Dec. 13, 1966 S. J. SOMERSET 3,292,136

COAXIAL CONNECTOR

Filed Oct. 1, 1964 2 Sheets-Sheet 1

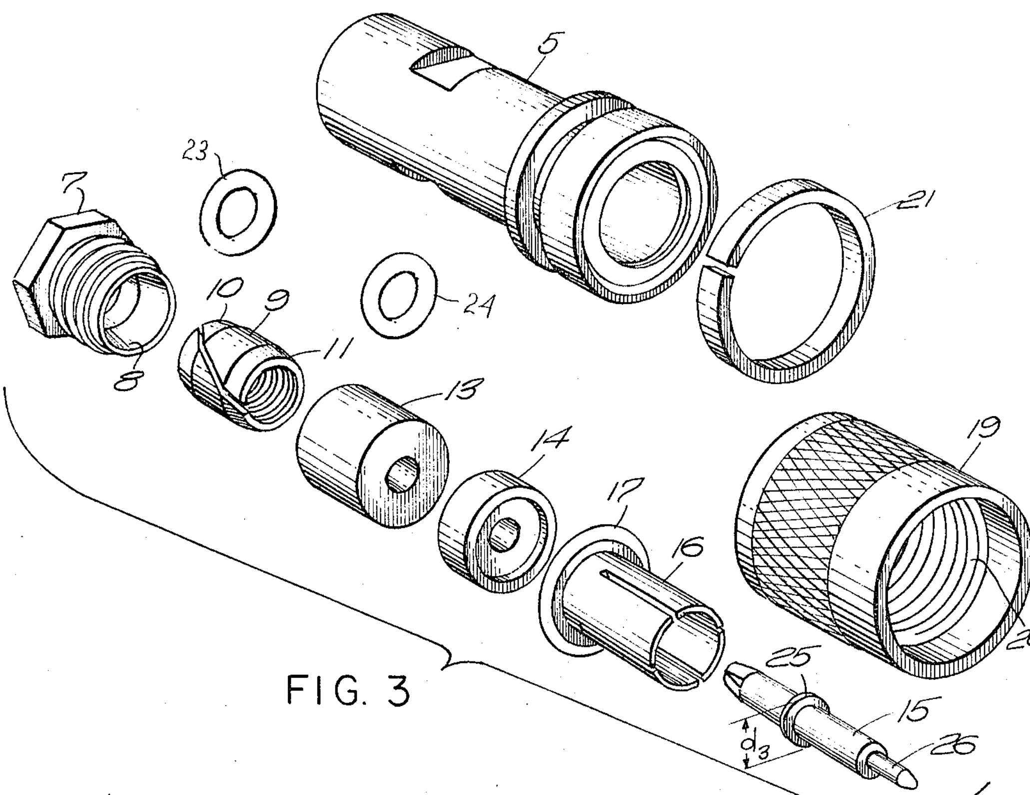

FIG. 3

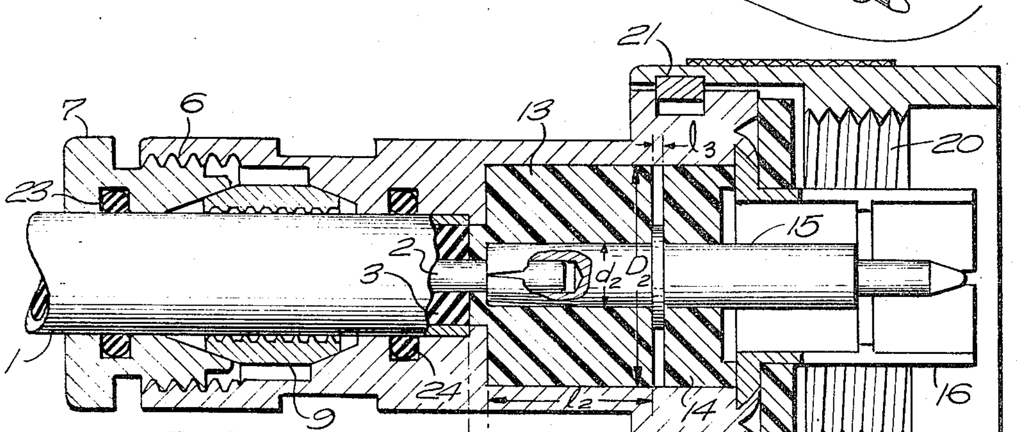

FIG. 4

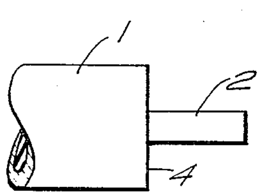

FIG. 1

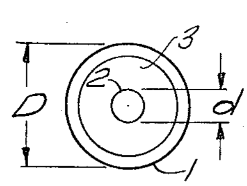

FIG. 2

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COAXIAL CONNECTOR

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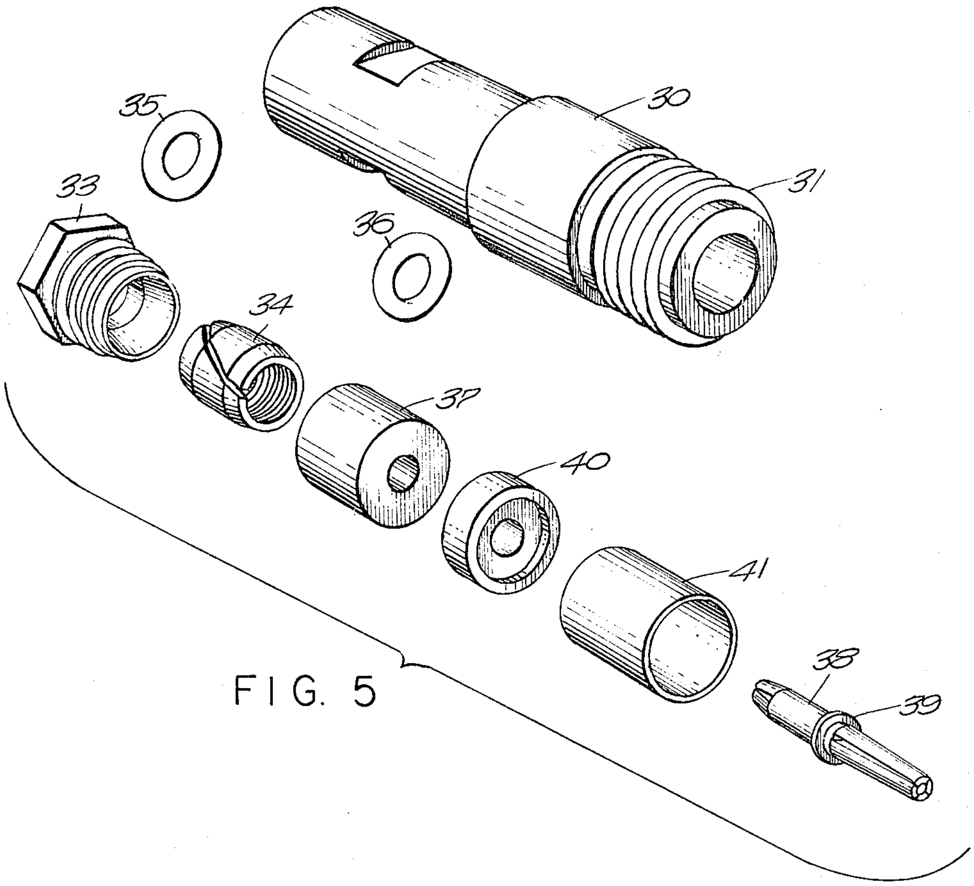

FIG. 5

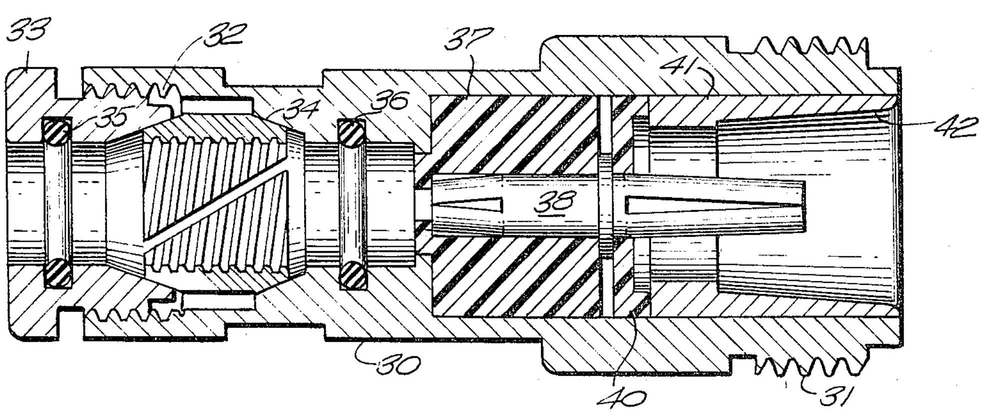

FIG. 6

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COAXIAL CONNECTOR

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This invention relates to connectors for joining together two lines of the coaxial type commonly employed in the transmission of radio frequencies and more particularly pertains to coaxial connectors that are attached to the lines in a manner which eliminates the need for soldering.

In the transmission of electrical wave energy, coaxial cables or lines are customarily employed for the transmission of frequencies extending over a large band of the electromagnetic spectrum. The coaxial lines usually employ a metal jacket or metallic braid as the outer conductor and solid or stranded copper wire is commonly employed as the center conductor. The metal jacket coaxial cable has a tubular metal sheath, usually a copper or aluminum tube, surrounding the center conductor which extends along the longitudinal axis of the tubular sheath. The center conductor of a coaxial cable is maintained in its axial position and is insulated from the outer conductor by a dielectric spacer which can take a variety of forms such as glass or plastic beads, a spiral of plastic material, a foamed plastic, or a solid dielectric filler. A braided coaxial cable, in contrast to a metal-jacketed cable, employs a sleeve of braided wire filaments as the outer conductor and the sleeve is usually protected by a covering insulative coat.

The invention pertains to fittings for coupling coaxial cables together so as to provide a mechanically strong joint while maintaining electrical continuity between the coaxial lines in a manner that substantially reduces impedance discontinuities. Much engineering effort has been expanded in attempts to produce coaxial connectors having optimum electrical continuity and V.S.W.R. (voltage standing wave ratio) characteristics. The coaxial connectors heretofore available have, in the main, failed to approach even moderately closely the theoretically attainable optimum characteristics. This invention provides a coaxial connector constructed so that the characteristic impedance of the coaxial lines is maintained substantially unchanged in the connector.

Convention coaxial connectors, to insure good electrical contact, have the center contact arranged so that the center conductor of the coaxial cable can be soldered to it. To permit the soldering operation to be performed by the purchaser, conventional coaxial connectors are constructed so that the center contact can be removed from the shell of the connector and, after soldering, be reassembled into the connector. In some conventional coaxial connectors even the outer conductor of the cable is soldered to the shell of the connector.

It is an objective of the invention to provide a coaxial connector that can be attached in a simple manner and without soldering to the coaxial line. A connector constructed in accordance with the invention, is attached to the coaxial line simply by baring a length of the line's center conductor, inserting the prepared end of the line into the connector, and tightening a nut on the end of the connector.

The invention, both as to its construction and mode of operation, can be better understood from the following exposition which is intended to be considered in conjunction with the accompanying drawings in which:

FIGS. 1 and 2 depict a coaxial line having its end prepared for attachment to a connector constructed in accordance with the invention;

FIG. 3 is an exploded view of a male connector embodying the invention;

FIG. 4 is a cross-sectional view through the assembled male connector;

FIG. 5 is an exploded view of the invention embodied as a female connector; and

FIG. 6 depicts, in cross-section, the assembled female connector.

Referring now to FIGS. 1 and 2, a metal-jacketed coaxial cable **1** is shown having its center conductor **2** exposed by the removal of the metal jacket and the solid dielectric filler **3**. The end of the cable is dressed to remove any burrs and to insure that the shoulder **4** is a planar surface that is perpendicular to the center conductor **2**. As used herein and as indicated in FIG. 2, the lower case letter d designates the diameter of the center conductor of a coaxial line, whereas the upper case letter D designates the internal diameter of the outer conductor of the coaxial line.

FIG. 3 is an exploded view of the male connector which is depicted in assembled form in FIG. 4. The shell or body of the connector is a hollow metal cylinder 5 having internal threads 6 at one end which are engaged, in FIG. 4, by the cooperating threads of a nut **7**. Nut **7** has a central bore of a size permitting the coaxial line **1** to be passed through the nut into the interior of the connector. The central bore of nut **7** terminates in a flared portion **8** which acts like an inclined plane in forcing a split ring **9** into the shell **5**. Each end of split ring **9** is tapered, as at **10** and **11**, to provide inclined surfaces which coact with the flared portion **8** of nut **7** and a similar flared opening **12** in the shell **5** to cause the ring to be compressed when nut **7** is turned into the connector's body. The ring is split along a helix and is provided with internal teeth which grip the outer conductor of the coaxial line **1** when the ring is compressed. The ring, when not compressed, is sufficiently resilient to permit the coaxial line **1** to be easily passed through it into the body of the connector. Within the body **5** of the connector are cylindrical dielectric members **13** and **14** which are constituted by a material whose dielectric constant, preferably, is the same as the constant of the dielectric material employed in coaxial line **1**. The dielectric members have central bores through which extend a central contactor **15** having one end adapted to receive the center conductor **2** of coaxial line **1** and the other end reduced in diameter.

Disposed concentrically with contactor **15** is an annular metallic element **16** having a barrel in which slots are cut. The slots divide the barrel of the annulus **16** into a plurality of resilient fingers. At one end, the annulus **16** has a flange **17** which abuts a shoulder in the shell **5** of the connector and the annulus is held in the assembly by spinning over a portion of a body **5** to wedge the flange against the shoulder. A washer **18**, preferably of a material such as Teflon, surmounts the periphery of annulus **16** and acts as a seal when the male and female portions of the connector are joined together.

A knurled hollow cylindrical coupling ring **19** is mounted upon the forward end of shell **5**. The coupling ring **19** has internal threads **20** which mate with matching threads on the female portion of the counter shown in FIG. 6. To permit the coupling ring to rotate while preventing its detachment from the body **5** of the male connector, the coupling ring is locked onto the body by a split retaining ring **21** located within a groove **22** in the body **5** and a registering groove in the coupling ring.

When assembling the metal jacketed coaxial line **2** to the male connector of FIG. 4, the coaxial line has its center conductor bared as in FIG. 1. The bared end of the coaxial line is inserted through the central opening in nut **7** until the bared center conductor is within the central contactor 15 and the shoulder of the coaxial line abuts dielectric member 13. The receiving end of the contactor has resilient fingers which grip the bared center conductor to insure good electric contact. The nut 7 is then turned into the body to cause split ring 9 to be compressed by the action of the inclined surfaces. On being compressed, the internal teeth of the split ring grip the metal sheath of the coaxial line so that the line is held tightly within the body of the connector. As the nut 7 advances, it urges the split ring further into the body, which in turn insures that the shoulder of the coaxial line is pressed against the dielectric member 13. The body 5 of the connector is provided with a pair of "flats" which can be gripped by a tool to prevent the body from turning when nut 7 is tightened. A pair of O-ring seals 23 and 24, disposed in grooves within the nut 7 and within the body 5, act, when the coaxial line is insered, to seal the interior of the connector against the entry of moisture and other foreign matter. The O-ring seal 23 also acts to dampen vibrations transmitted along the coaxial cable 1 and thus inhibits the vibrational forces tending to cause nut 7 to loosen.

It is evident from FIG. 4, that the dielectric members 13, 14 and central contactor 15 are locked within the shell 5 of the connector when the flange 17 of annulus 16 is wedged into a fixed position by spinning over a portion of the body 5. Once the connector has been assembled, its construction precludes soldering the center conductor 2 of the coaxial cable to the contactor. It is essential, therefore, when attaching the connector to the coaxial cable to insure that good electrical contact is established between the central contactor and the cable's center conductor as well as between the metal jacket and the shell of the connector. To insure good electrical contact between the center conductor and contactor 15, the contactor is preferably constructed by beryllium copper and its fingers are bent inwardly so that when the center conductor is inserted into the contactor, the fingers are forced outwardly and grip the surface of the center conductor. Good electrical contact with the cable's metal jacket is insured by the teeth of split ring 9 which, when the ring is compressed, penetrate through any oxide which may have formed upon the surface of the metal jacket and grip the jacket so that the cable is locked into the connector.

The characteristic impedance of a coaxial line is given approximately by the equation:

$$Z=\frac{138}{\epsilon}\log_{10}\frac{D}{d}$$

where

Z is the characteristic impedance,
ϵ is the dielectric constant of the medium in the line,
D is the internal diameter of the outer conductor, and
d is the diameter of the inner conductor.

When two identical coaxial lines are connected together, changes in the characteristic impedance at the connector give rise to reflections of the wave energy propagating along the lines, the amount of reflected energy being a function of the mismatch. The voltage standing wave ratio (VSWR) is, therefore, a measure of the impedance discontinuity existing at the connector. In the ideal connector, the transition from one coaxial line to the other would be electrically smooth, that is, the ideal connector would not introduce any impedance discontinuities.

It can be deduced from the equation for the characteristic impedance of a coaxial line,

$$Z=\frac{138}{\epsilon}\log_{10}\frac{D}{d}$$

that changes in the diameter of the inner conductor d can be offset by changing the internal diameter D of the outer conductor to maintain the characteristic impedance at a constant value. This deduction is used to advantage in the connector to prevent an impedance discontinuity where the coaxial line 1 is joined to the connector.

In the assemblage shown in FIG. 4, the metallic body 5 and the annulus 16 function as extensions of the outer conductor of coaxial line 1 whereas the central contactor 15 acts as an extension of the center conductor 2. Dielectric members 13 and 14 are preferably of the same material employed for the medium in coaxial line 1; other materials, however, may be used where their dielectric constants are substantially the same as the constant of the dielectric in the coaxial line.

The dielectric member 13 is reduced in diameter for a length l_1 at the end abutted by coaxial line 1. The distance l_1 is the length of the bared center conductor 2 that is not received within central contactor 15. For the distance l_1, the internal diameter D of body 5, the dielectric constant ϵ, and the diameter d of the center conductor are identical with those of coaxial line 1. The central contactor, for the length l_2, has a diameter d_2 that is larger than the diameter of center conductor 2. To maintain a constant characteristic impedance, the inner diameter D_2 of body 5 is increased to compensate for the increased value of d_2.

The capacitance of a coaxial line is given in micromicrofarads per inch ($\mu\mu$f./inch) by the equation

$$C=\frac{.612\epsilon}{\log_{10}\frac{D}{d}}$$

where

C is the capacity per unit length,
ϵ is the dielectric constant of the transmission medium in the line,
D is the internal diameter of the outer conductor,
d is the diameter of the inner conductor.

Where a coaxial line of one size is joined to a coaxial line of a different size, a mismatch occurs at the junction though the constant ϵ and the ratio D/d, is the same in both lines, unless compensation is made for the increase in capacitance due to fringing effects of the sharp corners of the transition. Such a transition occurs where the coaxial line of length l_1 joins the coaxial line of length l_2. The gaps between the resilient fingers of central contactor 15 serve to decrease the capacity at that transition and, therefore, are effective in offsetting the capacity due to fringing effects. It has also been found helpful to provide a slight champfer on the inside edge at the tips of the contactors fingers to provide additional compensation. Other techniques, such as shaping the contactor to obtain additional inductance at the transition may be used, if desired, to obtain the requisite compensation.

The central contactor is provided with a flange 25 that is clamped between dielectric members 13 and 14 so that the contactor cannot move axially. The gap between dielectric members 13 and 14 causes a change in the value of the dielectric constant ϵ as that gap is filled with air. To maintain the characteristic impedance unchanged, the diameter d_3 of the flange is such that it offsets the change in ϵ caused by the air dielectric in the gap. It has been determined empirically that the length l_3 of the flange 25 should be made as small as possible as a better impedance match is obtained when the gap between dielectric members 13 and 14 is reduced to a length that is insignificant compared to a wave length of the highest frequency for which the connector is intended. As the flange 25 holds the central contactor against axial displacement, it must provide sufficient mechanical strength to perform its function adequately. The flange must not be made so thin that the central contactor will be sheared off by axial thrust. Using a central contactor of beryllium copper, a flange having a length l_3 of .020" has been found to be satisfactory for a connector intended for use in the X-band of frequencies.

The mate to the male connector of FIG. 4 is depicted in FIGS. 5 and 6. The body **30** of the female connector is a hollow metallic cylinder having external threads **31** at its front which are engaged by the mating threads of the coupling ring on the male connector when the two units are united. The rear part of body **30** has internal threads **32** that are engaged by cooperating threads on a nut **33**. The nut **33**, split ring **34**, O-ring seals **35**, **36**, and dielectric member **37** are identical in shape, arrangement and function to their matching parts in the male connector.

The central contactor **38** of the female connector is prevented from being displaced axially within the body **30** of the connector because the flange **39** of the contactor is locked between dielectric members **37** and **40**. As in the male connector, the flange of the central contactor in the female connector is of such diameter that it maintains the characteristic impedance at a constant value by compensating for the dielectric members. The dielectric members, in turn, are secured within the body **30** by a metallic liner **41** that is pressed into or otherwise secured to the front portion of the connector's body. The liner is a hollow cylinder having a frusto-conical inner surface **42** terminating in a central cylindrical cavity.

The front part of the contactor **38** is similar to its rear portion as both ends of the contactor are hollow cylinders that have slotted to form resilient fingers. The rear portion of contactor **38** secures the center conductor of a coaxial line having its center conductor bared as in FIG. 1.

When the male and female connectors are joined together, the reduced diameter portion **26** of contactor **15** is secured within and gripped by the front part of contactor **38** and the barrel of annulus **16** slides along frusto-conical surface **42**. As the barrel of annulus **16** moves into the liner, the resilient fingers of the barrel are compressed, thereby insuring good electrical contact between the barrel of annulus **16** and the liner. Ideally, the front edge of annulus **16** should abut the shoulder within liner **42**, when the connectors are tightly locked together, so that the abutting annulus presents the same internal diameter as the central cylindrical bore of the liner.

In the mated male and female connectors, the contactors **15** and **38** act as the center conductor of an air filled coaxial line having the lining **41** and the annulus **16** as its center conductor. To maintain a constant value for the characteristic impedance throughout the connectors, the values of d and D are adjusted in relation to ϵ so that Z does not change. For example, if the characteristic impedance of the metal-jacketed coaxial line of FIG. 1 is 50 ohms, that 50 ohm characteristic impedance is maintained throughout the male and female connectors even though the transmission medium in the connectors changes from a solid dielectric, such as Teflon, to air and back to solid dielectric.

While only a preferred embodiment of the invention has been illustrated and described in this exposition, it should be understood that changes which do not depart from the essence of the invention can be made and, indeed are apparent to those skilled in the art of electrical connectors. It is intended, therefore, that the invention not be limited to the precise device depicted in the drawings, but rather that the scope of the invention be construed in accordance with the appended claims.

What is claimed is:

1. An electrical connector for attachement to a coaxial cable, the connector comprising:

(1) a cylindrical conductive shell having internal threads at one end, the shell having an internal flared opening intermediate its ends,

(2) an elongate contactor having resilient fingers at one end arranged to surmount and grasp the center conductor of the coaxial cable, the elongate contactor being within the shell and extending along the shell's longitudinal axis,

(3) dielectric means insulating the contactor from the shell and securing the contactor in its axial position within the shell,

(4) a nut having an externally threaded portion adapted to engage the internal threads of the shell, the nut having a central aperture for permitting the coaxial cable to extend therethrough into the interior of the shell, the central aperture of the nut terminating in a flared opening,

(5) a split ring adapted to surround a portion of the coaxial cable, the ring being split for its entire length along a spiral path, the split ring being disposable in the shell to extend between the nut and the shell's internal flared opening, and the split ring having tapering end portions that are urged against the flared openings in the shell and the nut when the nut is advanced into the shell whereby the entire split ring is compressed.

2. An electrical connector for attachment to a coaxial cable, the connector comprising:

(1) a cylindrical conductive shell having an internal flared opening intermediate its ends;

(2) an elongate contractor having resilient fingers at one end arranged to surmount and grasp the center conductor of the coaxial cable, the elongate contactor being within the shell and extending along the shell's longitudinal axis,

(3) a dielectric member having two concentric cylindrical portions of different diameters, the cylindrical portion of larger diameter having a central aperture in which the resilient end portion of the contactor is disposed, the smaller diameter cylindrical portion having a central bore permitting the center conductor of the coaxial cable to extend into the fingers of the contactor, the two concentric cylindrical portions of the dielectric member being disposed within the shell,

(4) means securing the dielectric member and the contactor in fixed positions within the shell,

(5) a nut having a central aperture for permitting the coaxial cable to extend therethrough into the interior of the shell, the central aperture of the nut terminating in a flared opening, the nut being mounted at one end of the shell and having threads cooperating with mating threads on the shell, and

(6) a ring adapted to surround a portion of the coaxial line, the ring being split for its entire length along a helical path, the split ring being disposable in the shell between the nut and shell's internal flared openings and the split ring having tapering end portions that are urged against the flared openings when the nut is advanced whereby the entire split ring is compressed.

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