

[54] **FLAT CONDUCTOR TRANSMISSION CABLE**

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[63] Continuation-in-part of Ser. No. 99,194, Dec. 17, 1970, abandoned.

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[58] Field of Search 174/88 R, 68.5, 117 FF;
339/17 R, 17 E, 17 F, 95 R, 97 R, 97 C;
29/624; 333/84 M

[56] **References Cited**

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3,079,458	2/1963	Hedstrom.....174/117 FF X
3,179,904	4/1965	Paulsen.....174/36 X
3,459,879	8/1969	Gerpheide.....174/36 X
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3,576,723	4/1971	Angele et al.....174/36 X

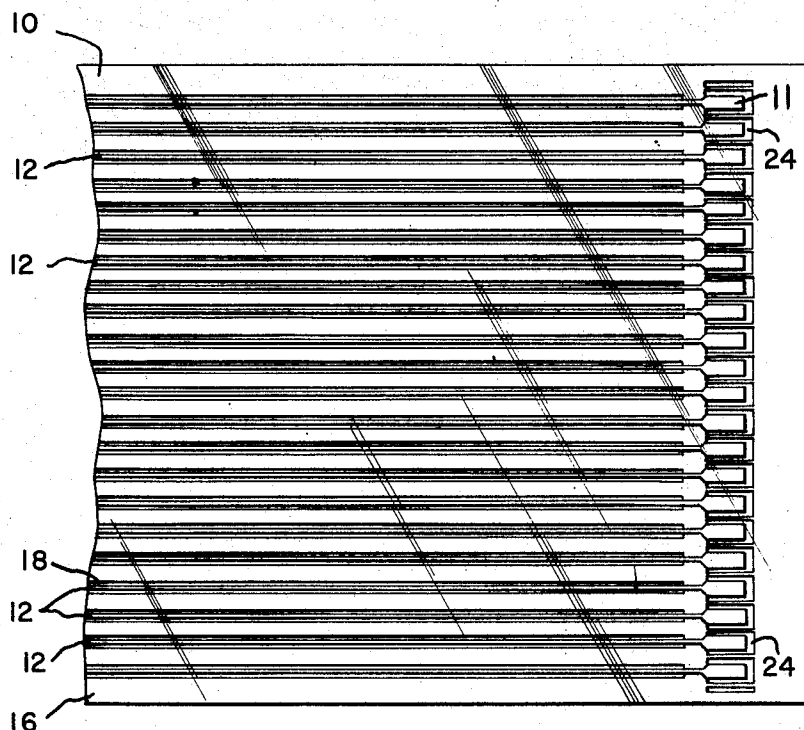
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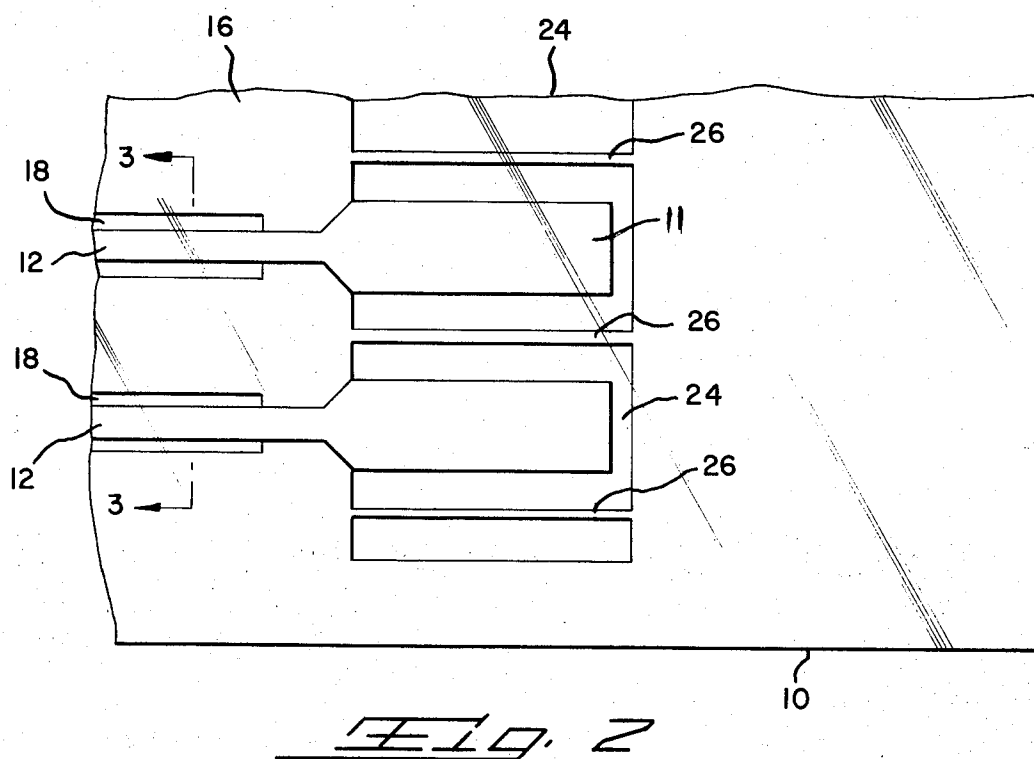
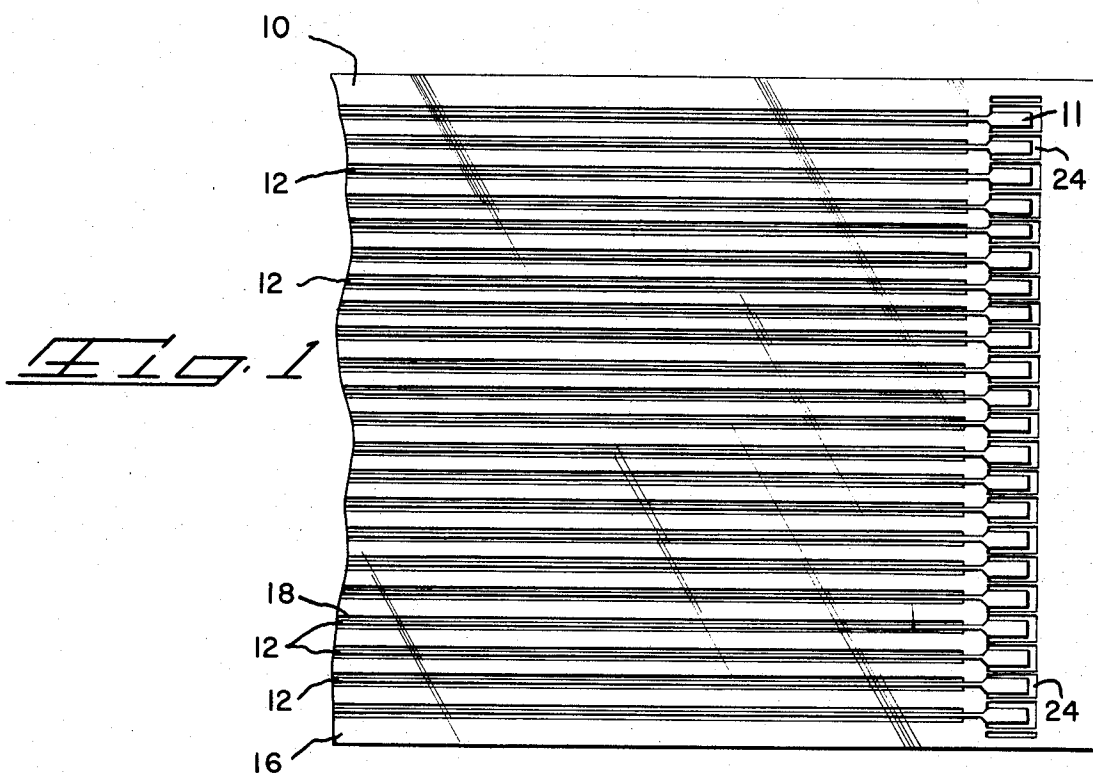
[57] **ABSTRACT**

A flat shielded cable comprising a plurality of parallel spaced-apart signal conductors in a first plane and a shield member in the form of a conductive ground plane facing said signal conductors and being positioned in a second plane, the shield member having preselected amounts of conductive material removed in the area opposite the signal conductors. By varying the amount of shield member surface area facing the signal conductors, the capacitance between the signal conductors and the ground plane can be significantly altered to thereby control the characteristic impedance of the cable.

At the terminating ends of the cable, a zone devoid of conductive material extends transversely across the ground plane in the vicinity of the signal conductors. This zone permits the interconnection of the signal conductors to suitable connector means while preventing electrical contact between the connector contact members, which engage the signal conductors, and the ground plane. To provide impedance matching between the connector and cable ends, the zone is bridged by thin conductive strips integral to the ground plane.

11 Claims, 8 Drawing Figures





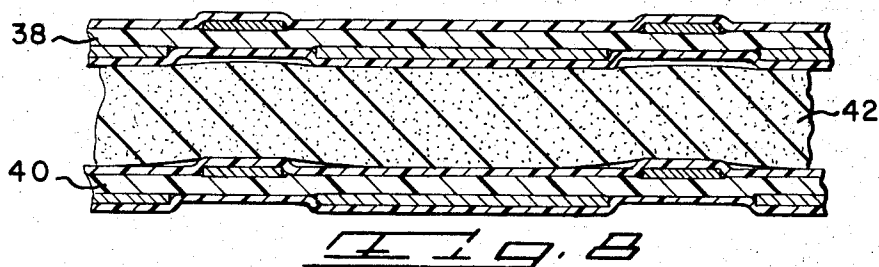
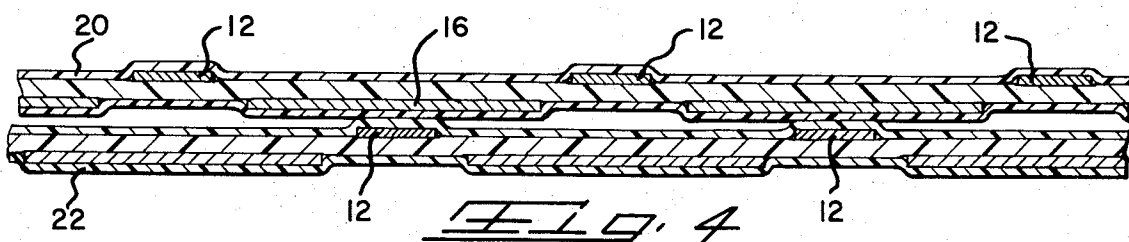
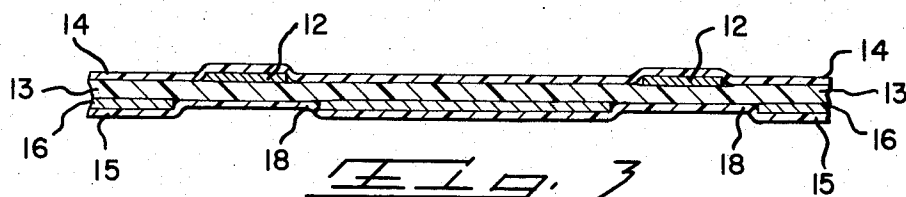
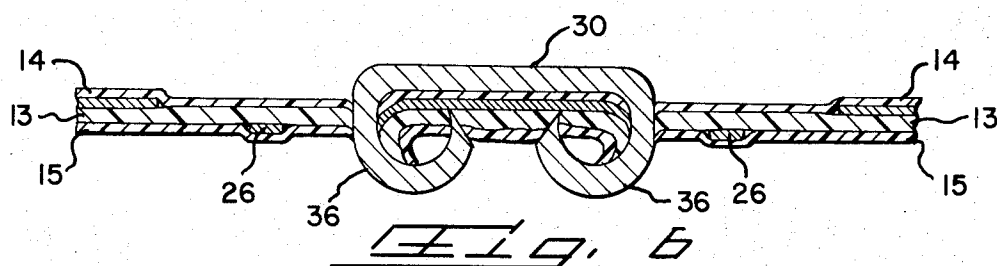
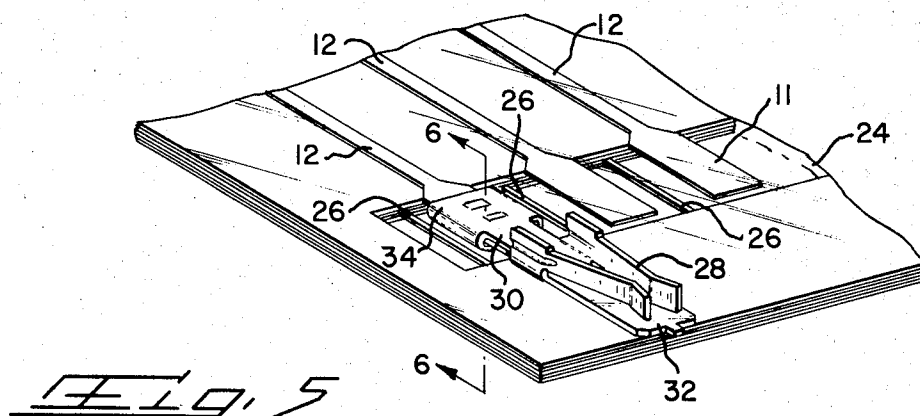
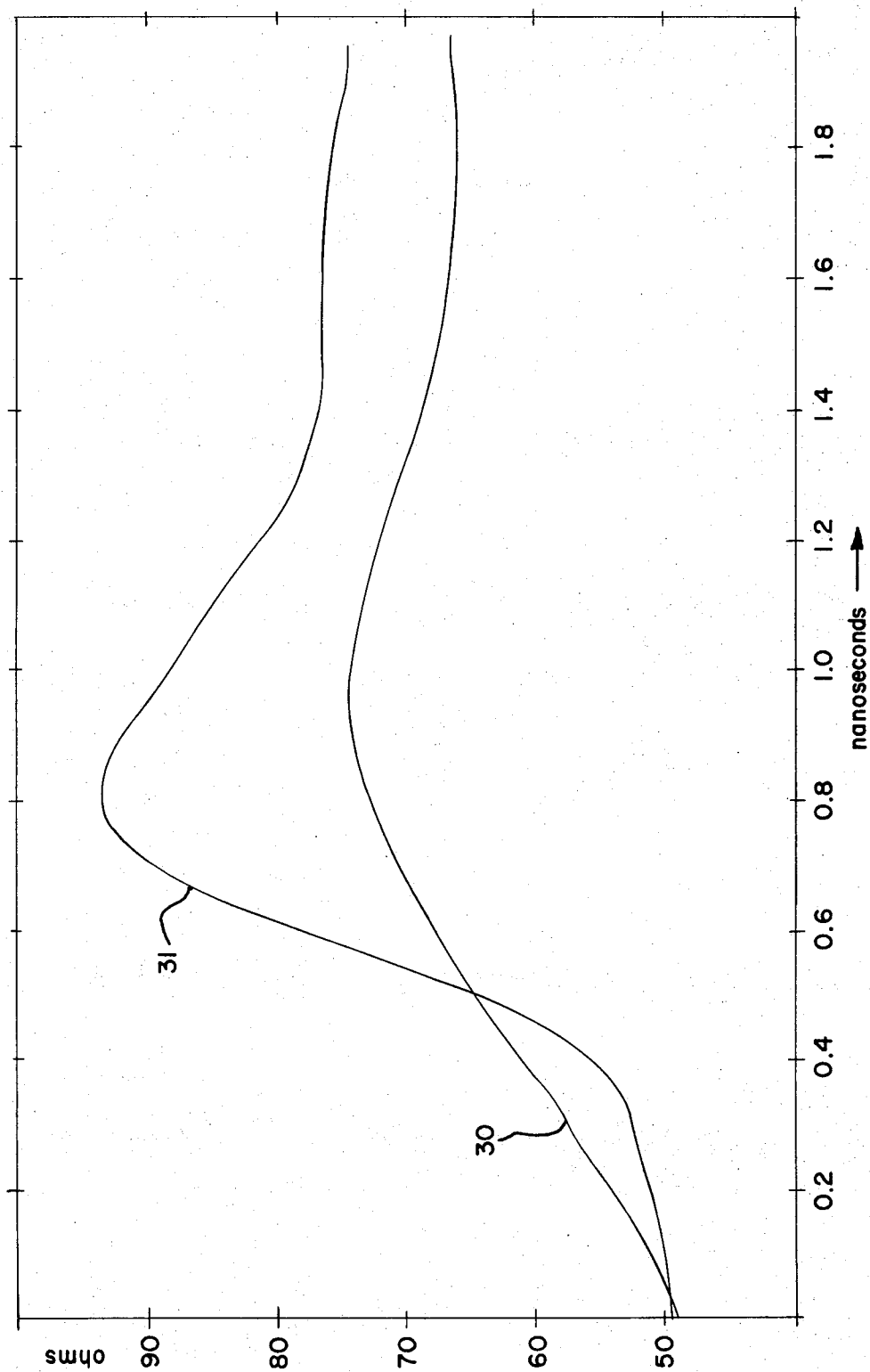


Fig. 7



FLAT CONDUCTOR TRANSMISSION CABLE

REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of Application Serial No. 99,194 filed on Dec. 17, 1970 and entitled Flat Shielded Cable now abandoned.

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to flat multiple conductor cables and more particularly to the controlling of the impedance of such cables.

2. Description of the Prior Art

Various flat multiple conductor cable configurations are known. These can be broadly classified into a first group comprising a plurality of round wires positioned in parallel relationship to each other and embedded in suitable dielectric and a second group comprised of flat ribbon like conductors also positioned in parallel relationship to each other and embedded in dielectric material. Descriptions of these known cable configurations can be found in U.S. Pat. No. 3,179,904 issued Apr. 20, 1965, U.S. Pat. No. 3,462,542 issued Apr. 1969, U.S. Pat. No. 3,459,879 issued Aug. 5, 1969 and U.S. Pat. No. 3,576,723 issued Apr. 27, 1971.

An important consideration in flat cable design is the control of the cable impedance. Prior attempts at providing suitable impedance control of known cable configuration have proved unsuccessful. In one cable design, illustrated in FIG. 3 of the aforementioned U.S. Pat. No. 3,179,904, round wires are laid side by side in an alternating ground and signal conductor configuration. With such a design, cable impedance control is limited to varying the spacing between the conductors and/or varying the dielectric material. When this cable is to possess a 125 ohm impedance, required for many applications, the wires must be made large relative to their spacings. For example, it is common to find such cable, when designed with impedances in the usable range of a 125 ohms or less to possess 0.0125 inch diameter wire on 0.025 inch centers. With such a configuration termination problems exist because of the relatively the small spacings between adjacent conductors. To vary the dielectric material to provide a cable having the 125 ohms or less impedance greatly increases the cost of the cable.

A second configuration, again using round wires for the signal conductors, is illustrated in FIG. 1 of U.S. Pat. No. 3,179,904. In this configuration a series of parallel, adjacent round signal conductors are located in a first plane while a ground plane is positioned in second plane in confronting relation to the signal conductors. Although, from an impedance control point of view this cable design is an improvement over the alternate ground and ground signal conductor configuration previously discussed, control of the impedance to place it in the desired 125 ohms range requires strict control of the spacing between the signal conductors and the ground plane and the dielectric constance of the dielectric. Further, with respect to the termination of such a cable, the ground plane must be peeled back presenting certain obvious manufacturing difficulties.

Still another cable configuration, illustrated for example in FIG. 5 of the aforementioned patent, comprises a plurality of flat ribbon like conductors arranged in parallel in the alternating ground and signal

conductor configuration. Such cables generally possess impedances in the range of 110 to 120 ohms. However, do to the limitations on cable dimensions as a result of constraints put on by the equipment with which the cable is to be used there is no possibility of substantially varying this impedance. Further, even though the impedance may be in the usable range for some applications, shielding effectiveness of the cable is very poor and thus cross talk between cables becomes extremely troublesome. Although the cross talk may be reduced somewhat by off-setting stacked cables as shown in FIG. 5 of U.S. Pat. No. 3,179,904, sufficient cross talk still remains to cause problems.

The configuration of FIG. 3 of U.S. Pat. No. 3,459,879, wherein a plurality of flat ribbon like signal conductors are positioned in a first plane with a ground plane positioned in a second plane in confronting relationship to the signal conductors, presents the problem that the impedance of the cable is reduced to a value so low that it is too low for use with many types of equipment. When these cables are stacked, as is often the case, the signal conductors are sandwiched between two ground planes and thus the impedance can obtain a value of 20 ohms or less which results in excessively high loads on driver circuits. An attempted solution to this low impedance problem has been to decrease the width of the signal conductors. Although this does have the tendency to increase the cable impedance, the increase is often insufficient to meet equipment criteria. Since the width of the signal conductors have been reduced there is also a substantial decrease in the current carrying capacity of the conductors. Further, since the signal conductors are made very fine and/or the dielectric is made relatively thick, bending of the cable often results in fracture of the signal conductors because of the greatly increased circumferential path which the signal conductor takes. Further, thick dielectric results in very stiff cables preventing its use in the certain physical environments.

In flat cables such as those described generally above, termination of the cable often presents a problem. In copending application Ser. No. 57,244 filed July 22, 1970 and assigned to the same assignee as the present application there is described a terminating connector which is inserted through the insulation of a flat cable to contact each signal conductor. A transfer zone on the shield member is devoid of electrically conductive material so that the connector contact may be inserted through the zone and contact the signal conductors without coming into contact with the shield member. A problem with such a termination technique is that the absence of shielding material in the area of the termination often significantly alters the cable impedance at the termination area which results in an intolerable cable/connector impedance mismatch.

SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved flat shielded cable design providing relatively simple control of the cable impedance over a wide range of impedance values.

It is another object of this invention to provide a cable design which permits significant variations in the signal conductor to ground plane capacitance to thereby control the cable impedance.

Still another object of the invention is to provide a technique for compensating for any loss in shielding effectiveness resulting from the capacitance altering technique disclosed.

Still another object of the invention is to provide control of the cable impedance at its terminating ends.

These and other objects are accomplished in accordance with the teachings of this invention by providing a shielded flat cable having a plurality of signal conductors in a parallel, spaced arrangement in a first plane and a conductive shield member in a second plane in confronting relationship with the signal conductors. The shield member or ground plane, as it will be called hereinafter, and the signal conductors are separated by a suitable dielectric. To control the cable impedance, portions of the ground plane facing the signal conductors are removed. Preferably, the deleted sections of the ground plane form thin slots running substantially the length of the signal conductors. This controlled removal of ground plane material decreases the signal conductor to ground plane capacitance to thereby alter the cable impedance. By selectively varying the ratio of the width of the signal conductors to the width of the slots in the ground plane, the cable can be effectively "tuned" over a wide range of impedances.

In a stacked cable configuration, the signal conductors of one cable are placed in confronting relationship to the ground plane of the other cable rather than in confronting relationship to its slots. To further increase isolation between cables they may be spaced a small distance from each with insulation material such as plastic foam filling the space.

The terminating ends of the cable may be formed with a ground plane free zone to accept a terminating connector such as that described in the aforementioned copending patent application. To aid in impedance matching the cable to the connector thin conductive bridging strips may be formed in this zone integral with the ground plane. The conductive strips tend to increase the cable capacitance in the terminating area to compensate for an inductive mismatch.

DESCRIPTION OF THE DRAWINGS

- FIG. 1 is a plan view of the end of a flat cable;
- FIG. 2 is an enlarged plan view of a portion of the cable;
- FIG. 3 is a section along the line 3—3 of FIG. 2;
- FIG. 4 is a cross section of two flat cables offset by one-half pitch;
- FIG. 5 shows a connector terminal in place;
- FIG. 6 is a section along the line 6—6 of FIG. 5;
- FIG. 7 is a time domain reflectometry plot of the impedance characteristics of a cable constructed in accordance with this invention; and
- FIG. 8 is a cross section of a modification of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, the flexible flat conductor cable 10 includes a plurality of spaced-apart ribbon-like signal conductors 12. Each of the conductors 12 terminates in a pad 11.

A ground plane 16, of electrically conductive material lies in a plane parallel to the plane of the spaced-

apart conductors 12. The conductors 12 are separated from ground plane 16 by a dielectric 13 of suitable material such as Mylar (polyethylene terephthalate). The Mylar is transparent and can be seen only in the cross section of FIG. 3. Two cover sheets 14 and 15 of similar material may encase the conductors and dielectric.

In accordance with this invention the ground plane 16 contains slots 18 devoid of electrically conductive material. These narrow slots are opposite each of the signal conductors. By selectively altering the width of these slots, the capacitance between the signal conductors and the ground plane can be changed without requiring a change in the thickness of the dielectric 13 or a change in the dielectric constant of this material.

A cable in accordance with the invention thus comprises signal conductors and shielding conductors, the shielding conductors extending in a plane parallel to the plane of the signal conductors.

To compensate for the slight degradation in shielding effectiveness resulting from the removal of ground plane material, stacked cables are arranged as illustrated in FIG. 4. This Figure illustrates two cables each constructed in accordance with the teachings of the invention. When arranged in the stacked configuration they are displaced with respect to each other so that a portion of the ground plane 16 of cable 20 confronts each signal conductor 12 of cable 22.

Another technique for providing isolation between stacked cables is illustrated in FIG. 8. Cables 38 and 40 are separated by a thin layer of dielectric 42 such as plastic foam. The plastic foam may be for example, polyvinyl foam. Still another technique for further reducing cross talk between stacked cables is to separate the off-set cables 20 and 22, shown in FIG. 4, by a layer of plastic foam as shown in FIG. 8.

It should be noted at this point that not only is the cable impedance effectively controlled over a wide range of values but also cable flexibility is greatly increased. With respect to the control of impedance, Table I illustrates some experimentally determined impedance values for a cable configured in accordance with the teachings of this invention, the cable having 0.020 inch width signal conductors centered over the ground plane slots.

TABLE I

Cable Impedance in Ohms	Width of Ground Plane Slots	Width of Shielding Conductors
50	0.080	0.080
75	0.040	0.060
100	0.060	0.040
125	0.080	0.020

It should further be understood that although the Table I values correspond to the situation when the signal conductors are centered over the slots in the ground plane, registration of the signal conductors over the center of the slots is not critical. Displacing a signal conductor from the center line merely brings it closer to a shielding conductor on one side of the signal conductor and further away from the edge of a shielding

conductor on its opposite side. This has a compensating effect on the cable impedance.

From a mechanical standpoint, not only is cable flexibility increased but since the signal conductors do not overlap the shielding conductors in the ground plane, the dielectric will deform to relieve the strain on the signal conductors when the cable is bent and creased back on itself.

At each end of the cable the ground plane 16 may have a transversely extending zone 24 which is devoid of conductive material. This zone is provided to facilitate coupling of the cable to a connector. The zone extends only partially across the cable to allow for a single contact to carry the ground plane circuit through the connector. The ground plane circuit can be carried through the connector with a single contact connected to a portion 27 of the ground plane situated past the zone. The portion 27 is connected to all of the shielding conductors by a commoning strip 29.

The presence of the zone devoid of conductive material substantially decreases the cable capacitance in this area. The capacitance in this area may become so markedly below that of the main cable body that an intolerable cable to connector impedance mismatch results. It therefore becomes necessary to increase the zone capacitance without preventing use of a terminating connector such as that disclosed in the copending application Ser. No. 57,244.

To this end, the teachings of the invention provide for bridging strips 26 of conductive material on both sides of the terminating pads 11 of the signal conductors 12. These strips have the effect of increasing the zone capacitance to thereby effect a cable to connector impedance match.

The width of each strip 26 is sufficiently small to permit the insertion of a contact 28 which engages the conductors 12 but which does not engage the conductive material of the ground plane 16. (See FIGS. 5 and 6). One or more contacts, (not shown) may also engage the commoning strip 29 to carry the shielding conductors through the connector. When a contact is coupled to each of the shielding conductors a shield member will be positioned between each pair of signal conductors. Such a configuration would be desirable in high frequency applications.

The terminal connector contacts 28 are the subject of the aforementioned copending application and are particularly suitable for use with the cable of the present invention. Such a contact includes an elongated web 30 having a forward end 32, and a rearward end 34. The width of the web is substantially the same as that of the pads 11 which terminate each signal conductor. Sidewalls 36 extend from the longitudinal edges of the rearward end of the web. These sidewalls constitute a crimping means for establishing electrical contact with a conductor 12 of the cable as more fully explained in U.S. Pat. No. 3,389,381- Huffnagle. Specifically, the edges of the sidewalls are forced through the insulation on each side of a conductor and the sidewalls are then formed inwardly and upwardly until they capture the conductor between their edges and the upper edges of the lances.

The distance between the bridging strips 26 is sufficient to permit the insertion of the sidewalls 36 between two adjacent bridging strips without contacting the conductive material of the bridging strips.

That the bridging strips 26 do indeed improve the impedance characteristics of the cable can be seen by referring to FIG. 7. This figure shows a time domain reflectometry plot in which the abscissa is calibrated in time which is directly related to distance along the cable and the ordinate is the reflection coefficient calibrated in ohms. For a description of time domain reflectometry techniques used to produce a plot such as that of FIG. 7, refer to Impedance Matched Printed Circuit Connectors by Homer E. Henschen and Emerson M. Reyner II, a paper presented at NEPCON '70.

The FIG. 7 plot shows the reflection impedance as a function of length along the cable for two different cables. The plot 30 depicts the impedance as a function of length for a cable in which narrow strips of conductive material bridge the transverse zone on both sides of the signal conductor. The plot 31 shows the impedance as a function of length for the same cable but in which there are no bridging conductive strips at the termination. Note that both plots exhibit an increase in impedance at the cable/connector interface situated in the vicinity of the conductor devoid zone located in the area of about 0.8 nanoseconds from the position of the reflectometer. However, in the plot 30 the impedance discontinuity is substantially decreased.

While a particular embodiment of the invention and certain modifications have been described, other modifications may be made. The following claims are, therefore, intended to cover any such modifications within the true spirit and scope of the invention.

What is claimed is:

1. A flat cable comprising:

a plurality of flat parallel spaced-apart signal conductors lying in a single plane

a plurality of parallel flat shield conductors lying in a plane parallel to the single plane of said signal conductors,

said shield conductors extending parallel to said signal conductors and being laterally offset from said signal conductors,

said shield conductors having a width which is no greater than the spacing between said signal conductors whereby edge portions of said shield conductors do not overlap edge positions of said signal conductors, and

insulating material between said conductors and encasing said conductors.

2. A cable as set forth in claim 1, each of said signal conductors having an enlarged contact pad at its end, said pads being adjacent to, and spaced from, one end of said cable, said shield conductors having reduced width portions in the vicinity of said pads, a continuous layer of shielding material at the end of said cable, said reduced width shield conductors extending to said continuous layer.

3. A cable as set forth in claim 2 having electrical contact terminals crimped onto said pads, each of said terminals being between adjacent reduced width portions of said shield conductors.

4. A cable as set forth in claim 3 wherein each of said contact terminals comprises a generally channel crimp portion having a web and sidewalls, said web having a width which is substantially equal to the width of one of said pads, said web being against said cable and said sidewalls extending through said cable in straddling relationship to said pad, said sidewalls being reversely

formed towards each other and towards said web and being in engagement with said pads.

5. A cable as set forth in claim 2 further comprising a commoning strip interconnecting said shield conductors in the vicinity of said reduced width portion.

6. A cable as set forth in claim 1 and a second cable which is identical to said cable, said cables being separated by a layer of plastic foam.

7. A flat cable configuration comprising a first and second cable each constructed as claimed in claim 1, said first and second cables positioned in parallel planes and being spaced from each other and further including insulating material in said space between the cables.

8. The flat cable configuration of claim 7 wherein said insulating material is plastic foam.

9. The flat cable configuration of claim 7 wherein the signal conductors of said first cable are positioned opposite the signal conductors of said second cable.

10. The flat cable configuration of claim 7 wherein the signal conductors of said first cable are positioned opposite said shield conductors of said second cable.

11. A terminated flat cable comprising:

a plurality of parallel spaced-apart signal conductors lying in a single plane,

flat electrically conductive shielding means lying in a plane extending parallel to, and spaced from, said single plane,

insulating material between said signal conductors and said shielding means and encasing said conductors and said shielding means,

a transversely extending zone adjacent to one end of said cable which is devoid of said conductive shielding means, and

bridging strips of said conductive shielding means extending across said zone on both sides of each of said signal conductors.

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