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 3,459,879 8/1969 Gerpheide 174/117.11

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[54] **FLEXIBLE FLAT CONDUCTOR CABLE OF VARIABLE ELECTRICAL CHARACTERISTICS**
14 Claims, 7 Drawing Figs.

[52] U.S. Cl. **174/36,**
174/117 FF, 333/84 M

[51] Int. Cl. **H01b 7/08**

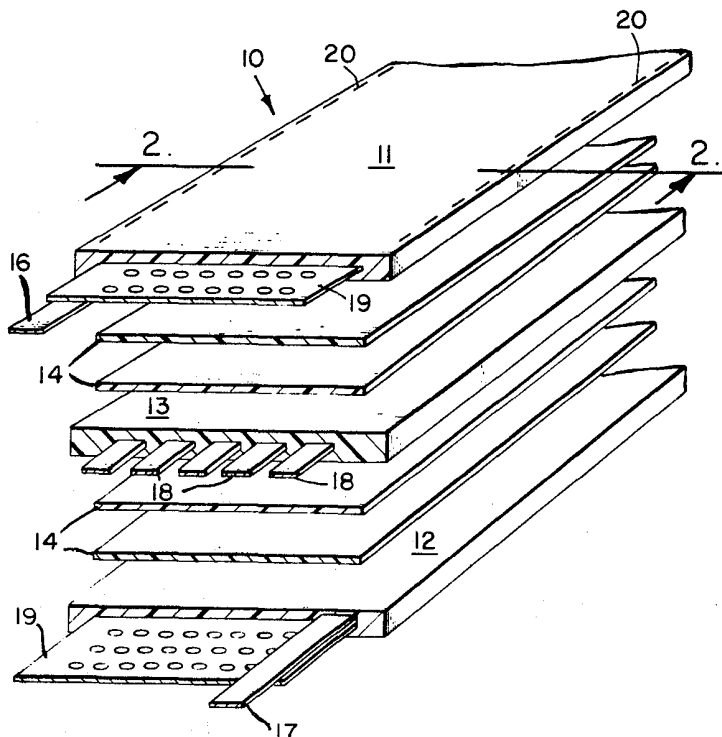
[50] Field of Search **317/258;**
338/84, 84 M; 174/117, 117.1, 117.11, 126, 36,
105 (1); 156/91

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ABSTRACT: A flexible multiple flat conductor electric cable fabricatable in long lengths with variable and uniform characteristic impedance. The cable comprises a conductive layer, at least one flat dielectric layer continuous to each face of the conductive layer, and a ground plane layer contiguous to the outer face of each outermost dielectric layer. The flat conductor layer or continuous-wiring cable comprises a planar array of parallel spaced flat conductive strips preferably encapsulated in thin dielectric film. The dielectric layers are of materials, thicknesses, number, and configurations to provide a specific predetermined or a range of desired electrical characteristic values. The ground plane layer comprise conductive metal foil, optionally solid or perforated and optionally encapsulated. A flat conductor drain line may be disposed contiguously inward of the ground plane layer. The cable layers are loosely coupled by sewing or other interrupted bonding near the cable edges.



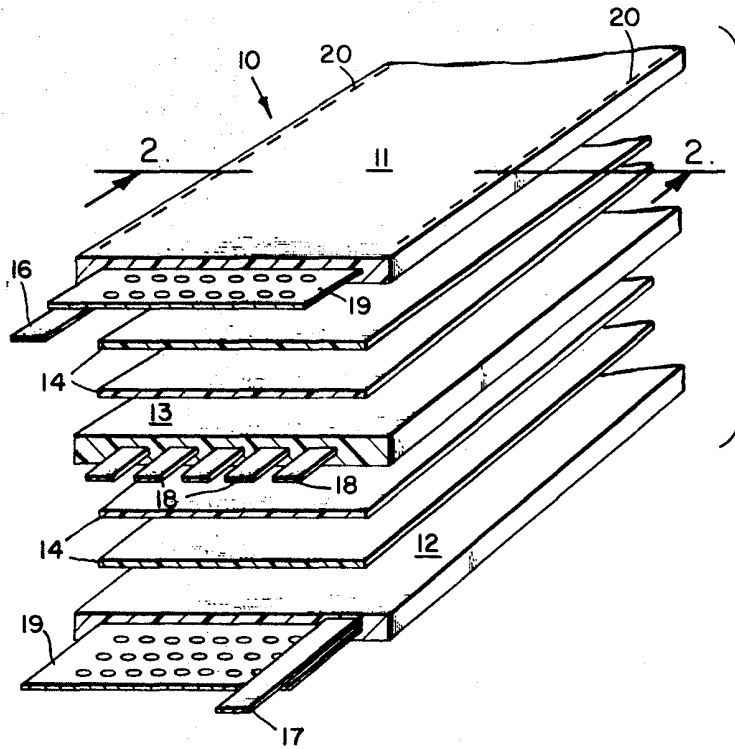


Fig. 1.

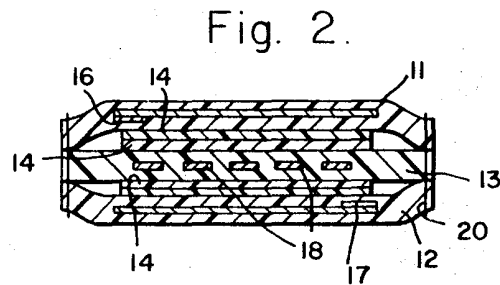


Fig. 2.

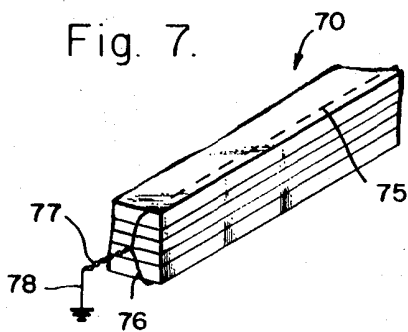


Fig. 7.

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Fig. 3.

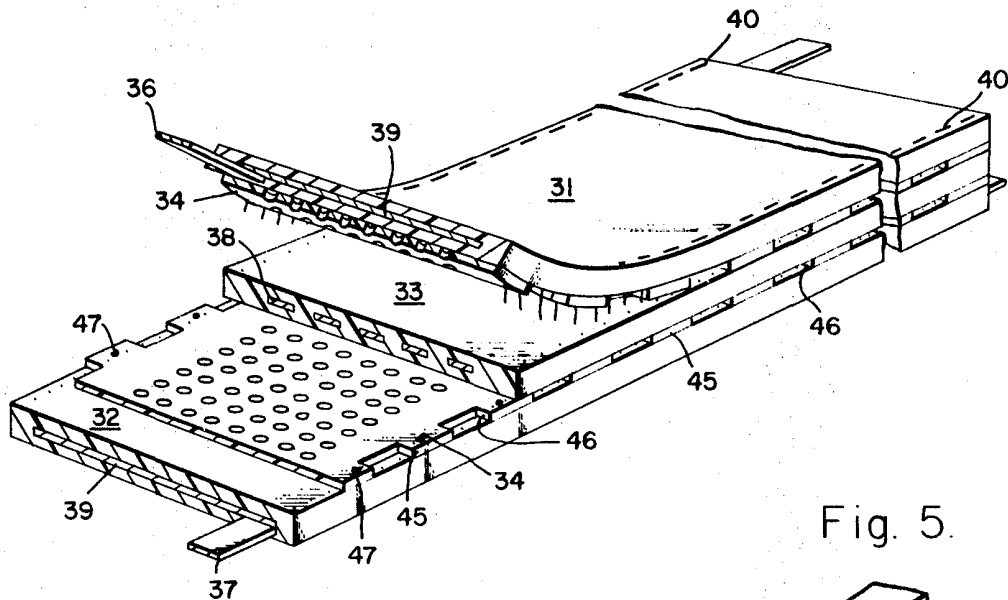


Fig. 5.

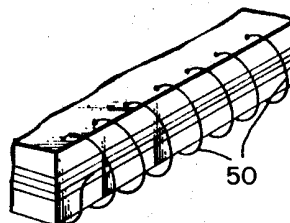


Fig. 4.

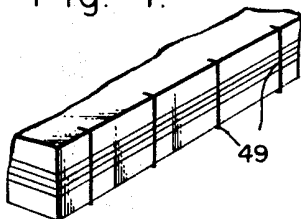
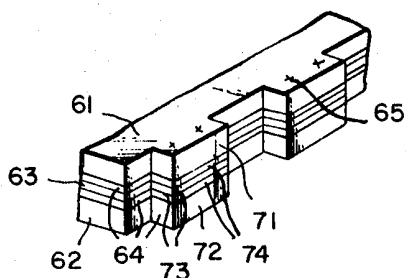


Fig. 6.



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FLEXIBLE FLAT CONDUCTOR CABLE OF VARIABLE ELECTRICAL CHARACTERISTICS

CROSS-REFERENCE TO RELATED APPLICATIONS

This disclosure of the copending application Ser. No. 642,046 of Burton A. Gerpheide, filed May 29, 1967, now U.S. Pat. No. 3,459,879, for FLEXIBLE MULTIFLAT CONDUCTOR CHARACTERISTIC IMPEDANCE CABLE, and assigned to the assignee of the present invention, is incorporated by reference to into the application herein set forth.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improvements in flexible multiple flat conductor electrical cable. More particularly the present invention relates to such improved flexible cable wherein loosely coupled layers of predetermined, material, number, dimensions and configuration are provided and structured so as to enable controllable, uniform, and adjustable capacitance and characteristic impedance and capability of quality fabrication in lengths which may approximate 50 feet or longer and wherein may be provided a drain line for ease of termination.

2. Description of the Prior Art

Prior art cable includes round cable coax, a type of cable having an inner wire conductor surrounded by an insulating material and in turn surrounded by a metal shield and an insulating jacket. The impedance characteristic of such cable is a function of the dielectric distance between the inner and outer conductors or shield and the dielectric constant of the insulator which separates the coaxial pair of conductors. This type of cable has disadvantages. Round wire coax cable is formed of an extruded dielectric. In presently available stock the smallest diameter available is approximately 0.100 inches for 90 ohms characteristic impedance. Round wire coax cable is limited in flexibility such that bending requires a minimum curvature of $\frac{1}{2}$ -inch radius. Upon bending, the inner surface becomes thicker with respect to the outside bent surface which becomes of reduced linear thickness. This causes some bunching of material on the inside and stretching of the material on the outside. The characteristic impedance of a round cable coax is a function of the dielectric distance between the inner and outer conductors and the dielectric constant of the insulator which separates the coaxial pair of conductors. The compression of the inside radius upon bending and stretching of the outside ring radius causes a change in the dielectric distance between signal and ground conductors. This change in dielectric distance results in unequal impedance down the line and therefore causes unwanted reflections of signals being transmitted back toward the source of energy due to the impedance variations. This results not only in loss of energy but often in distortions because of the mixing of signals and reflection back along the path of mixed signals.

Another type of characteristic impedance cable employs a ground conductor opposed to a signal conductor and adjacent alternate opposed ground and signal conductors all embedded in an insulating member having a preselected dielectric constant. An example of this type is described in U.S. Pat. No. 3,179,904 to R. C. Paulsen issued Apr. 20, 1965. In such configurations, the impedance is determined by the spacing between adjacent signal and ground conductors and the spacing between opposed signal and ground conductors. The characteristic impedance also depends upon the relative widths and location precision of the shading ground conductors with respect to the signal conductors. Such configurations have disadvantages of being generally limited to small, e.g., milliamper current levels. To increase current carrying capability to 1-4 ampere current levels, for example, requires relatively very large widths of cable. Additionally, for a given thickness this cable configuration is comparatively rigid and inflexible.

Another prior art construction comprises a series of individual discrete thin substantially coplanar flat metal signal

conductors and a ground conductor shield on either side spaced from the signal conductors. The shields and the coplanar conductors are spaced from one another and embedded in dielectric material. These cables have disadvantages in that the solid bond between the conductors layers and the shield layers causes cable stiffness substantially proportional to the square of the total cable thickness. Even with elastomer adhesive bonding the layers together, upon folding of such cable, delamination and buckling of the cable frequently occurs. The rigidity or cable stiffness of such a configuration is the antithesis of flexibility, a principal advantageous characteristic of flat cable.

Other cable configurations of interest are disclosed in the aforementioned application Ser. No. 642,046 now U.S. Pat. No. 3,459,879 of Gerpheide. The cable provided therein in one embodiment provides alternate configurations of opposing layers wherein the signal conductors are opposed by and are adjacent to the ground conductors. The opposed layers of adjacent signal and ground conductors are each embedded in a dielectric material. The Gerpheide application also discloses an embodiment having a layer comprising a plurality of adjacent signal conductors embedded in dielectric material and having an opposed layer comprising a single flat conductor extending the width of the plurality of signal conductors and which acts as a ground plane. The single wide conductor is also embedded in dielectric material. In the first above-described Gerpheide patented embodiment characteristic impedance is determined by spaced layers of signal and ground conductors wherein within each layer alternate signal conductors and ground conductors are interlaced. The end conductors of each layer are ground conductors. To accomplish this, two adjacent ground conductors at one end are made ground conductors. The conductor layers are opposed so that in one layer the adjacent ground conductors are at one end and in the opposed layer the ground conductors are at the opposite end. This effects registry of the layers such that in each case except at the end a ground conductor is opposite a signal conductor. A shadowing effect is obtained by superimposing a ground conductor over a signal conductor. This is also a good cable structure. However, this configuration requires precision of shading ground conductors with respect to signal conductors, presents registration requirements and its use is limited to lower current levels than in the present invention. This configuration does not provide the means of the present invention for readily varying the impedance characteristic, does not readily provide its ease of manufacture whereby longer characteristic guaranteeable lengths of cable are enabled, does not provide the flexibility and improvement of shadowing of the present invention and does not provide its termination improvements and ease.

SUMMARY OF THE INVENTION

The invention is directed to flexible multiple flat conductor cable formed of loosely coupled contiguous layers comprising outer ground plane layers, a central signal conductor layer having an array of substantially planarly aligned conductor strips, and one or more separate dielectric layers between the signal conductor layer and each ground plane layer. The dielectric layer or layers are interchangeable with other dielectric layers of material, thickness, structural configuration, and number of layers, to provide the desired electrical characteristics in each case in accordance with customer requirements. A conductor strip may be provided contiguous to the ground layer and extends beyond the ground layer ends to enable termination. The loose coupling is afforded by joining the layers of the cable together at intermittent points along the edges, for example, by sewing stitches, spaced adhesive bonding, staples, or a spiral spring. This construction enhances flexibility, presents loose coupling, and enables predetermination and uniformity along the cable length of electrical characteristics. The dielectric layers may be narrower than the distance between the edge bonding, or may

have stepped rectangular tab edges, for example, to facilitate interrupted securing of the layers along the edges.

Individual dielectric, ground plane and/or conductive layers are conveniently insertable, interchangeable and removable to provide from a relatively small stack of types of individual layers, a relatively large family of cables which are predeterminedly tailored to the customer's requirements and which enable ready servicing and design modification.

The present invention overcomes the disadvantages enumerated herein in the previous section and other disadvantages of the prior art devices and affords additional advantages, for example, as set forth hereinbelow. As compared with round wire coax the cable thickness is reduced and may, for example, range from 0.013 inches to 0.040 inches thick. Configurations embodying the present invention may be sharply folded upon themselves with fold curvature radii of less than the cable thickness due to the loose coupling afforded by joining intermittently along the edges and/or central areas. The inventive configuration enables manufacturing with less special design and assembly training skill requirements without reducing end product quality. Necessity for precision in alignment of the shading ground conductors with respect to signal conductors is minimized or eliminated. The current-carrying range of devices incorporating the invention is extended to ampere current loads as well as milliamperes current loads without the relatively large widths of cable required in prior art cable. Along with the advantages provided of avoiding close registry requirements of types such as above enumerated, the present invention provides greater cable flexibility. By providing for incorporation of predetermined thickness, material, number and configuration of dielectric films and/or layers and for adjustability, the values of impedance and capacitance can be predetermined or adjusted readily to desired values. A variety of thicknesses and materials of dielectric layers between the shield and conductor layers may be provided to broaden the scope of the environments into which the cable may be applied. The ground plane or shield layers, the conductive layers and the dielectric layers each can be standardized and assembled from stock to provide a marketable family of characteristic cables. A combination of shield layers, conductor layers and/or dielectric layers of a multitude of different configurations and materials is provided. Positioning tolerances and need for critical registration can be relaxed and scrap can be reduced. Individual layer yields can be increased thus reducing costs. Since a loose coupling technique is employed, there is a lower risk operation and higher acceptable cable yield and assembly costs are lowered. Changes in the design for customer requirements are easier, more quickly implemented and at less cost. The flexibility of cables made in accordance with the invention better enables folding without ground drain or shield buckling, cable delamination or inducing latent or actual shield discontinuities. Inspection is facilitated. Quality assurance is maximized for individual layers and cable assemblies. For example, double-shielded cable minimum lengths can be guaranteed up to 50 feet, an improvement of degree over the prior art maximum guaranteeable length of 10 feet. Cost savings are effected in manufacturing the invention by reducing or avoiding equipment complexity, maintenance and need for surveillance in assembly operations. Employing solid foil for perforated foil shielding optionally provided in the cable of the invention permits an increase in shielding effectiveness of from 80 percent to close to 100 percent and reduces costs by eliminating the perforation operation and allowing use of standardized widths, for example, 1, 2 and 3 inch wide shielding. The requirements of compatibility for fusion bonding or adhesive bonding between shield and conductive layers are minimized or eliminated. Mechanical coupling between layers by a variety of methods and material may be effected so as to provide the most advantageous cable for the needs of the user. For example, metallic wire may be employed and the ends of the wire utilized to enable electrically coupling individual shielded layers separate from a ground drain. The use of separate layers

in the inventive configuration facilitates stripping when preparing to join to terminals of connectors, printed circuit boards, components, or other wire, etc., tooling for terminations is more simple; less skill is required; the separate shield and conductive layers are easier to join to terminals; and potting materials couple more effectively to individual layers with increased bond strength and strain relief. The separate layers enable potting fixtures to cause the potting materials to flow to different levels at each layer to effect a leaf-spring-type effect, reduce the section modulus and distribute the strain over a larger portion of the cable.

Accordingly, an object of the invention is to provide a simple, relatively low cost, flat conductor cable readily fabricatable to predetermined desired capacitance and impedance characteristics, of relatively high flexibility, and which may be provided with an improved termination means.

Another object of the present invention is to provide a flexible multiple flat conductor cable of controllable and uniform characteristic impedance, and which may be fabricated in long lengths wherein uniformity of electrical characteristics is maintained.

Another object of the present invention is to provide a flexible multiple flat conductor cable wherein shield or ground plane, dielectric, and conductor layers may be preformed and stored, and interchangeably combined in various combinations so as to permit ease of design and fabrication of cables of desired electrical characteristics in accordance with predetermined requirements.

Another object of the present invention is to provide electrical cables of predetermined characteristics formed such that they comprise shield, dielectric and/or conductor layers which may be standardized and stocked to yield a family of characteristic cables.

Still another object of the present invention is to provide flexible multiple flat conductor cable formed such as to facilitate manufacturing such that scrap material not up to standard is minimized, positioning tolerances for ground plane conductors and signal conductors can be increased and critical registration relaxed, high yields or usable cable may be produced at assembly, and wherein changes in the design to meet customer requirements readily are enabled.

Yet another object of the present invention is to provide flexible cable which can be easily folded without ground drain or shield buckling, cable delamination or causing latent or actual shield discontinuities; wherein the layers are easier to separate in order to strip, and to join for termination; may be more readily and reliably inspected, verified and certified for quality assurance levels; and wherein there is afforded capability to form the cable with desired mechanical properties and electrical characteristics which may be made uniform over relatively long lengths.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and objects will be apparent by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is an exploded view in perspective, of a first preferred illustrative embodiment of the loosely coupled flexible multiple flat conductor cable of desired predetermined electrical characteristics of the invention showing ground plane outermost layers each having a contiguous termination strip a central conductive layer having a planar array of conductive strips, and dielectric layers disposed between the conductive layer and the ground plane layers and intermittent mechanical jointure means disposed inwardly adjacent the cable edges;

FIG. 2 is a cross-sectional view of the cable of FIG. 1 taken in the direction of the arrows 2—2 but showing the cable in unexploded formed condition;

fig. 3 is a perspective view of a second preferred embodiment of the loosely coupled flexible multiple flat conductor cable of the invention, as in FIG. 1 showing the ground plane

layer and termination strip, central conductive and dielectric layers, and an alternative interrupted-bonding means, with the upper ground plane layer and termination strip and an upper dielectric layer shown separated and turned upward and with portions broken away for clarity, in this exemplified showing, the ground plane layer being solid and the dielectric layer being perforated and having edges which comprise stepped alternate tabs and spaces to provide discontinuity of joinder along the edges;

FIG. 4 is a fragmentary perspective view of another preferred embodiment of the flat cable of the invention illustrating shield or ground plane, dielectric and conductive layers intermittently joined near the edges in loosely coupled arrangement with staples;

FIG. 5 is a fragmentary perspective view of another preferred embodiment of the flat cable of the invention illustrating ground plane, dielectric, and conductive layers intermittently joined near the edges in loosely coupled arrangement by a continuous spiral-wound coil spring edge attachment;

FIG. 6 is a fragmentary perspective view of another embodiment of the cable of the invention illustrating joined ground plane, conductive and dielectric layers wherein the edges of the layers comprise rectangular alternate tabs and spaces in a stepped discontinuous edge arrangement and wherein the rectangular tabs are joined near the edges discontinuously or at intervals along the tabs; and

FIG. 7 is a fragmentary perspective view of another preferred embodiment of the invention illustrating joined ground plane conductive and dielectric layers intermittently joined by metal thread stitches which continue from the edges to form strands which are twisted together to couple the ground plane layers and form termination means.

Refer to FIGS. 1 and 2. There may be provided a cable 10 which may comprise an upper (as illustrated in FIG. 1) ground plane layer 11 and a lower ground plane layer 12, a central conductive layer 13, and one or more, in the illustrated example shown as two, dielectric layers 14 which may be retained between the conductive layer 13 and each of the ground plane layers 11 and 12. The structurally identical layer, for example layer 11 or 12, may be used as a ground plane or common and/or shield layer and therefore these terms will be utilized interchangeably in this application. Contiguous or collated to each of the shield layers 11 and 12 may be provided respective flat conductor drain lines or termination strips 16 and 17. The termination strips 16 and 17 are preferably disposed inwardly near or at and parallel to an edge of the ground plane 11 and an edge of the ground plane 12 respectively. The ground plane layers 11 and 12 are formed either of perforated foil 19 or a solid foil of a conductive material, for example, copper or aluminum, and may be unencapsulated or may further comprise dielectric film encapsulating material. The copper may, for example, be of the type set forth in Federal Specification QQ-C-576. The perforated copper, for example, may have 20 percent maximum openings 0.0005 to 0.0008 inch thick cold-rolled copper. The aluminum may be that known commercially as E.C. or 1100 Series and described in Material Engineering, Materials Selector Issue, A Chapman Rheinhold Publication, vol. 66, No. 5 pg. 116 (1967). The nickel alloy may be permalloy 82-18, an alloy comprising 82 percent nickel and 18 percent iron. The conductive layer 13 may comprise a substantially planar array of parallelly disposed individual strip conductors 18 which extend parallel to one another, at spaced intervals along the length of the cable 10. Conductive strips 18 are formed of conductive material, for example, copper or aluminum, such as for the ground planes. One-ounce copper spaced down to 0.025 pitch or finer can be used, for example. The drain lines 16 and 17 may be of the materials of the conductors 18 and of the same or similar geometrical construction as individual ones of the conductors 18. The ground plane layers 11 and 12 and the conductive layer 13 are shown in a configuration wherein respective ground plane foil members 19 and the conductive strips 18 are

encapsulated or embedded within dielectric film (not numbered). Alternatively, the strips 18 of conductive layer 13 and/or the foil members 19 of common layers 11 and 12 may be not encapsulated, formed, or enclosed in a dielectric film. The dielectric film around the ground plane foil members 19 and around the conductive strips 18 to form layers 11, 12 and 13 are preferably of minimum dielectric thickness. Generally, any dielectric film can be utilized either by itself or in combination with other dielectric films or with air. Examples of suitable dielectrics include those of the following table:

Material	Company	Trademark	Type
polyimide	E. I. duPont de Nemours & Co. Wilmington, Del.	Kapton	H or F
Tetrafluorethylene fluorocarbon resin	E. I. duPont de Nemours & Co. Wilmington, Del.	Teflon	FEP type A or C
Polyester film	E. I. duPont de Nemours & Co. Wilmington, Del.	Mylar	A or C
Epoxy glass	Narmco Division of Whittaker Corp. Newport Beach, Calif.		M-50
Polyvinyl chloride (PVC)	MacIn Co. Los Angeles, Calif.		MF 115

The dielectric separator 14 may be also formed generally of any dielectric film either by itself or in combination with another dielectric film material or with air and may be formed of the materials exemplified above for the encapsulating film. Dielectric layers 14 may be of lesser width than the ground plane layers 11 and 12 or the conductive layer 13. The dielectric layers 14 are made of thickness in accordance with the customer's requirements for electrical and possibly mechanical characteristics, e.g., capacitance and dielectric constant. Dielectric layers 14 may be solid dielectric layers as illustrated in FIG. 1, may be perforated as illustrated in FIG. 3, or may be formed of woven material structure, for example. Localized mechanical coupling at spaced intervals inwardly adjacent to the edges of cable 10 may be provided for example by the sewn stitches 20. The widths of the dielectric layers 14 may be such that layers 14 lie approximately just inwardly of the stitches 20 provided on the sides of the grounding planes 11 and 12 and conductive layers 13. Alternatively, the stitches 20 and the widths of layers 14 may be such that layers 14 are bound within the cable. Stitches 20 may be either continuous or discontinuous. Alternatively, also other types of intermittent bonding can be utilized, for example, as will be described hereinafter. The cable 10 edges may be at intervals stapled, riveted, grommited, bonded by adhesive, staked, or heat sealed in spots. Almost all of the interfacing flat surface of each of the layers is thus disjoined by these means to discontinuously join the layers to present a loosely coupled cable configuration. The sewing thread material where utilized may, for example, comprise polyamide resins such as nylon, metallic thread, and other materials. Particularly where the cable 10 is wide, the layers 11, 12, 13 and 14 may be joined at the center along the cables 10. If desired, for these wider cables for example, fusion or adhesive bonding between the layers 11, 12, 13 and 14 may be provided. Examples of the adhesive bonding material include the following:

Material	Company	Type
Amid-Imid	Westinghouse East Pittsburgh, Penna.	AI 134
Epoxy	Circuit Materials Company, Princeton, N.J.	CMC-14
Polyester	Circuit Materials Company, Princeton, N.J.	CMC-141
Phenolic butyrol	Circuit Materials Company, Princeton, N.J.	CMC-10

In accordance with the invention, an inventory of ground plane layers 11 and 12, and of conductive layers 13 may be separately stored. The ground plane layers 11 and 12 and the conductive layers 13 may be encapsulated or nonencapsulated and may optionally be formed with contiguous drain lines 16 and 17 or the drain lines 16 and 17 may be separately stored. The ground plane layers 11 and 12 may be formed of perforated or of solid conductive metal foil material. The conductive layers 13 may be stored in various strip number, width, length and other configurations. Dielectric layers 14 of various thickness, widths, configurations, lengths, materials or compositions may be stored. For example, the dielectric layers 14 may be woven or may comprise compositions including more than one dielectric.

In accordance with the invention, inserted between the ground plane layer 11 and the conductive layer 13 and between the ground plane layer 12 and the conductive layer 13, are one or more dielectric layers 14 of width, and structure in accordance with the parameters including the dielectric constant and the capacitance and impedance characteristic desired for the cable. The intermittent coupling for example, by stitches 20 rather than fusion together over the entire interfacing surface of the layers 11, 12, 13 and 14 provides for greater flexibility.

For example, as Case I assume the entire cable were made up of a solid array of completely fused together layers the thickness of which is t . The rigidity R is then determined by K , a constant times the square of the total thickness.

On the other hand, where the cable is made as shown in accordance with the invention, of loosely coupled intermittently joined layers then the individual layers may afford a degree of slidability with respect to each other. The cable rigidity R_c is equal to a first constant K_1 times the thickness squared of the first layer, t_1^2 , plus a second constant K_2 times the thickness squared of the second layer, t_2^2 , etc. This may be expressed mathematically as follows:

For Case I—solid cable material:

$$\text{Rigidity} = R = Kt^2.$$

For Case II—loosely coupled separate layers:

$$\text{Rigidity} = R_c = K_1 t_1^2 + K_2 t_2^2 + \dots + K_n t_n^2.$$

$$\text{For simplicity assume: } K_1 = K_2 = \dots = K_n = K_c;$$

$$\text{Then, } R_c = K_c(t_1^2 + t_2^2 + t_3^2 + \dots + t_n^2).$$

$$\text{For simplicity, also assume, } t_1 = t_2 = t_3 = \dots = t_n = t_s;$$

$$\text{Then, } R_c = 5K_c(t_s^2).$$

In the first case where t_c equals solid thickness, then $t_c = t_1 + t_2 + t_3 + \dots + t_n$.

If it is assumed that $t_1 = t_2 = t_3 = \dots = t_n$ and that $K = K_1 = K_2 = K_3 = \dots = K_n = K_c$, then $t_c = 5t_s$;

$$\text{Hence, } R_c = K(t_c)^2 = K(5t_s)^2 = 25Kt_s^2.$$

And the rigidity of Case I compared to Case II is as follows:

$$\frac{\text{Case I}}{\text{Case II}} \approx \frac{R}{R_c} \approx \frac{K(t_c)^2}{K_c(t_s)^2} \approx \frac{K(5t_s)^2}{K5(t_s)^2} \approx \frac{25t_s^2}{5t_s^2} \approx \frac{25}{5} \approx 5$$

In this analysis the rigidity effect of the edge coupling is presumed to be extremely small as will be the case for very wide and very thin cable.

It is thus demonstrated that the loose-coupling configuration of the invention provides several times the flexibility of a solid construction. Additionally, the inventive feature of providing separate readily removable dielectric layers of various thickness, material and configuration provides a cable of variable physical characteristics tailored in accordance with predetermined desired needs.

Refer to FIG. 3. A first outer ground plane layer 31 and a second ground plane layer 32 are provided. Layers 31 and 32 may each comprise a solid foil shield member 39 which may be encapsulated in thin dielectric film. Alternatively a perforated foil shield may be provided. The materials may be the same as that of the corresponding elements 11, 12 and 19 respectively of the FIG. 1 embodiment. Between the shield or ground plane layers 31 and 32 is a conductive layer 33. Con-

ductive layer 33 may comprise an array of aligned parallel conductive strips 38 which may be encapsulated in dielectric material similar to that of the layer 13 of FIG. 1. A first drain lead 36 and a second drain lead 37 are provided. Drain lead 36 may be disposed contiguous to the foil 39 of ground plane layer 31 and may extend beyond the ends. Disposed between one face of the conductive layer 33 and the ground plane layer 31 may be one or more dielectric layers 34. Similarly, between the opposite face of conductive layer 33 and the inner face of ground plane layer 32 are disposed the same number of dielectric layers 34. Dielectric layers 34 are perforated to reduce weight. Alternatively, it will be understood that the dielectric layers may be of solid dielectric material, may be woven or otherwise formed, and may be made of the same material(s) as the dielectric layers 14 of the FIG. 1 embodiment. Considerations of flexibility and dielectric constant variation (air/plastic ratio) are also determined by the construction and material of the dielectric layers 34.

The dielectric layers of the FIG. 3 embodiment may be edged at the sides with alternate rectangular tabs 45 and rectangular grooves 46. This provides discontinuous edges to enable to discontinuous joining of edge material and to thereby provide or enhance flexibility of the cable. Intermittent joiner of the layers 31, 32, 33 and 34 at the side edges may be provided by sewing stitches 40. An adhesive bond 47 may be applied to the tab 45 upper and lower dielectric surfaces. Alternatively of course, the upper and lower edges of the tabs 45 of the dielectric layers 34 may be bonded to the other layers only by the sewing stitches 40 or all the layers may be bonded at the edges (in the case of the dielectric layers, only the tabs 45) by the intermittent-bonding-wheel means described in the aforementioned patent application Ser. No. 642,046, now U.S. Pat. No. 3,459,879.

Refer to FIG. 4. Staples 49 are provided to mechanically join discontinuously the several layers (not numbered) including the ground plane layer, conductive layer and, where or at portions of sufficient width, relative to the other layers, the dielectric layer.

Refer to FIG. 5. A continuous spiral spring 50 is provided for securing the layers along the side edges to form the flexible cable of this embodiment.

Refer to FIG. 6. A plurality of layers comprising ground plane layers 61 and 62, the conductive layer 63, and the dielectric layers 64 are each edged at the sides with alternate rectangular tabs 71, 72, 73 and 74 and rectangular grooves. Discontinuous connection interval bonds 65 may be provided. Alternatively, other discontinuous mechanical jointures of layers may be provided, for example, any of the aforementioned sewing stitches, bonding at intervals, staples, spiral springs, etc. Further alternatively, tabs 71, 72, 73 and 74 may be adhesively secured together or combined intermittent joining and other joining together of the edges of the layers may be provided. That is, loose coupling by any of the above and other means and by combinations thereof may be effected in accordance with the mechanical, thermal, electrical and/or other characteristics desired for the cable.

The materials and configuration of the individual layers of the embodiments of FIGS. 4 and 5 and the materials of the layers of FIG. 6 may, for example, be similar to the materials and configurations of the layers of the embodiments of FIGS. 1 and 2.

Refer to FIG. 7. Ground plane, dielectric and conductive strip layers (not numbered) may be provided of various suitable materials and configurations, for example, those of the embodiments of FIGS. 1-6. Drain line strips such as strips 16 and 17 of the FIG. 1 embodiment are not provided. Threads 75 and 76 are provided to sew the layers (not numbered) together to form the cable 70. Threads 75 and 76 are formed of electrically conductive material, e.g., conductive metal threads. Threads 75 and 76 may be two threads forming one cable side edge jointure means as illustrated or may be both single threads each joining one of the opposite cable side edges. Threads 75 and 76 continue beyond the ends of the

cable layers. Since this extra dangling thread beyond the last stitch remains in conventional sewing, the continuation of threads 75 and 76 beyond the cable layer ends is conveniently effected, and avoids necessity for cutting off the ends of the threads 75 and 76. The ends of the threads 75 and 76 may then be twisted together to form twisted thread pair 77 and the twister pair 77 can be wrapped around or otherwise connected to a termination means 78 which may be provided. Optionally, of course, the top layer threads 75 and bottom layer threads 76 may be left dangling and individually connected to the termination means 78; or thread 75 may be connected to a first termination means and thread 76 connected to a second termination means (not illustrated). The twisted pair of threads 75 and 76 provide interconnection between the ground planes when desired (such as between ground plane conductive foils 19, 39, etc.).

There has been herein described a flexible multiple flat conductor cable which provides the above-set-forth and other objects and advantages and which may comprise a conductor layer comprising an array of aligned parallel flat conductors, a pair of flat ground plane layers extending substantially the width of the array of signal conductors to shadow them, optional means whereby the ground planes may be coupled together to have a common impedance and improve the shadowing of individual signal conductors to substantially double the capacitance and halve the capacitive reactance of the line. The invention enables broad design flexibility. Configurations embodying the invention incorporate the advantageous features of round wire coax cable together with greater mechanical flexibility and space advantages. The term physical characteristics is used herein as comprising electrical, chemical, thermal and mechanical characteristics. The invention provides a device of variable electrical, chemical, thermal, and mechanical desired physical qualities and characteristics. It enables variable cable capacitance. The invention enables readily adding to or ready withdrawal of cable layers and enables different configurations such as woven or perforated such that for example, the dielectric layer may approach characteristics of air to the extent required. A wide variety of dielectric constants, impedance characteristics, and other parameters and characteristics are possible in accordance with the inventive provision for variations in the number and thickness of layers, the type of material, the type of configuration, the composite mixture of these, and the adjustability features. In configurations of the invention perforated or grounded shield planes may be provided. There may be provided contiguous relatively narrow ribbon conductive drain lines to enable convenient termination of the entire shield, for example, to an external printed circuit board merely by terminating the end of the narrow contiguous ribbon conductor in a similar fashion to the termination of the signal conductors. While the illustrative embodiment has described a cable, the inventive principles including loose coupling, removability, interchangeability and variability of layers can be also utilized in etched and nonparallel circuit devices and in other configurations.

While salient features have been illustrated and described with respect to particular embodiments, it should be readily apparent that modifications can be made within the spirit and scope of the invention, and it is therefore not desired to limit the invention to the exact details shown and described.

What is claimed is:

1. An electrical cable comprising:

- a. a first flat layer, said first layer further comprising at least one relatively flat conductive strip,
- b. a second flat layer, said second layer further comprising a first flat conductive ground plane strip,
- c. at least one separate third layer disposed between said first and second layers; said third layer further comprising a dielectric layer of predetermined material composition, thickness and configuration to provide desired physical characteristics, and

d. means loosely and intermittently joining only at localized intervals said first layer and said second layer to retain said separate third layer therebetween to provide a device of predetermined physical characteristics readily assembled from stocked layers such that when the cable is bent there is permitted relative movement of said dielectric layer with respect to said first and second layers to provide increased flexibility while substantially maintaining said predetermined characteristics along substantial lengths of the device.

2. The device of claim 1 wherein:

- a. said first layer further comprises additional flat conductive strips, said flat conductive strips being arranged in an array, and
- b. said ground plane strip further comprises a conductive material foil of at least the width of said array.

3. The device of claim 1 wherein:

- a. in addition to said at least one dielectric layer, said device further comprises additional layers of predetermined total number of layers and composite materials, widths, configurations and compositions to provide desired physical characteristics.

4. An electrical cable comprising:

- a. a first flat layer, said first layer further comprising at least one relatively flat conductive strip,
- b. a second flat layer, said second layer further comprising a first flat conductive ground plane strip,
- c. at least one separate third layer disposed between said first and second layers, said third layer further comprising a dielectric layer of predetermined material composition, thickness and configuration to provide desired physical characteristics,

d. means loosely and intermittently joining only at localized intervals said first layer and said second layer to retain said separate third layer therebetween to provide a device of predetermined physical characteristics readily assembled from stocked layers such that when the cable is bent there is permitted relative movement of said dielectric layer with respect to said first and second layers to provide increased flexibility while substantially maintaining said predetermined characteristics along substantial lengths of the device, and

e. said means intermittently joining said first layer and said second layer further comprises thread formed of conductive metal and said thread extends beyond the ends of said layers and is thereby adaptable to terminate said ground plane layer.

5. The device of claim 4 including:

- a. a second ground plane strip,
- b. said thread further comprising stitches inserted through said first and said second ground plane strips to directly electrically couple said strips.

6. An electrical-signal-carrying device comprising:

- a. a first-type flat layer,
- b. said first-type layer further comprising an array of parallel ribbon-shaped strip conductors,
- c. a pair of second-type flat layers one disposed on one side and the other disposed on the opposite side of said conductive layer, each of said second-type layers further comprising a ribbon-shaped shield member,
- d. at least one separate dielectric material layer of predetermined material, configuration and composition disposed between said first-type layer and each of said second-type layers, and

e. means to loosely couple said first-type, said dielectric material, and said second-type layers together so that individual layers of predetermined material, composition, number and configuration are coupled to provide desired electrical, mechanical, chemical and thermal characteristics.

7. An electrical-signal-carrying device comprising:

- a. a first-type flat layer,
- b. said first-type layer further comprising an array of parallel ribbon-shaped strip conductors,

- c. a pair of second-type flat layers one disposed on one side and the other disposed on the opposite side of said conductive layer, each of said second-type layers further comprising a ribbon-shaped shield member,
 - d. at least one separate dielectric material layer of predetermined material, configuration and composition disposed between said first-type layer and each of said second-type layers,
 - e. means to loosely couple said first-type, said dielectric material, and said second-type layers together so that individual layers of predetermined material, composition, number and configuration are coupled to provide desired electrical, mechanical, chemical and thermal characteristics, and
 - f. said at least one dielectric material layer disposed between said first-type layer and each of said second-type layers is perforated.
8. An electrical-signal-carrying device comprising:
- a. a first-type flat layer;
 - b. said first-type layer further comprising an array of parallel ribbon-shaped strip conductors,
 - c. a pair of second-type flat layers one disposed on one side and the other disposed on the opposite side of said conductive layer, each of said second-type layers further comprising a ribbon-shaped shield member,
 - d. at least one separate dielectric material layer of predetermined material, configuration and composition disposed between said first-type layer and each of said second-type layers,
 - e. means to loosely couple said first-type, said dielectric material, and said second type layers together so that individual layers of predetermined material, composition, number and configuration are coupled to provide desired electrical, mechanical, chemical and thermal characteristics,
 - f. said device further comprises a pair of elongated sides and a pair of short ends,
 - g. said separate dielectric layer is formed with alternate tabs and grooves at the elongated side edges and
 - h. said means to loosely couple are disposed adjacent the elongated side edges so as to join said separate dielectric layer to said first-type and said second-type layers along said tabs to provide almost all of the surface area of said separate dielectric layer with a degree of movability with respect to said first- and second-type layers to enable bending over a wide range of angles to said sides and ends along the surface of said device with flexibility and protection against destruction.
9. The device of claim 6 wherein:
- a. said device further comprises a pair of elongated sides and a pair of short ends,
 - b. said means to loosely couple further comprises first and second means disposed adjacent the respective elongated side edges,
 - c. said dielectric layer is of lesser width than the distance between said first and second means to loosely couple to thereby enable said dielectric layer to be secured in readily removable and insertable relationship.
10. A flexible conductor cable comprising:
- a. a separate first layer, said first layer further comprising a first layer ground plane member,
 - b. a separate second layer having at least one conductor;

- c. a separate third layer, said third layer further comprising at least one dielectric material layer,
 - d. each of said layers being flexible and of predetermined characteristics and having substantially flat surfaces, and
 - e. means discontinuously and loosely joining said first layer, said third layer and said second layer together with said flat surfaces respectively interfacing such that almost all of the interfacing flat surface of each of said layers is disjoined to provide a loosely coupled readily assembled flexible cable of predetermined characteristics and configuration.
11. A flexible conductor cable comprising:
- a. a separate first layer, said first layer further comprising a first layer ground plane member,
 - b. a separate second layer having at least one conductor,
 - c. a separate third layer, said third layer further comprising at least one dielectric material layer,
 - d. a separate fourth layer, said fourth layer further comprising a fourth layer ground plane member,
 - e. a separate fifth layer, said fifth layer, additional to said third layer at least one dielectric material member, also comprising at least one dielectric material layer disposed between said second layer and said fourth layer,
 - f. each of said layers being flexible and of predetermined characteristics and having substantially flat surfaces,
 - g. means discontinuously and loosely joining said first layer, said third layer, said second layer, said fifth layer, and said fourth layer together with said flat surfaces respectively interfacing such that almost all of the interfacing flat surface of each of said layers is disjoined to provide a loosely coupled readily assembled flexible cable of predetermined characteristics and configuration,
 - h. said second layer further comprising a plurality of relatively narrow conductive strips in substantially planar parallel array, said second layer conductor being one of said last-named relatively narrow conductive strips,
 - i. said ground plane members each further comprising a layer of metal foil extending substantially the width of said array of conductive strips,
 - j. said dielectric layers being of thickness, material, and configuration such as to provide predetermined desired electrical capacitance and dielectric constant characteristics of said cable, and
 - k. said first and fourth layers and said dielectric layers disposed on either side of said second layer providing a transmission line having substantially double the capacitance of a transmission line having one ground plane comprising layer, one conductive strip comprising layer and one dielectric material comprising layer.
12. The cable of claim 11 wherein
- a. said ground plane members are perforated.
13. The cable of claim 11 wherein:
- a. said dielectric layers are of discontinuous material configuration.
14. The cable of claim 11, said cable further comprising:
- a. at least one additional dielectric layer, disposed between at least one of said ground-plane-member-comprising layers and said conductive-strips-comprising layer, said dielectric layers forming a composite mix of thickness, configuration, material and composition to provide desired electrical characteristics of said cable.