **116**, and **118** formed within a flat hollow envelope of an extruded outer sheath **120**. The cable is provided with separator ribs **122** between a top and a bottom of the sheath to divide the outer sheath into the separate compartments and to prevent lateral movement of the twisted pairs out of their respective compartments. However, one problem with this flat configuration for a cable is that it has limited flexibility as compared to that of a round cable, which hinders installation of the cable in conduits and around bends.

Another cable implementation which addresses the problem of twisted pairs lying too closely together within the cable is described, for example, in U.S. Pat. No. 5,789,711 and is illustrated in FIG. **2**. In particular, the cable includes, for example, four twisted pairs **124** disposed about a central pre-shaped support **126**, wherein the support positions a twisted pair within grooves or channels **128** formed by the support. In particular, the support provides the grooves or channels which keep the twisted pairs at fixed positions with respect to each other. The support can have any of a number of shapes, including, for example, a standard "X", a "+", or the separator as is illustrated in FIG. **2**. The prongs or protrusions **130** of the support preserve the geometry of the pairs relative to each other, which helps reduce and stabilize crosstalk between the twisted pairs. However, some problems with the support is that the support adds cost to the cable, may limit the flexibility of the cable and increases the size; e.g., the diameter, of the cable. Another problem may be that the material which forms the support may result in the overall cable being a potential fire and/or smoke hazard.

Still another known industry cable implementation **132** is illustrated in FIG. **3**. The cable utilizes a jacket **134** with inward protrusions **136** that form channels **138** within the cable. A twisted pair **140** of conductors **142**, **144** is disposed within each channel. The protrusions are used to provide adequate pair separation. However, one problem with these protrusions is that they can be difficult to manufacture. In addition, the protrusions may not provide adequate separation between the twisted pairs where the stability of the protrusions is difficult to provide, and thus performance repeatability of the cable is an issue. Further, another problem is that the jacket is not easily strippable. When the cable is to be stripped by removing the outer jacket, which is often done with a sharp device such as, for example, a razor, the protrusions will not be cut by the incision around the circumference of the jacket and will have to be broken off separately in order to remove the jacket.

Accordingly, some of the problems with the above known configurations are that they are expensive, difficult to use, are generally undesirably large, and have decreased flexibility of the cables and workability of the twisted pairs of wires.

SUMMARY OF THE INVENTION

Therefore, a need exists for a high-speed data cable having multiple twisted pair wires with desired crosstalk performance, improved handling and termination capabilities, that is inexpensive, flexible and has a desired size. This invention provides an improved data cable.

According to the invention, a data communications cable has been developed so as to better facilitate the cable for its the intended use of high speed data transmission, yet maintain a form factor that has desired flexibility and workability, and that is compatible with industry standard hardware, such as plugs and jacks. The data communications cable of the invention has the additional benefit of a reduced cabled size relative to other known cables within its performance class.

In particular, the present invention provides these advantages by utilizing a substantially flat configurable, highly flexible, core-filling, dielectric separator to provide twisted pair separation for the cable.

One embodiment of a data communications cable of the invention includes a first twisted pair of insulated conductors, a second twisted pair of insulated conductors, and the substantially flat dielectric pair separator. The substantially flat configurable dielectric pair separator is disposed between the first twisted pair of insulated conductors and the second twisted pair of insulated conductors. The data communications cable also includes a jacket assembly enclosing the first twisted pair of insulated conductors, the second twisted pair of insulated conductors, and the substantially flat dielectric pair separator.

With this arrangement, the data communications cable can be made with desired crosstalk isolation between the twisted pairs of insulated conductors. In addition, due to the conforming nature and the desired thickness of the substantially flat configurable dielectric pair separator, the cable has desired flexibility, workability and size. Moreover, these advantages do not come at the expense of other properties of the cable such as, for example, size or reduced impedance stability. The substantially flat configurable dielectric pair separator also facilitates termination of the data communications cable to known industry standard hardware.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects, features and advantages of the present invention will become more apparent in view of the following detailed description of the invention when taken in conjunction with the figures, in which:

FIG. **1** is a perspective view of an embodiment of a communications cable according to the related art;

FIG. **2** is a cross-sectional view of another embodiment of a communications cable according to the related art;

FIG. **3** is a cross-sectional view of another embodiment of a communications cable according to the related art;

FIG. **4** is a perspective view of a data communications cable according to one embodiment of the invention;

FIG. **5** is a cross-sectional view of the embodiment of the data communications cable of FIG. **4**;

FIG. **6** is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. **7** is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. **8** is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. **9** is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. **10** is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. **11** is a cross-sectional view of a data communications cable according to another embodiment of the invention;

FIG. **12** is a perspective view of a system for practicing a method of making a cable in accordance with an embodiment of the invention;

FIG. **13**A illustrates a core of a four twisted pair cable; and

FIG. **13**B is an exploded view of the core of the cable of FIG. **13**A, having a filler material according to the invention.

DETAILED DESCRIPTION

A number of embodiments of a data communications cable according to the invention will now be described in which the cable is constructed with a plurality of twisted pairs of insulated conductors and a core made from a configurable, dielectric pair separator. However, it is to be appreciated that the invention is not limited to any number of twisted pairs or any profile for the configurable, dielectric pair separator illustrated in any of these embodiments. The inventive principles can be applied to cables including greater or fewer numbers of twisted pairs and having different core profiles of the configurable dielectric pair separator. In addition, although these embodiments of the invention are described and illustrated in connection with twisted pair data communication media, it is to be appreciated that other high-speed data communication media can be used instead of twisted pairs of conductors in the constructions of the cable according to the invention, such as, for example, fiber optic media.

FIG. **4** depicts an embodiment of a data communications cable **10** according to the present invention. The cable **10** includes two twisted pairs **12** of insulated conductors **13**. The twisted pairs **12** are separated by a low dielectric constant, low dissipation factor, polymer "pair separator" **14**. The twisted pairs **12** and the pair separator **14** are encased within a jacket assembly **16**. The outer jacket can be a PVC, a low-smoke, low-flame PVC, or any plenum or non-plenum rated thermoplastic.

FIG. **5** depicts a cross-sectional view of an embodiment of the cable of FIG. **4**. The configurable pair separator **14** runs along a longitudinal length of the cable, and is configured such that the twisted pairs are disposed within channels or grooves **15** of the pair separator along the length of the cable. As illustrated, the grooves **15** do not form completely enclosed channels. Some of the advantages of this cable according to the invention are that the pair separator provides structural stability during manufacture and use of the data communications cable, yet does not degrade the flexibility and workability of the cable, and does not substantially increase the size of the cable. In addition, the pair separator improves the crosstalk isolation between the twisted pairs by providing desired spacing between the twisted pairs. Therefore, the configurable pair separator of the invention lessens the need for complex and hard to control twist lay procedures, core filling arrangements and jacket embodiments described above with respect to the related art.

The above-described embodiment of the data communications cable can be constructed using a number of different materials as the pair separator **14**. While the invention is not limited to the materials described herein, the invention is advantageously practiced using these materials. In particular, the configurable pair separator is preferably a flame-

retardant, low-dielectric constant, low-dissipation factor, foamed polymer tape, such as, for example, a foamed flame retardant, cellular polyolefin or fluoropolymer like NEPTC PP500 "SuperBulk", a foamed fluorinated ethylene propylene (FEP) or a foamed polyvinyl chloride (PVC). The above-described pair separators are preferably used in a non-plenum rated application where the cable is not required to pass industry standard flame and smoke tests such as the Underwriters Laboratories (UL) 910 test. Another preferable configurable pair separator is a woven fiberglass tape normally used as a binder for cables, such as, for example, Allied Fluoroglass CTX3X50. This woven fiberglass binder is preferably used in a plenum rated application where the cable must satisfy the UL 910 test.

Still another pair separator material that may be used in the cable of the invention is a bulk filling material such as a polyolefin or glass fiber filler that is flame-retardant and is typically shredded or fibrulated, but may also be solid, such as, for example, Chadwick AFT 033 Fiberglass. Such a bulk filling material is typically twisted up and used as a filling material in a core of the cable, with no other purpose. In particular, referring to FIG. **13**A, the bulk filler is typically used as a core filling material that fills 100% of the core area **50** between the illustrated four twisted pair, that is used to keep the cable in a more or less round construction. However, referring to FIG. **13**B, according to the present invention it is preferable to provide less than 100% of the core area **50** with the filling material; and it is more preferable us use less than 42% of the core with the filler material **52** for providing isolation between the twisted pairs. In a preferred embodiment, approximately 32% of the overall core area between the four twisted pairs of the cable is filled with such a filler and shaped as described herein. Therefore, one aspect of the present invention is the recognition that the filler or tape described above can be used to prevent physical contact between opposite and adjacent twisted pairs, thereby increasing the isolation between the twisted pairs, while not requiring the entire core area be filled, and therefore not sacrificing the size, cost or flexibility of the overall cable.

FIG. **6** depicts a cross-sectional view of a preferred embodiment of the data cable **10** of this invention. The cable includes the low-dielectric constant, low-dissipation factor polymer pair separator **14** formed into a cable core in such a way as to physically separate the four twisted pairs **12**, thereby decreasing field coupling between the twisted pairs, providing a desired opposite twisted pair-to-pair physical distance, as well as providing a desired adjacent pair separation. It is to be appreciated that like components of the data communications cable illustrated in FIGS. **4**–**5** have been provided with like reference numbers and the description of these components applies with respect to each of the cable embodiments to be described herein.

In the embodiment of the cable of FIG. **6**, the pair separator **14** is a flat configurable tape used as a core filler, that is shaped to have the illustrated profile and that is provided in the cable between the four twisted pairs **12**. In particular, in this embodiment, the configured pair separator has a shape somewhat like a "+", providing four channels **15** between each pair of protrusions **17** formed by the pair separator. Each channel carries one twisted pair **12** that is placed within the channel during a process of manufacturing the cable that will be described in further detail below. As is discussed above, the illustrated configurable core profile should not be considered limiting. In particular, although it is preferred that the pair separator is supplied as a flat extruded tape, the configurable pair separator may be made by a process other than extrusion and may have a number of different shapes or provide a number of different channels, as is illustrated by some of the embodiments described in further detail below.

Referring again to FIG. **6**, the data communications cable may also be provided with a binder **19**, as illustrated in phantom, that is wrapped around the configurable core pair separator **14** and the plurality of twisted pairs **12**. For this embodiment, it is preferable that the configurable core pair separator be an aluminum/mylar tape, with an aluminum layer on a side of the tape facing the plurality of twisted pairs. In addition, it is preferred that the binder be made of the aluminum/mylar tape, with the aluminum layer of the tape facing the plurality of the twisted pairs so that the combination of the binder and the configurable pair separator provide four electrically shielded, enclosed channels. With this embodiment, the four enclosed channels are isolated from one another to provide desired crosstalk isolation. In addition, another benefit of the embodiment of the cable is that a cable adjacent this cable will have reduced coupling with the cable of the invention, or in other words, reduced alien cross talk as it is known in the industry.

The embodiment of FIG. **6** further illustrates a shield **21** may also be laterally wrapped around the binder **19**; the shield is preferably made from a foil or metal. The shield may be applied over the cable before jacketing the cable with the jacket **16**, and is also used to help reduce crosstalk between the twisted pairs, to reduce alien crosstalk, and prevent the cable from causing or receiving electromagnetic interference. It is to be appreciated that the shield can also be provided in lieu of the binder. In particular, greater crosstalk isolation between the twisted pairs of the cable, and reduced alien crosstalk may also be achieved by using a conductive shield **21** that is, for example, a metal braid, a solid metal foil, or a conductive plastic that is in contact with ends of the protrusions **17** of the configurable filler **14**. If the configurable pair separator is also conductive or semi-conductive as described above for the aluminum/mylar tape, then the combination of the pair separator and the shield forms conductive compartments that shield each twisted pair from the other twisted pairs.

Referring to FIG. **6**, the cable can advantageously include a metal drain wire **23** exposed, for example, within the middle of the configurable pair separator **14**. The metal drain wire runs the length of the cable and acts as a ground. However, it is to be appreciated that the metal drain wire need not be so placed and may also be arranged in arrangements known to those of skill in the art such as, for example, spirally wrapped around the binder **19** or the shield **21**.

It is preferable in the embodiments described herein that the protrusions **17** of the configurable pair separator extend at least beyond a center axis of each twisted pair, known in the art as a pitch radius. The pitch radius is illustrated in FIG. **6** as the radius R between the center of the cable core and the center axis of the twisted pairs **12** of conductors. This preferred configuration of the configurable pair separator ensures that the twisted pairs do not escape their respective spaces or channels. It is also to be appreciated that the process of jacketing of the cable, to be described in detail below, may bend the ends of the protrusions **17** over slightly (not illustrated), since the configurable pair separator is relatively formable.

As discussed above, it is to be appreciated that the twisted pairs of insulated conductors and configurable pair separator of the communications data cable of the invention, can be configured in a variety of ways. FIGS. **7**–**12** depict cross-sectional views of various embodiments of the data communications cable of the invention. As illustrated, for

example, in FIGS. 7, 9 and 10, the configurable pair separator may be configured such that the grooves 15 do not form completely enclosed channels. FIG. 7 depicts a cable 10 wherein six twisted pairs 12 are encased within the jacket assembly 16, and are separated from each other by the configurable pair separator 14. The pair separator 14 is configured in a somewhat "*" shape that provides support and placement of the twisted pairs so that the twisted pairs 12 have a desired spacial arrangement and do not come into direct physical contact with each other.

FIG. 8 depicts still another embodiment of the data communications cable 10 having multiple twisted pairs 12 encased within the jacket assembly 16 and having at least one of the twisted pairs isolated by the pair separator 14, from the remainder of the twisted pairs. In particular, referring to FIG. 8, the twisted pairs have been labeled TP1, TP2, TP3 and TP4, wherein twisted pair TP4 is isolated from twisted pairs TP1, TP2 and TP3 by the pair separator 14. It is an advantage of this embodiment, that the pair separator 14 can be provided with an appropriate number of twists or wrappings around the twisted pair TP4, so as to provide selective isolation between twisted pair TP4 and twisted pairs TP1, TP2 and TP3. This embodiment of the cable according to the invention can be used, for example, to provide better isolation between a weakest one or a weakest combination of twisted pairs of cables, in an environment where there is known to be a low amount of isolation between a particular twisted pair and another twisted pair, or a plurality of twisted pairs. Accordingly, with this embodiment of the cable of the invention, there can be selective enhancement of isolation between twisted pairs TP1-TP4, TP2-TP4, and TP3-TP4. It is to be appreciated that although the twisted pair TP4 has been illustrated as being isolated from the remainder of the twisted pairs, that any of the twisted pairs can be so wrapped with the filler and isolated. This embodiment of the invention may also be used in conjunction with a lessening of the twist lays requirements for the twisted pairs, to provide cable having a same amount of isolation between twisted pairs as a cable with tighter twist lays. Accordingly, this embodiment of the cable according to the invention allows for selective design of isolation between particular twisted pairs of the cable and lessening of the twist lay requirements for the cable.

FIG. 9 depicts still another embodiment of the data communications cable 10 having multiple twisted pairs 12 encased within the jacket assembly 16 and physically separated from each other by the configurable pair separator 14, and also including a central core filler 18 positioned at the middle of the cable and that runs along the longitudinal length of the cable, provided less than 100% of the core is filled with the filler. The configurable pair separator provides desired separation between the individual twisted pairs 12 as discussed above. The central core 18 provides additional support or structure and may be formed of, for example, a solid or foamed flame retardant polyolefin or other materials that are known in the industry. For plenum rated cables, it is preferable that the core be any of one or more of the following compounds: a solid low-dielectric constant fluoropolymer, e.g. ethylene chlorotrifluoroethylene (E-CTFE), FEP, a foamed fluoropolymer, e.g. foamed FEP, and PVC in either solid, low dielectric constant form or foamed. The central core filling 18 may also be constructed of the same materials as the configurable pair separator 14 discussed above.

FIG. 10 depicts yet another embodiment of a data communications cable 10, having a substantially flat configuration. Twisted pairs 12 are encased within a substantially flat jacket assembly 16 and physically separated from each other by the configurable pair separator 14. The cable of FIG. 10 is an alternative to the cable of the related art as illustrated in FIG. 1, and other known flat cables. It is to be understood, that although this embodiment is illustrated with a single fold of the pair separator material between each twisted pair, that the number of folds can be increased to further adjust the distance between each of the twisted pairs and thereby increase the isolation between each of the twisted pairs. Other variations known to those of skill in the art are also intended to be within the scope of the invention and this embodiment. For example, the pair separator may also be disposed at a bottom of the cable with folds directed upwardly towards the top of the cable, in contrast to at the top of the cable with the folds directed towards the bottom of the cable as illustrated in FIG. 10, or the pair separator may be disposed at both the bottom and top.

FIG. 11 depicts an embodiment of a data communications cable 22 including a plurality of data communications cables 10 according to any of the embodiments described above. In particular, each data cable 10 contains multiple twisted pairs 12 separated by the configurable pair separator 14 according to any of the above-described configurations, and encased in the jacket assembly 16. The plurality of data cables are enclosed within outer casing 20. The cable 22 may also have a central core filler 24, as illustrated in phantom, that may be formed from any of the above-described materials and may be used to, for example, to keep the data cables in a desired arrangement so as to, for example, minimize crosstalk between each of the data cables 10.

Referring now to FIG. 12, there is illustrated a perspective view of a system for practicing a method of making a cable in accordance with an embodiment of the invention. The pair separator 26 is drawn from a reel or pad (not shown), and is formed around a round cob 28 into a shaped pair separator such as, for example, in the shape of a cylinder. The shaped pair separator is aligned with four twisted pairs 12 by passing the four twisted pairs through openings 30 in first die 32, and the shaped pair separator through central opening 34. The shaped pair separator is then further configured into a desired shape (formed pair separator) as illustrated in FIG. 12. It is to be appreciated, as discussed above, that this shape can be varied. The formed pair separator 15 is then passed through opening 36 in second die 38 and brought together with the four twisted pairs 12 which are passed through corresponding openings 40 in the second die. The plurality of twisted pairs are then cabled with the formed pair separator by a third die 42, in an operation referred to as "bunching". The third die places the twisted pairs in the channels 15 (see FIGS. 5–10) of the formed pair separator prior to twisting of the cable. It is to be appreciated that the cable can be twisted with any known twisting arrangement such as a helix, or an S-Z configuration. It is also to be appreciated that this method can be varied to include any of the components illustrated and discussed above, such as, for example, to include a drain wire, a binder, a shield, or central core filler.

Accordingly, some of the advantages of the various embodiments of the data communications cable of the invention are crosstalk performance and isolation enhancement can be configured and provided as customized cable solutions for hardware manufactures who request special requirements. For example, specific twisted pair combinations can receive a dedicated amount of isolation tape folds, thereby enhancing separation of selected twisted pairs and enhancing crosstalk isolation between the selected twisted pairs where an end user, for example, needs more crosstalk

isolation. The data communications cable can also be made with a desired crosstalk isolation between the opposing twisted pairs of insulated conductors. In addition, due to the conforming nature and the thickness of the pair separator material, this advantage does not come at the expense of, for example, the size of the data communications cable, and does not result in a reduced impedance stability of the data communications cable. Another advantage is that the amorphous nature of the pair separator yields a desired cable that better facilitates termination of the data communications cable to known industry hardware, than larger diameter cables of the related art.

The present invention has now been described in connection with a number of specific embodiments thereof. However, numerous modifications which are contemplated as falling within the scope of the present invention should now be apparent to those skilled in the art. Therefore, it is intended that the scope of the present invention be limited only by the scope of the claims appended hereto.

What is claimed is:

1. An unshielded twisted pair communications cable comprising:

a plurality of twisted pairs of insulated conductors including a first twisted pair of insulated conductors and a second twisted pair of insulated conductors;

a configurable tape separator disposed between the plurality of twisted pairs of conductors in the unshielded twisted pair communications cable and arranged so as to separate the first twisted pair of insulated conductors from the second twisted pair of insulated conductors; and

a jacket enclosing the plurality of twisted pairs of insulated conductors and the configurable tape separator;

wherein the plurality of twisted pairs of insulated conductors and the configurable tape separator are cabled about a common axis to form the unshielded twisted pair communications cable; and

wherein the configurable tape separator is substantially non-conductive.

2. The unshielded twisted pair communications cable as claimed in claim 1, wherein the configurable pair separator is arranged so as to define at least two channels and wherein the first twisted pair of insulated conductors is disposed at least partially within a first channel and the second twisted pair of insulated conductors is disposed at least partially within a second channel.

3. The unshielded twisted pair communications cable as claimed in claim 1, wherein, prior to cabling, the configurable tape separator comprises a substantially flat tape.

4. The unshielded twisted pair communications cable as claimed in claim 3, wherein, after cabling, the configurable tape separator is arranged so as to provide at least one concave surface defining a channel, and wherein the first twisted pair of insulated conductors is disposed at least partially within the channel.

5. The unshielded twisted pair communications cable as claimed in claim 1, wherein the separator is constructed such that when a portion of the jacket is removed from an end of the cable to expose the plurality of twisted pairs and the separator, the exposed separator is substantially flat.

6. The unshielded twisted pair communications cable as claimed in claim 1, wherein the configurable tape separator occupies less than approximately 50% of a core area between the plurality of twisted pairs of insulated conductors.

7. The unshielded twisted pair communications cable as claimed in claim 1, wherein the configurable tape separator occupies approximately 32% of a core area of the cable between the plurality of twisted pairs of insulated conductors.

8. The unshielded twisted pair communications cable as claimed in claim 1, wherein the configurable tape separator includes a foamed polymer.

9. The unshielded twisted pair communications cable as claimed in claim 1, wherein the configurable tape separator includes a woven fiberglass tape.

10. The unshielded twisted pair communications cable as claimed in claim 1, wherein the cable is suitable for plenum applications and wherein the configurable tape separator comprises at least one of a solid low-dielectric constant fluoropolymer, fluoroethylenepropylene, a foamed fluoropolymer, and polyvinyl chloride.

11. The unshielded twisted pair communications cable as claimed in claim 1, wherein the configurable tape separator includes a flame-retardant, low-dielectric constant, foamed polymer tape.

12. The unshielded twisted pair communications cable as claimed in claim 11, wherein the configurable tape separator comprises at least one of a foamed flame-retardant cellular polyolefin, a foamed flame-retardant fluoropolymer material, foamed fluorinated ethylene propylene, and foamed polyvinyl chloride.

13. The unshielded twisted pair communications cable as claimed in claim 1, wherein the configurable tape separator is disposed so as to prevent direct physical contact between the first twisted pair and the jacket.

14. An unshielded twisted pair communications cable comprising:

a plurality of twisted pairs of insulated conductors including a first twisted pair of insulated conductors and a second twisted pair of insulated conductors;

a configurable pair separator that, prior to cabling, comprises a substantially flat, non-conductive tape disposed between the plurality of twisted pairs of conductors and that is arranged so as to separate the first twisted pair of insulated conductors from the second twisted pair of insulated conductors; and

a jacket enclosing the plurality of twisted pairs of insulated conductors and the configurable pair separator;

wherein the plurality of twisted pairs of insulated conductors and the configurable pair separator are cabled about a common axis to form the unshielded twisted pair communications cable.

15. The unshielded twisted pair communications cable as claimed in claim 14, wherein, after cabling, the configurable pair separator is arranged so as to provide at least two channels, and wherein the first twisted pair of insulated conductors is disposed at least partially within a first channel and the second twisted pair of insulated conductors is disposed at least partially within a second channel.

16. The unshielded twisted pair communications cable as claimed in claim 14, wherein the configurable pair separator occupies less than approximately 50% of a core area between the plurality of twisted pairs of insulated conductors.

17. The unshielded twisted pair communications cable as claimed in claim 14, wherein the configurable pair separator includes a foamed polymer.

18. The unshielded twisted pair communications cable as claimed in claim 14, wherein the configurable pair separator includes a woven fiberglass tape.

19. The unshielded twisted pair communications cable as claimed in claim 14, wherein the configurable pair separator comprises at least one of a foamed flame-retardant cellular

polyolefin, a foamed flame-retardant fluoropolymer material, foamed fluorinated ethylene propylene, and a foamed polyvinyl chloride.

20. An unshielded twisted pair communications cable comprising:

a plurality of twisted pairs of insulated conductors including a first twisted pair and a second twisted pair;

a separator disposed among the plurality of twisted pairs of insulated conductors so as to separate the first twisted pair from the second twisted pair; and

a jacket enclosing the plurality of twisted pairs of insulated conductors and the separator;

wherein the separator is substantially non-conductive and is constructed such that, when a portion of the jacket is removed from an end of the cable to expose the plurality of twisted pairs and the separator, the exposed separator is substantially flat.

* * * * *

JS 44 (Rev 3/99)

CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. (SEE INSTRUCTIONS ON THE REVERSE OF THE FORM.)

I. (a) PLAINTIFFS

Belden Technologies, Inc. and Belden CDT (Canada) Inc.

(b) County Of Residence Of First Listed Plaintiff: (Except In U.S. Plaintiff Cases)

DEFENDANTS

Superior Essex Inc. and Superior Essex Communications LP

County Of Residence Of First Listed Defendant: (IN U.S. PLAINTIFF CASES ONLY)
NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE TRACT OF LAND INVOLVED

(c) Attorneys (Firm Name, Address, And Telephone Number)

John W. Shaw (No. 3362)
Karen E. Keller (No. 4489)
Young Conaway Stargatt & Taylor, LLP
The Brandywine Building
1000 West Street, 17th Floor
Wilmington, DE 19801
(302) 571-6600

Attorneys (If Known)

II. BASIS OF JURISDICTION (PLACE AN X IN ONE BOX ONLY)

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question (U.S. Government Not a Party)
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES (Place An X In One Box For Plaintiff And One Box For Defendant) (For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated or Principal Place of Business in This State	☐ 4	☐ 4
Citizen of Another State	☐ 2	☐ 2	Incorporated and Principal Place of Business in This State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

V. NATURE OF SUIT (Place An X In One Box Only)

CONTRACT
- ☐ 110 Insurance
- ☐ 120 Marine
- ☐ 130 Miller Act
- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment & Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted (Excl. Veterans)
- ☐ 153 Recovery of Overpayment of Veteran's Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault, Libel & Slander
- ☐ 330 Federal Employers Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury

PERSONAL INJURY
- ☐ 362 Personal Injury - Med Malpractice
- ☐ 365 Personal Injury - Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

PERSONAL ROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

CIVIL RIGHTS
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accommodations
- ☐ 444 Welfare
- ☐ 440 Other Civil Rights

PRISONER PETITIONS
- ☐ 510 Motions to Vacate Sentence Habeas Corpus
- ☐ 530 General
- ☐ 535 Death Penalty
- ☐ 540 Mandamus & Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition

FORFEITURE/PENALTY
- ☐ 610 Agriculture
- ☐ 620 Other Food & Drug
- ☐ 625 Drug Related Seizure of Property 21 U.S.C. 881
- ☐ 630 Liquor Laws
- ☐ 640 R R & Truck
- ☐ 650 Airline Regs
- ☐ 660 Occupational Safety/Health
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Mgmt Relations
- ☐ 730 Labor/Mgmt. Reporting & Disclosure Act
- ☐ 740 Railway Labor Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Empl Ret Inc Security Act

BANKRUPTCY
- ☐ 422 Appeal 28 U.S.C. 158
- ☐ 423 Withdrawal 28 U.S.C. 157

PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 840 Trademark

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405(g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405(g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U.S. Plaintiff or Defendant)
- ☐ 871 IRS - Third Party 26 U.S.C. 7609

OTHER STATUTES
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce/ICC Rates, etc.
- ☐ 460 Deportation
- ☐ 470 Racketeer Influenced and Corrupt Organizations
- ☐ 810 Selective Service
- ☐ 850 Securities/Commodities/ Exchange
- ☐ 875 Customer Challenge 12 U.S.C. 3410
- ☐ 891 Agricultural Acts
- ☐ 892 Economic Stabilization Act
- ☐ 893 Environmental Matters
- ☐ 894 Energy Allocation Act
- ☐ 895 Freedom of Information Act
- ☐ 900 Appeal of Fee Determination Under Equal Access to Justice
- ☐ 950 Constitutionality of State Statutes
- ☐ 890 Other Statutory Actions

IV. ORIGIN (PLACE AN "X" IN ONE BOX ONLY)

☒ 1 Original Proceeding ☐ 2 Removed from Court ☐ 3 Remanded from Appellate Court ☐ 4 Reinstated or Reopened ☐ 5 Transferred from another district (specify) ☐ 6 Multidistrict Litigation ☐ 7 Appeal to District Judge from Magistrate Judgment

VI. CAUSE OF ACTION

(CITE THE U.S. CIVIL STATUTE UNDER WHICH YOU ARE FILING AND WRITE BRIEF STATEMENT OF CAUSE DO NOT CITE JURISDICTIONAL STATUTSE UNLESS OIVERSITY.):
35 U.S.C. § 101 et seq.

Brief description of cause:
Patent infringement.

VII. REQUESTED IN COMPLAINT: ☐ CHECK IF THIS IS A CLASS ACTION UNDER F.R.C.P. 23 ☐ YES ☒ NO **DEMAND** $

Check YES only if demanded in complaint
JURY DEMAND ☒ YES ☐ NO

VIII. RELATED CASE(S) (See instructions) IF ANY JUDGE: DOCKET NUMBER:

DATE 1-29-08 SIGNATURE OF ATTORNEY OF RECORD Karen E. Keller (#4489)

FOR OFFICE USE ONLY

RECEIPT # _____ AMOUNT _____ APPLYING IFP _____ JUDGE _____ MAG. JUDGE _____

JS 44 Reverse
(Rev. 3/99)

INSTRUCTIONS FOR ATTORNEYS COMPLETING CIVIL COVER SHEET FORM JS-44

Authority For Civil Cover Sheet

The JS-44 civil cover sheet and the information contained herein neither replaces nor supplements the filings and service of pleading or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. Consequently a civil cover sheet is submitted to the Clerk of Court for each civil complaint filed. The attorney filing a case should complete the form as follows:

I. (a) **Plaintiffs - Defendants.** Enter names (last, first, middle initial) of plaintiff and defendant. If the plaintiff or defendant is a government agency, use only the full name or standard abbreviations. If the plaintiff or defendant is an official within a government agency, identify first the agency and then the official, giving both name and title.

(b) **County of Residence.** For each civil case filed, except U.S. plaintiff cases, enter the name of the county where the first listed plaintiff resides at the time of filing. In U.S. plaintiff cases, enter the name of the county in which the first listed defendant resides at the time of filing. (NOTE: In land condemnation cases, the county of residence of the "defendant" is the location of the tract of land involved).

(c) **Attorneys.** Enter firm name, address, telephone number, and attorney of record. If there are several attorneys, list them on an attachment, noting in this section "(see attachment)."

II. Jurisdiction. The basis of jurisdiction is set forth under Rule 8(a), F.R.C.P., which requires that jurisdictions be shown in pleadings. Place an "X" in one of the boxes. If there is more than one basis of jurisdiction, precedence is given in the order shown below.

United States plaintiff. (1) Jurisdiction is based on 28 U.S.C. 1345 and 1348. Suits by agencies and officers of the United States are included here.

United States defendant. (2) When the plaintiff is suing the United States, its officers or agencies, place an "X" in this box.

Federal question. (3) This refers to suits under 28 U.S.C. 1331, where jurisdiction arises under the Constitution of the United States, an amendment to the Constitution, an act of Congress or a treaty of the United States. In cases where the U.S. is a party, the U.S. plaintiff or defendant code takes precedence, and box 1 or 2 should be marked.

Diversity of citizenship. (4) This refers to suits under 28 U.S.C. 1332, where parties are citizens of different states. When Box 4 is checked, the citizenship of the different parties must be checked. (See Section III below; federal question actions take precedence over diversity cases.)

III. Residence (citizenship) of Principal Parties. This section of the JS-44 is to be completed if diversity of citizenship was indicated above. Mark this section for each principal party.

IV. Cause of Action. Report the civil statute directly related to the cause of action and give a brief description of the cause.

V. Nature of Suit. Place an "X" in the appropriate box. If the nature of suit cannot be determined, be sure the cause of action, in Section IV above, is sufficient to enable the deputy clerk or the statistical clerks in the Administrative Office to determine the nature of suit. If the cause fits more than one nature of suit, select the most definitive.

VI. Origin. Place an "X" in one of the seven boxes.

Original Proceedings. (1) Cases which originate in the United States district courts.

Removed from State Court. (2) Proceedings initiated in state courts may be removed to the district courts under Title 28 U.S.C. Section 1441. When the petition for removal is granted, check this box.

Remanded from Appellate Court (3) Check this box for cases remanded to the district court for further action. Use the date of remand as the filing date.

Reinstated or Reopened. (4) Check this box for cases reinstated or reopened in the district court. Use the reopening date as the filing date.

Transferred from Another District. (5) For cases transferred under Title 28 U.S.C. Section 1404(a). Do not use this for within district transfers or multidistrict litigation transfers.

Multidistrict Litigation. (6) Check this box when a multidistrict case is transferred into the district under authority of title 28 U.S.C. Section 1407. When this box is checked, do not check (5) above.

Appeal to District Judge from Magistrate Judgment. (7) Check this box for an appeal from a magistrate's decision.

VII. Requested in Complaint. Class Action. Place an "X" in this box if you are filing a class action under Rule 23, F.R.Cv.P.

Demand. In this space enter the dollar amount (in thousands of dollars) being demanded or indicate other demand such as a preliminary injunction.

Jury Demand. Check the appropriate box to indicate whether or not a jury is being demanded.

VIII. Related Cases. This section of the JS-44 is used to reference relating pending cases if any. If there are related pending cases, insert the docket numbers and the corresponding judge names for such cases.

Date and Attorney Signature. Date and sign the civil cover sheet.

AO FORM 85 RECEIPT (REV. 9/04)

United States District Court for the District of Delaware

Civil Action No. - 08 - 63 -

ACKNOWLEDGMENT OF RECEIPT FOR AO FORM 85

NOTICE OF AVAILABILITY OF A UNITED STATES MAGISTRATE JUDGE TO EXERCISE JURISDICTION

I HEREBY ACKNOWLEDGE RECEIPT OF 2 COPIES OF AO FORM 85.

1/29/08
(Date forms issued)

Matthew D. Gordon
(Signature of Party or their Representative)

Matthew D. Gordon
(Printed name of Party or their Representative)

Note: Completed receipt will be filed in the Civil Action