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Reynolds

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[54] **COAXIAL CONNECTOR CONTROLLED CHARACTERISTIC IMPEDANCE PROCESS**

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[73] Assignee: **AMP Incorporated,** Harrisburg, Pa.

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Related U.S. Application Data

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[52] **U.S. Cl.**.....**29/593,** 29/407, 29/630 A, 29/629, 324/57 Z, 29/203 D, 29/601, 73/1 F, 339/276 T, 339/220 T

[51] **Int. Cl.**.....**H02g 15/00,** H01p 11/00

[58] **Field of Search**....29/593, 628, 630 A, 629, 407, 29/600, 601, 203 D, 203 R; 324/57, 62, 64, 63, 60, 59; 73/1 F; 339/276 T, 220 T

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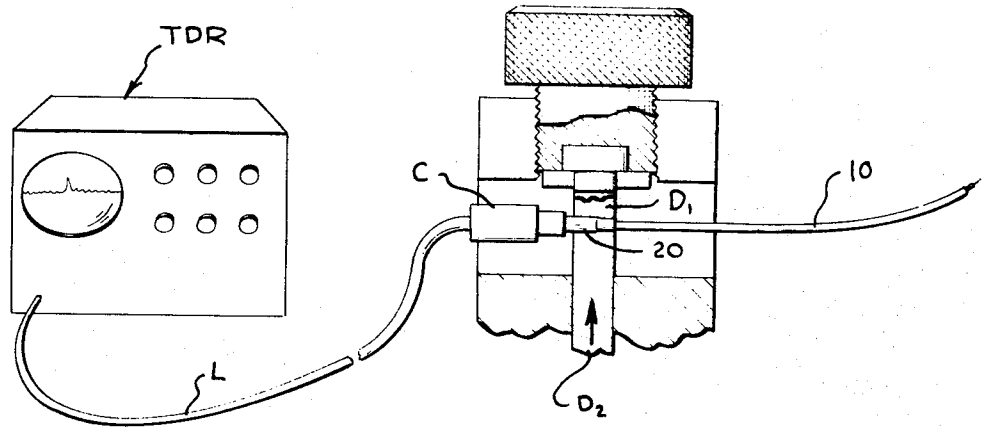
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[57] **ABSTRACT**

A coaxial connector for use with signals haVing components of an appreciable frequency is disclosed which includes a forward connector plug structure having a pair of spring arms shaped relative to an underlying dielectric insert and a center conductor to provide impedance matching. The connector includes a structure which facilitates termination of shielded and coaxial cable and a method is disclosed for controlling the deformation of material of the connector to provide impedance matching relative to a circuit path of use.

5 Claims, 12 Drawing Figures



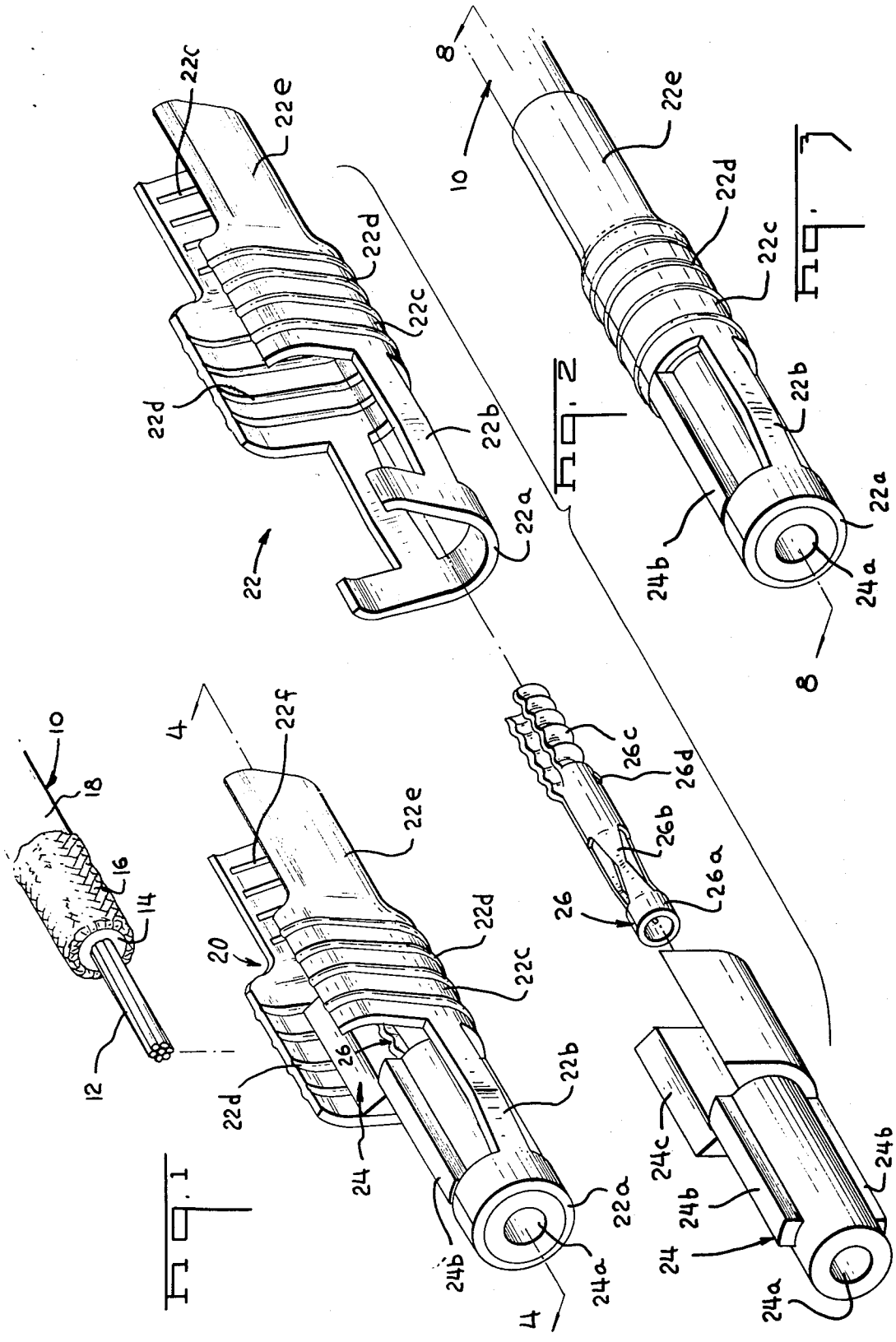


Fig. 1

Fig. 2

Fig. 3

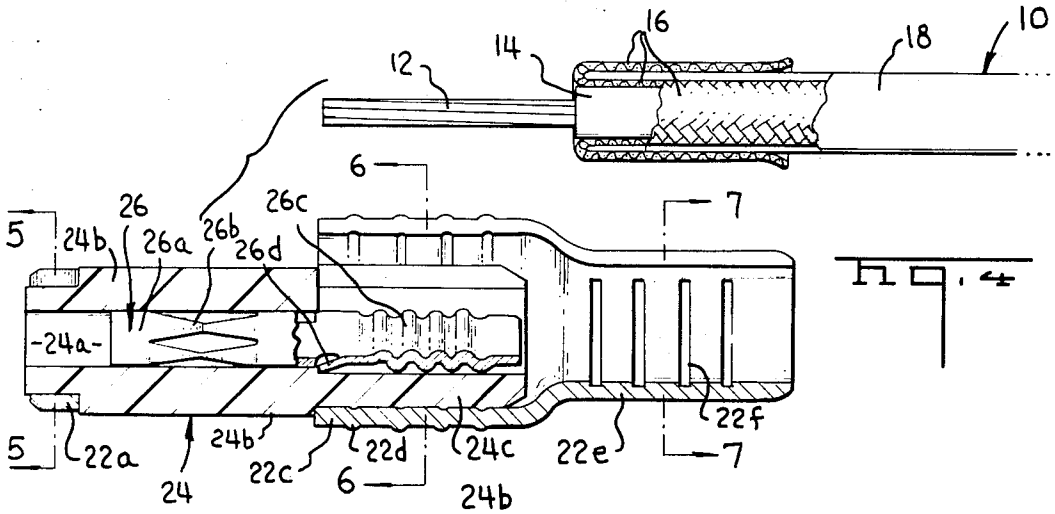


Fig. 4

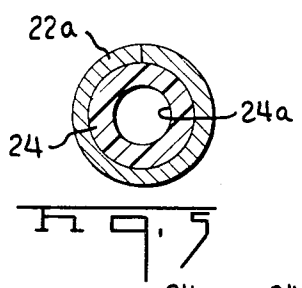


Fig. 5

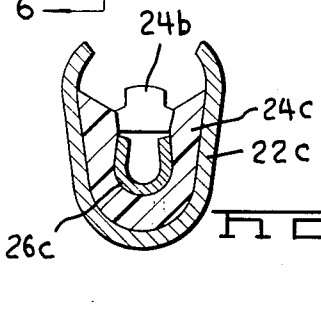


Fig. 6

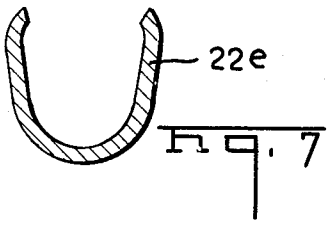


Fig. 7

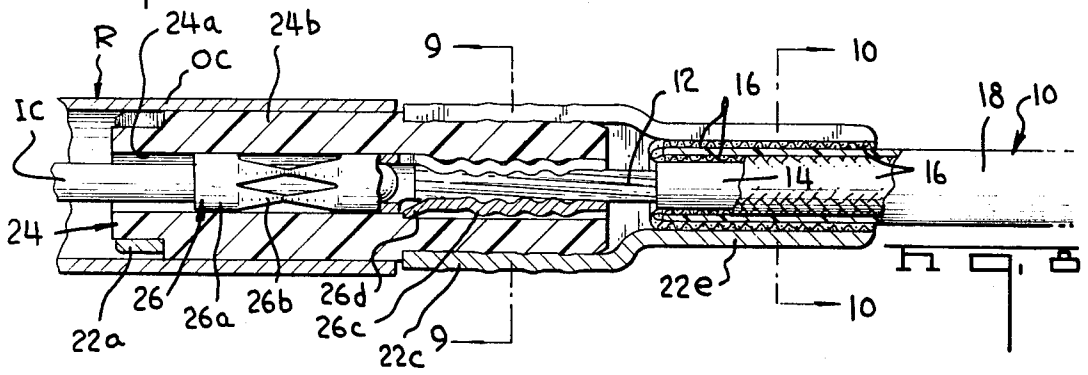


Fig. 8

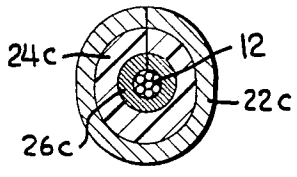


Fig. 9

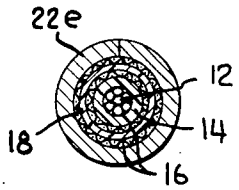


Fig. 10

Fig. 11

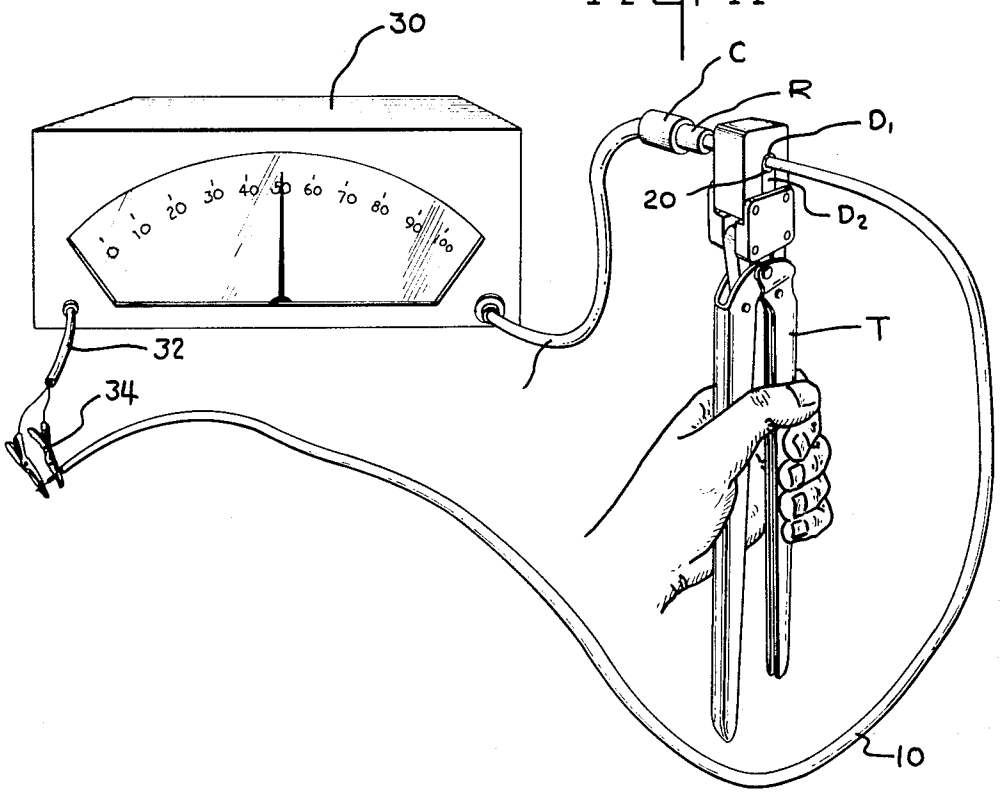
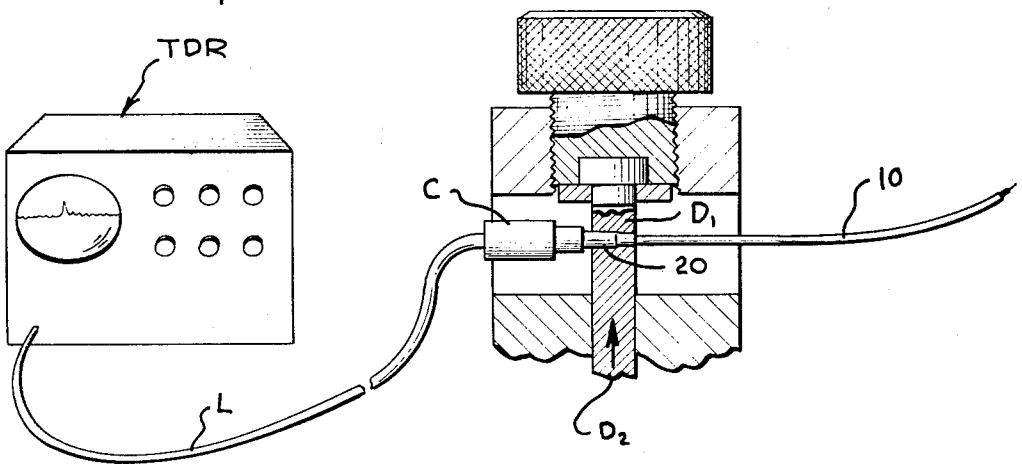


Fig. 12



COAXIAL CONNECTOR CONTROLLED CHARACTERISTIC IMPEDANCE PROCESS

This is a division of U.S. patent Application Ser. No. 698,092 filed Jan. 4, 1968, now U.S. Pat. No. 3539976.

BACKGROUND OF THE INVENTION

In applications calling for the termination of coaxial leads which define circuit paths for signals of an appreciable frequency range such as several hundred megacycles and above, the prior art has generally turned to a precision screw machined structure. The general approach has been one of carefully defining the conductive surfaces of inner and outer conductors by rather heavy and solidly continuous metallic bodies with spring members provided to assure matability and electrical continuity. Viewed in terms of actual mechanical and electrical requirements prior art structures represent an adequate but over-engineered solution to the problem of terminating coaxial cable. Viewed in terms of cost and overall reliability, the use of connectors having a relatively large number of small parts which must be assembled together in a cooperative relationship the prior art approach represents a solution which is somewhat less than optimum from the standpoint of the end user.

As a problem related to the use of crimping techniques to terminate coaxial cable, some considerable difficulties has been experienced in achieving a proper match of the impedance of the connector to that of a given cable and circuit of use. In any connector structure which must be crimped to a coaxial cable there is always the possibility that in deforming portions of the connector to effect a mechanical and electrical termination of the cable, the spacing between inner and outer conductive surfaces of the coaxial path represented by the connector and by portions of the cable within the connector may be so altered as to appreciably affect the characteristic impedance of such path. This is a particular problem with so-called open barrel connectors wherein there is no back-up ferrule against which the outer connector of a cable is driven and supported under crimping forces applied to a surrounding ferrule portion of a connector. With open barrel type connectors there is also a problem caused by the presence of the seam which may or may not be deformed to an extent to present a proper spacing of conductive surface for impedance matching purposes.

SUMMARY OF THE INVENTION

The present invention relates to a connector for coaxial and shielded cable which is capable of providing a matched impedance termination through a structure which is simple to manufacture and simple to terminate and which has fewer parts than heretofore required. The present invention also relates to a method of termination of coaxial devices wherein deformation is controlled in accordance with an actual reading of impedance to assure a properly matched termination of a connector to cable.

It is one object of the present invention to provide a coaxial connector device providing a matched impedance termination of coaxial and shielded cable which can be quickly and easily accomplished. It is a further object to provide a connector device for coaxial and shielded cable wherein impedance matching to a cable of use can be readily determined during termination of the device to a cable. It is yet a further object to provide a stamped and formed coaxial connector capable of use with signals having components of appreciable frequency content. It is another object of the invention to provide a method of application of connector devices to coaxial and shielded cable which yield a termination of improved electrical characteristics. It is yet another object of the invention to provide a connector device of a simple construction having very few parts and capable of providing a matched termination of cable relying upon a mating receptacle structure to complete the configuration necessary for achieving a matched connection.

The foregoing objectives are attained through the present invention by an assembly of elements including a stamped and formed center contact mounted in an insulating and dielectric insert in turn mounted in a stamped and formed outer conductive structure. The inner contact has an open barrel portion which is aligned by the insert relative to the outer conductive portion so that a stripped cable may be laid into the connector device with the outer conductive portion then being deformed inwardly to terminate both the inner and outer conductive portions of a cable in a single stroke by dies simultaneously closed together. The center contact includes a forward spring portion shaped with respect to a particular shaping of the dielectric insert and the forward portion of the outer conductor of the contact to provide impedance match when the connector is inserted with a mating receptacle. As a separate aspect of the invention a method is disclosed relative to the foregoing connector device wherein as the connector is deformed inwardly to terminate the inner and outer conductive portions thereof to inner and outer conductors of the cable, the impedance presented by such deformation is measured with deformation being stopped when a proper impedance is achieved. The connector device of the invention may be utilized with cables of rather widely varying impedance characteristics by controlling such deformation. Alternatively, connector devices made to a loose tolerance can be applied in a manner providing a matched connection.

In the drawings:

FIG. 1 is a perspective view showing a connector device in accordance with a preferred embodiment of the invention just prior to receiving a stripped coaxial and shielded cable;

FIG. 2 is an exploded view of the connector device of the invention shown in FIG. 1;

FIG. 3 is a perspective view of the connector device as terminated to a cable and prepared for use;

FIG. 4 is a side view showing portions of the connector of FIG. 1 and of the cable of FIG. 1 in section;

FIGS. 5, 6 and 7 are cross-sectional views of portions taken through lines 5—5, 6—6 and 7—7 of FIG. 4;

FIG. 8 is a sectional view of a connector like that shown in FIG. 3 as mated with a receptacle;

FIGS. 9 and 10 are cross-sectional views taken through lines 9—9 and 10—10 of FIG. 8;

FIG. 11 is a perspective view illustrating the method aspect of the invention in one embodiment wherein deformation of a connector device to terminate it to a cable is monitored in terms of impedance characteristics; and

FIG. 12 is a schematic view illustrating the invention method in an alternative embodiment.

Referring now to FIG. 1, a coaxial and shielded cable 10 is revealed as including a center conductor 12 which is surrounded by a dielectric sheath 14 and an outer conductor in the form of braid 16. The braid 16 is shown folded back on the cable over an outer protective sheath 18. It is contemplated that cable may be prepared in this fashion as shown in FIG. 1 or alternatively, in a similar manner but without folding the braid back; merely exposing a length of the braid by stripping off the outer protective sheath 18 so that a similar portion of the braid is laid bare. Cable of this type is widely used to interconnect circuit paths where there is a requirement for shielding of signals carried by the center conductor 12 or limiting radiation from the conductor 12 of signals carried thereby to adjacent circuit paths. Cable of this type is also utilized to transmit signals having frequency components resulting in transfer of energy at least in part through the dielectric medium 14 between the conductive surfaces 12 and 16. Cable of the general configuration of 10 may be made to have a specific characteristic impedance such as 50 ohms or, with only a change in the inner conductor and the dielectric material of the sheath 14, to have the characteristic impedance of 75 ohms or some other value. From external appearance the only difference in the cable may appear as a reduction in diameter of the center conductor 12. Cable of the general configuration of 10 may be made to a very close tolerance to provide a characteristic impedance varying no more than ± 1 percent or it may be made to a looser tolerance to provide variation in characteristic impedance of ± 10 percent or the like. The choice between precision cable or loosely toleranced cable is determined by the requirements of the circuit of use and by the cost permitted in a given application.

In FIG. 8 to the left of the view is a receptacle R including a tubular outer conductor OC and an inner conductor IC in the form of a pin member. In accordance with a widely accepted practice, the receptacle R is made to standard specification with respect to the inner diameter of OC and the outer diameter of IC. Considering air as the dielectric medium therebetween, R provides a fixed and standard characteristic impedance such as 50 or 75 ohms. The receptacle may be mounted on or proximate to a circuit of use with characteristic impedance consideration taken into account by the configuration of conductive paths therein or thereto. The general problem to which the present invention relates is one of providing a mechanical and electrical termination or connection extending between the cable 10 and the receptacle R. There is the mechanical consideration of physically joining the connector to the cable in a manner so that electrical continuity of inner and outer conductive paths will be maintained in a constant and stable manner throughout the life of the connection formed. There is the related consideration of providing a signal transmission path which is sufficiently matched to the characteristic impedance of the receptacle and of the cable to preclude the connector device from operating as a source of reflections or in causing signal degradation or signal loss with respect to signals transmitted to or from the receptacle between the circuits connected thereto and the cable of use.

Referring again to FIG. 1, a connector device embodying aspects of the invention and illustrating the invention is shown to be comprised of an assembly of three elements including an outer conductive shell 22, a dielectric and insulating insert 24 and a center contact member 26. The arrangement of elements is such that a stripped and prepared cable may be laid into the device rather than axially inserted. This permits an initial installation of the prepared cable while minimizing alignment problems and the opportunity for displaced strands of 12 or 16 accidentally coming into engagement with conductive portions other than those desired.

The outer conductive shell 22 shown in FIGS. 1–3 is comprised of a one-piece stamping of sheet metal such as brass, the forward contact portion, a center portion and a rear terminating portion. The forward portion is, in FIG. 1, formed into a circular configuration 22a which is slightly less than the inner diameter of the receptacle R into which the device is to be plugged. The portion 22*a* also serves to look the assembly of the center contact member 26 and the insert 24 within shell 22. Extending from 22*a* and approximately 180° apart are spring arms shown as 22*b* which, in a relaxed state, are bowed outwardly as indicated in FIG. 1. The spring arm 22*b* join the sidewalls of the center portion 22*c* at a point thereon so as not to be appreciably displaced upon deformation of portion 22*c* from the configuration shown in FIGS. 1 and 2 to the configuration shown in FIG. 3. The bow of spring arms 22*b* is made to be sufficient to provide a spring action notwithstanding deformation of the portion 22*c* inwardly. Portion 22*c* includes a series of grooves shown as 22*d* on the inner surface of the portion which operate to grip the material of the insert 24 during closure of the portion and tend to stabilize displacement of 24 against axial flow under the compression of the crimp which closes 22*c*. As can be discerned from FIG. 6, the precrimped configuration of portion 22*c* is generally U-shaped with the ends turning in to an extent to prevent the insert 24 from being displaced even slightly in a radial sense with respect to the shell.

Joining portion 22*c* and extending rearwardly is a portion 22*e* which contains a series of relatively sharp grooves therewith shown as 22*f*. FIG. 4 shows the grooves 22f in greater detail. The grooves 22*f* serve the bite into the outer conductor 16 of the cable upon deformation of 22*e* from the configuration shown in FIGS. 1 and 7 to the configuration shown in FIGS. 8 and 10. The grooves also operate to better grip the cable mechanically against pullout.

The dielectric insert 24 includes a central bore 24a which is roughly D-shaped to admit the insertion of the center contact member 26 from the front of the insert. The forward portion of the insert has an outside circular configuration as indicated from FIG. 2. Adjacent the forward portion of 24 are two projections shown as 24*b*, which extend along the length of the insert in the manner depicted in FIG. 2. These projections define an outside surface slightly greater than the diameter of the portion 22*a*, so as to engage the walls of R upon insertion of the device within the receptacle. The portions 22*b* also serve to hold the insert in position within the shell prior to deformation; the forward portions engaging 22*a* and the rearward portions engaging the lower forward surface of 22*c* in the manner indicated in

FIGS. 1 and 4. The portions 22*b* are controlled in width to provide a surface of engagement stabilizing the device as terminated to a cable and inserted within R with the width of these portions being held to a minimum to accomplish this purpose for impedance matching considerations. In other words, the portions 22*b* are held to a width wherein a substantial portion of the dielectric medium surrounding the center contact is comprised of air rather than dielectric material. As shown in FIG. 2 the rear portion of 24, shown as 24*c* is generally U-shaped to provide access of the cable center conductor to the center contact when the center contact is fitted within the insert. FIG. 6 depicts the cross-sectional configuration of 24*c* and shows the beveling of the upper surfaces and the general thickening of the structure for the upper portion thereof which has been found to result in a better control of the deformation of the center contact structure which is made through the dielectric material in accordance with the invention device.

The center contact 26 includes a forward circular portion 26*a* of a size to receive in sliding engagement the inner contact member IC of R as shown in FIG. 8. Adjacent 26*a* and as an integral extension are a plurality of spring arms shown as 26*b* which have an inward bow in a relaxed configuration to provide a spring loaded wipe of the inner contact of R. The spring arm 26*b* are tapered toward the center to control insertion force and to minimize the conductive surface of 26 in the spring region. The rear of 26 shown as 26*c* is open to receive the center conductor 12 of the cable inserted transverse to the length of 26. The portion 26*c* has a corrugated surface which has been found to provide an improved mechanical engagement with the center contact member 12 and thereby to provide a low-resistance stable interface with the conductive surface of the center conductor 12. As an additional point the serrations serve to lock the center contact member following crimping against axial displacement forwardly or rearwardly of the device. The center contact 26 further includes small flange 26*d* struck out at one point from the bottom thereof which serves to position 26 in 24.

In assembly of the device, the center contact 26 is loaded from the front of 24 and pushed back along the bore thereof until it is the position shown in FIG. 4. At this time the outer shell 22 is in the configuration shown in FIG. 2 and the insert is positioned therein with the lower projection 24*b* engaging the lower forward edge of 22*c* as shown in FIG. 4. Next, the forward portion 22*a* is deformed about the insert in the manner indicated in FIG. 1 or in FIGS. 4 and 5 to lock the assembly of elements together for use.

In use the connector devices are made to receive cable prepared like the cable shown in FIG. 1 or prepared without folding the cable back but exposing a portion of the braid 16 followed by a crimping and deformation of the portions 22*c* and 22*e* into the configuration shown in FIGS. 9 and 10. As can be observed from FIG. 10, the conductive surfaces of 22 and 26 are maintained generally concentric. As can be observed from FIG. 9, at least in one embodiment, the cross-sectional configuration of portion 22*c* is not quite concentric being slightly oval or oblong. This configuration leaves opposing outside edges of the forward portion of 22*c* at a greater radius than the radius of the bore of R and this portion engages the end of R upon insertion into R to act as a stop limiting rather precisely the axial position of the device relative to R. From FIG. 8 it will be apparent that cable is laid into the connector so as to leave a substantial space between the end of the braid and the rear end of the insert and center contact member 26. This serves to preclude accidental shorting of the outer conductive path to the inner conductive path.

In an application calling for a termination to a receptacle R of a standard size for 50 ohm impedance use, a connector having a solidly formed outer shell in the forward portion including a spring member was found to provide a mismatch which was unacceptable. In the standard expression for characteristic impedance $Z_0 = 138/\sqrt{e} \log b/A$, the effective dielectric constant e for a solid dielectric insert and the inner diameter *b* of the outer conductive path of the connector were too high. The connector shown in this application matches impedance by providing an effective spacing between inner and outer conductive paths (adjusting *a* and *b*) considering the dielectric material or medium (decreasing e) between conductive surfaces formed of the composite of air and the material of the dielectric insert 24. The effective characteristic impedance in the region of the spring configuration of the center contact member and the spring configuration of the outer shell takes into account the conductive surfaces of OC and the inner conductive surfaces of OC, as defining in part the conductive surfaces "seen" by energy transferred through the connection formed by 20 and R. The selective removal of conductive material and of dielectric material and the arrangement thereof has been found to offer a solution to the problem of providing a spring type coaxial connector mateable with a standard receptacle which is far simpler than devices heretofore known.

Turning now to a further aspect of the invention, FIG. 11 depicts the termination of a connector device like 20 through the use of a hand tool shown as T containing dies driven to effect the deformation heretofore described of portions of the device to terminate it to a cable 10. The tool contains a fixed die D1 and a movable die D2 which are driven together to crimp the portions 22*c* and 22*e*. In accordance with this aspect of the invention a length of cable 10 is laid into the terminal device which is then positioned within the tool. A further connector shown as C which includes a forward receptacle R is then fitted on the forward portion of the connector device to be terminated. The connector C is connected by a coaxial lead L to an impedance bridge 30 for measuring impedance. The bridge 30 includes an output 32 which is terminated to the inner and outer conductors of the cable 10 as by some suitable means shown as alligator clips 34. The bridge includes on the face thereof a scale in ohms and an indicator. In accordance with this aspect of the invention as the dies D1 and D2 are closed the signal injected into 10 is returned to 30 through the inner and outer conductive portions of the cable and of the terminal. As continuity is made with the conductive portions of the cable and the device, the indicator will begin to drop from some high impedance level (open circuit, infinity) down toward a lower level. For example, the indicator will move from full scale down toward 50 ohms. When the

indicator reaches 50 ohms further deformation of the device onto the cable is stopped with the terminated connector device and the cable then being removed from the tool. Experience with the set-up shown in FIG. 11 may show that due to slight spring back of the deformed portions of the center contact member and the outer shell an impedance of precisely 50 ohms can be achieved by deforming the crimp portions until the indicator reads somewhere a little less than 50 ohms with release of the dies resulting in the indicator returning to precisely 50 ohms. An impedance bridge of the type manufactured by Hewlett Packard Company as a VHF Model 803A is commercially available for use with the foregoing method.

FIG. 12 shows an alternative set-up wherein the method of the invention may be employed without connecting the free end of cable **10**. In accordance with the showing in FIG. 12 a time domain reflectometer shown as TDR is made to have an output lead L connected to a connector C into which the device to be terminated is plugged. The connector device is shown as **20**. The cable **10** is laid into the terminal device and deformation follows by closure of dies D1 and D2 with the impedance level being observed on the TDR and deformation continuing until the appropriate impedance level is reached. The approach shown in FIG. 12 utilizes standard apparatus which is commercially available. With lower frequencies care must be taken to make L long enough so that the site of the lumped impedance represented by the termination of **20** to **10** is not too close to the TDR; i.e. so that L is longer than or ¼ wavelength of the lowest frequency employed. A Hewlett Packard Company Model HP1415A Time Domain Reflectometer is commercially available for use with the foregoing method.

The foregoing methods are visualized as having numerous applications for experimentation and for production. As a most important aspect of the method as related to the type of device disclosed, the elements may be manufactured with relatively loose tolerances to reduce the cost thereof and to facilitate assembly with the functional performance thereof being assured by controlling the deformation of portions of the elements to yield the proper impedance. Variations in tolerances or construction of cable can also be accommodated.

In a typical use for a given quantity of connector devices and a given quantity of certain types of cable the application tooling employed, be it hand tool, as depicted or what is more likely, a bench mounted press or the like, the first connector device to be terminated on a given work shift can be installed in the manner shown in FIGS. 11 and 12. Using either circuit a crimp may be made to achieve a desired impedance with the dies of the application tooling being adjusted accordingly to provide the precise control of deformation desired. After the dies have been set connector devices may be terminated to cables with a better assurance that the desired impedance will be achieved. Alternatively, it may be that in certain applications each connector device will be measured in accordance with a circuit arrangement shown in FIGS. 11 or 12 or it may be that the method can be practiced by measuring only every tenth or every hundredth termination.

In an actual embodiment of the invention device for use with 50 ohm cable having a solid silver flash copper center conductor surrounded by sheath of Teflon material and a braided outer conductor. The outer shell was made of sheet stock brass approximately 0.010 of an inch in thickness. The insert was of polyethylene molded to the configuration shown and the center contact was of beryllium copper stamped and formed to the configuration shown out of 0.004 of an inch thick stock. The forward portion of the device of **22*a*** was of an outer diameter of 0.100 of an inch. The spring arms were approximately 0.035 of an inch in width. The dielectric insert measured approximately 0.030 of an inch in the widest dimension across the projections **24*a*** and approximately 0.080 of an inch in outer diameter in the cylindrical portion apart from the projections **24*a***. The device was used with a receptacle having an inner diameter of OC equal to approximately 0.105 of an inch with an inner contact member IC of an outer diameter of approximately 0.040 of an inch. The device was found to operate satisfactorily in a 50 ohm circuit.

Having now disclosed the invention in terms intended to enable a preferred practice thereof, the following claims are set forth to define what is asserted to be inventive.

What is claimed is:

1. In a method of terminating coaxial or shielded cable of the type having an inner conductor surrounded by a dielectric and an outer conductor and wherein such cable has a given characteristic impedance, which comprises the steps of:
   a. placing a stripped and prepared coaxial cable into a stamped and formed U-shaped connector;
   b. commencing to connect said connector to said coaxial cable by crimping said connector onto said cable;
   c. measuring the impedance of said connection during said crimping; and
   d. stopping said crimping when the impedance of said connection matches the given characteristic impedance of said coaxial cable.

2. The method of claim 1 including the step of injecting a signal through the connector in engagement with said cable and measuring the effect upon said signal in terms of the impedance of the circuit formed by said connector and said cable during deformation of said connector portion.

3. The method of claim 1 wherein the step of measuring the impedance of said connection includes the step of injecting a signal into said connector device and the cable to which it is being terminated and measuring the signal components reflected by said termination to determine impedance.

4. The method of terminating coaxial cable to a connector which comprises the steps of:
   a. supplying a stamped and formed electrical connector of the type having a U-shaped outer conductive shell;
   b. laying a coaxial cable of a given impedance and of the type having an inner conductor surrounded by a dielectric and an outer conductor, into said electrical connector;
   c. crimping said electrical connector onto said coaxial cable causing a connection thereinbetween;
   d. measuring the impedance of said connection; and

e. continuing said crimping until the impedance of said connection matches that of said coaxial cable.

5. A method of connecting an electrical connector onto a coaxial cable of a given impedance and having an outer conductor, an inner conductor and a dielectric thereinbetween, which comprises the steps of:

a. providing an electrical connector of the type having a U-shaped outer conductive shell, a center contact member having a opened U-shaped rear portion and a dielectric member positioned between said outer shell and said center member;

b. preparing the coaxial cable whereby a end of the inner conductor is uncovered and a portion of the outer conductor is exposed;

c. positioning said inner conductor of said coaxial cable into said U-shaped rear portion of said center contact member of said connector so that said exposed outer conductor of said coaxial cable is positioned into a portion of said U-shaped outer shell of said connector;

d. causing a connection between said connector and said coaxial cable by crimping said U-shaped rear portion of said center contact member over said inner conductor and by crimping a portion of said U-shaped outer conductive shell over said exposed outer conductor and simultaneously measuring the impedance of said connection; and

e. stopping said crimping when the impedance of the connection matches the impedance of said coaxial cable.

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