Sept. 28, 1965 E. S. OXNER ET AL 3,209,287

ELECTRICAL COAXIAL CABLE CONNECTING ASSEMBLY WITH IMPEDANCE MATCHING

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FIG. 2

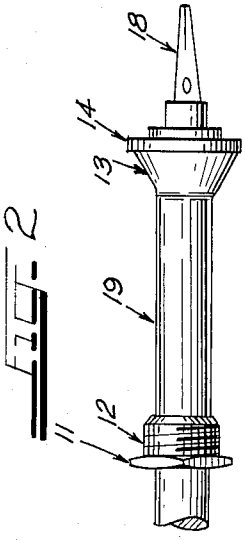


FIG. 3

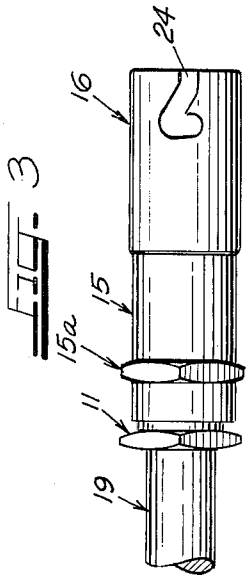


FIG. 4

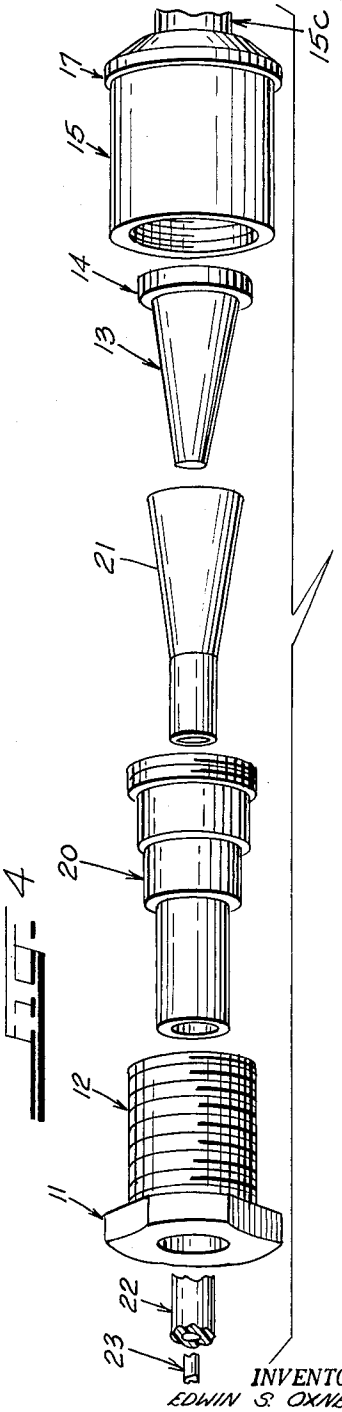
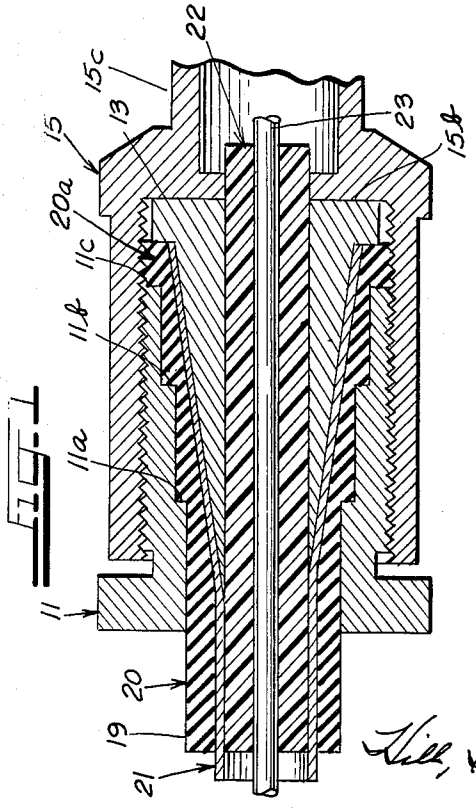


FIG. 1



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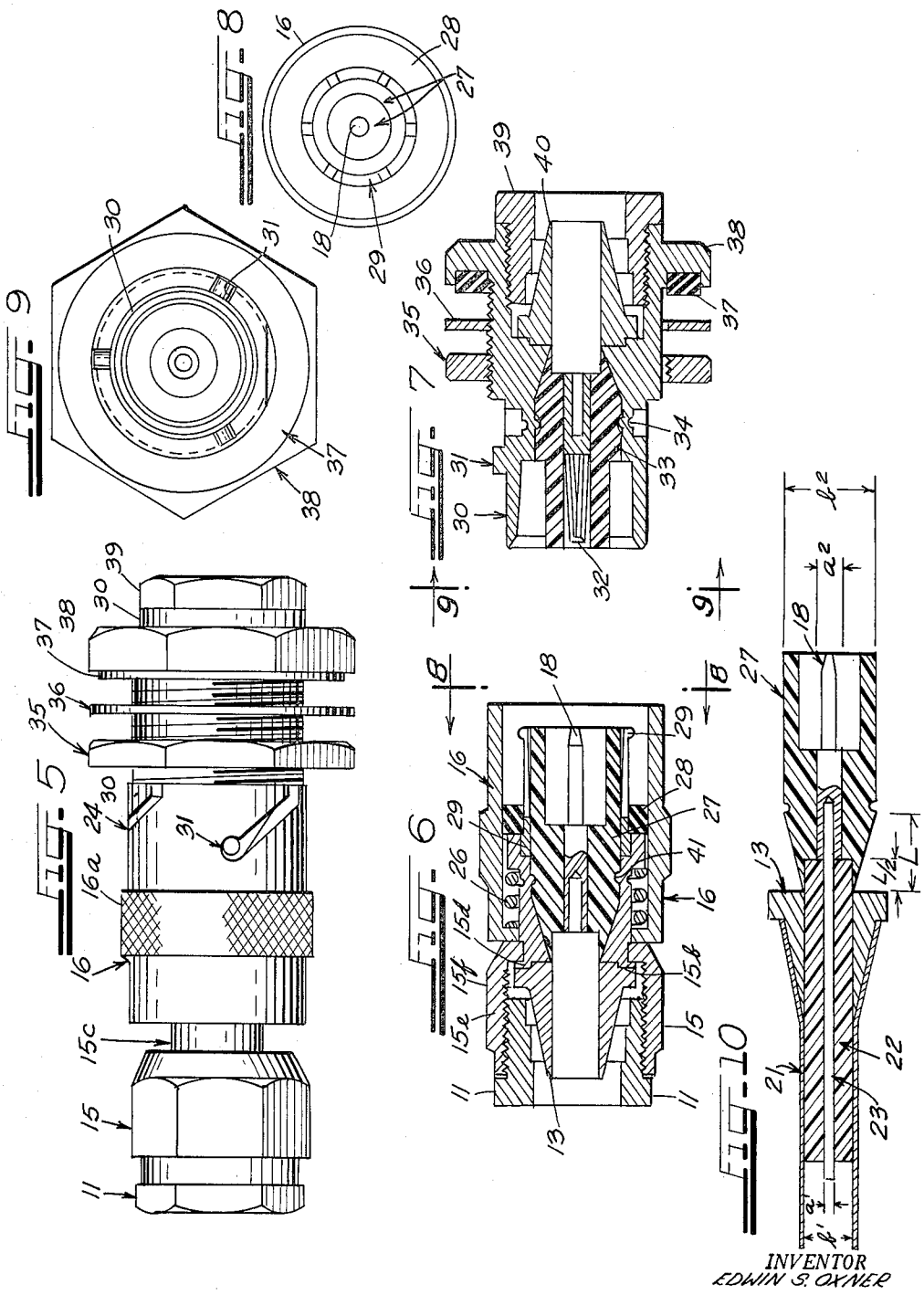
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ELECTRICAL COAXIAL CABLE CONNECTING ASSEMBLY WITH IMPEDANCE MATCHING

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8 Claims. (Cl. 333—34)

The present invention deals with electrical connectors and more particularly, is directed to the multi-conductor or coaxial type connector assembly.

Up to the present time most coaxial connectors have required fanning of the cable braid in the normal assembly procedure. A technique to obviate the fanning process is a special clamping device in the form of two sleeves which are passed under and over the cable's outer conductor and then stamped, under extreme pressure, by a stamping machine. In both of the types mentioned a gasket must be included at the rear of the connector to effect a water seal. Furthermore, the second type of connector mentioned is not reusable. That is to say, the stamped sleeve must be replaced since it is permanently affixed to the coaxial cable.

In the case where braid fanning is required, a discontinuity may exist at the interface of the cable braid and the connector body resulting in unwanted reflections of transmitted signal. Absent a discontinuity the radius of the outer conductor may change hence, the characteristic impedance would change. The characteristic impedance of a coaxial line is defined as:

$$(1) \qquad Z_0 = \frac{60}{E_r 1/2} \log_e b/a$$

wherein, Z_0 is the characteristic impedance, b is the diameter of the outer conductor, a is the diameter of the inner conductor and E_r is the relative dielectric constant of the medium therebetween. An abrupt change in Z_0, like a discontinuity results in wave reflection along a transmission line.

In contradistinction to the teachings and practices of the prior art we have designed a unique, reusable connector assembly having a self sealing feature and one that is substantially reflection free.

It is, accordingly, a general object of the instant invention to provide an improved connector assembly of the type described.

Another object of the instant invention is to provide a coaxial connector offering good radio frequency performance coupled with ease of assembly.

Another more specific object of the instant invention is to provide a coaxial radio frequency connector having excellent cable gripping properties.

Yet another object of the instant invention is to provide a coaxial cable connector wherein fanning of the cable braid is not necessary.

Still another more specific object of the instant invention is to provide a radio frequency coaxial cable connector providing impedance characteristics substantially equal to that of the cable.

A still further, more specific object of the instant invention is to provide an impedance transition device enabling substantially reflection free power transmission between coaxial cables of unequal physical dimensions.

Yet still another more specific object of the instant invention is to provide a radio frequency coaxial cable connector which is reusable and which forms a natural water seal without a gasket.

The invention possesses other objects and features of advantage which, with the foregoing, will become apparent to the reader in the following detailed description of the preferred form of the invention which is illustrated in the accompanying drawings as forming a part of the specification.

Referring to the drawings wherein like reference numerals denote like parts:

FIGURE 1 is a view, in cross section, of the left end of a completely assembled connector plug.

FIGURE 2 is a side view of a coaxial cable with some of the plug components mounted thereon, illustrating the manner of assembly.

FIGURE 3 is a side view of a coaxial cable with a completely assembled connector plug.

FIGURE 4 is an exploded view of the structure shown in FIGURE 1.

FIGURE 5 is a side view of a preferred form of connector assembly comprising a plug and jack.

FIGURE 6 is a view in cross section of the plug illustrated in FIGURE 5.

FIGURE 7 is a view in cross section of the jack illustrated in FIGURE 5.

FIGURE 8 is an end view of the plug of FIGURE 6 looking in the direction of arrows **8—8**.

FIGURE 9 is an end view of the jack of FIGURE 7 looking in the direction of arrows **9—9**.

FIGURE 10 is a sectional view of the connector elements providing impedance compensation.

Briefly stated, the foregoing objects and others, are accomplished by a unique design and cooperation of; a hollow externally threaded collar, a ferrule having a frusto-conical projection and a sleeve for engaging the collar. The ferrule, in addition to providing excellent electrical contact with the cable braid, provides clamping pressure to outer conductor and insulation of the cable between the ferrule and the inner surface of the threaded collar.

Referring to FIGURES 1 and 4, a coaxial cable **19** comprising; center conductor **23**, dielectric **22**, outer conductor (cable braid) **21** and rubber jacket **20** is shown. A hollow externally threaded collar **11** having an hexagonal flange is provided and adapted to frictionally engage jacket **20**. Such engagement is effected by having the minimum diameter of collar **11** nearly equal to the outer diameter of cable **19**. Collar **11** has successively increased internal diameter sections **11***a*, **11***b* and **11***c* along the body thereof.

Ferrule **13**, having an annular flange **14** and a wedge shaped projection is adapted to be inserted between dielectric **22** and outer conductor **21**. The inner diameter of ferrule **13** is nearly equal to the external diameter of dielectric **22**. An internally threaded sleeve **15**, is provided to receive collar **11**. The wedge shaped portion of ferrule **13** cooperating with collar **11** and sleeve **15** is forced into a position whereby it applies radial pressure to braid **21** and rubber jacket **20**. This pressure is of sufficient magnitude to insure excellent engagement of cable **19**. Likewise, this pressure forces jacket **20** into a confined volume and thereby creates a waterproof seal in addition to providing excellent radio frequency contact between the outer conductor **21** and ferrule **13**.

The flat end of ferrule **13** abuts the shoulder **15***b* in sleeve **15** and insures proper positioning of ferrule **13** when the plug is assembled. Sleeve **15** has an opening, large enough to pass dielectric **22** and center conductor **23** into its tubular portion **15***c* enabling connection to contact pin **18**.

After cable **19** is trimmed, collar **11** is slipped thereover. Next ferrule **13** is inserted between conductor **21** and dielectric **22**. Contact pin **18** is passed over a bare projecting end of conductor **23** and soldered thereto. Following this, sleeve **15** is journaled onto the cable passing over ferrule **13**. Collar **11** is brought into engagement therewith and the threaded portion **12** thereof is screwed into the body of sleeve **15**. A hexagonal head **15***a*, on sleeve **15**, provides a gripping surface for tightening the connection between collar **11** and sleeve **15**. Seat **15***b* urges ferrule **13** under braid **21**, and into its proper position, as the connection between collar **11** and sleeve **15** is secured.

In securing collar **11** and sleeve **15**, ferrule **13** is properly positioned. In this position the transmission line experiences no discontinuity or change in radius because ferrule **13** is a conductor and its inner radius is equal to that of outer conductor **21**. This pressure on jacket **20** provides waterproofing, however, the internally stepped portions **11***a*, **11***b* and **11***c* of ferrule **11** enhance this characteristic in addition to providing eminently good cable gripping properties. Furthermore, the section **20***a* of jacket **20** is forced within the threads of sleeve **15** forming a gasket to prevent water leakage through the threaded region between sleeve **15** and collar **11**.

A member **16**, concentric with sleeve **15** and passing thereover, is shown in position in FIGURE 3. Member **16** is adapted for locking engagement with a jacket having a female contact pin **32** (see FIGURE 7) adapted to mate with contact pin **18**.

Referring now to FIGURES 5 and 6, the composite connector assembly including the complementary or right hand end thereof is shown. The right hand end of the connector assembly will hereinafter be referred to as the jack. In this embodiment the connector clamp structure is somewhat modified as will be described hereinbelow. Collar **11** and ferrule **13** are substantially identical to those previously illustrated and function in the same manner. On the other hand, sleeve **15** is made up of two separate parts **15***d* and **15***e*. This change in design was primarily for ease of manufacturing. In assembly, parts **15***d* and **15***e* are mated and stamped together. It is noted that member **15***d* has a circumferential seat therein adapted to accommodate an annular ridge on ferrule **13** of diameter nearly equal to the seat on member **15***d*. This arrangement insures proper alignment of ferrule **13**.

Member **16** encircles a portion of sleeve **15***d* and defines a cavity therebetween. Positioned within said cavity is spring **26** which is arranged to urge member **16** to the left as far as it will go; in this particular case, to the point where member **16** abuts a hexagonal flange **15***f*. Guideway **24** on member **16** is provided for locking engagement with the jack having bayonet type locking fingers **31** projecting radially therefrom. In this particular embodiment three locking fingers **31** spaced 120° apart were used satisfactorily.

As will readily be understood from a reconsideration of Equation (1), a change in Z_0 should result from the changing diameter of the conductors caused by the connector assembly. More specifically, the addition of contact pin **18** to enter conductor **23** causes a discontinuity in the propagating transverse electric-magnetic mode (hereinafter referred to as TEM). If a constant diameter outer conductor is utilized, the equivalent circuit consists of two sections of different characteristic impedances coupled by a shunt capacitance due to the presence of transverse magnetic (hereinafter referred to as TM) modes at the point of discontinuity. Reflections are caused by the TM capacitance and the mismatch in characteristic impedances for the TEM mode. There are many ways to compensate for these possible reflections as is obvious to those skilled in this particular art. Whatever the method the ratio b/a must remain constant to avoid a change in Z_0. Theoretically this condition is easily met, however, as a practical matter it is not. In this respect, we have found that a linear transition between equal ratios of the diameters satisfactorily eliminates power reflections.

Referring next to FIGURE 10 this linear transition will now be described. As previously noted Z_0 will not vary if the factor b/a is constant. The coaxial cable has a specific Z_0 which relates to the parameters of the cable and to b_1 and a_1. Assuming that dielectric **22** and inserts **27** and **33** have nearly the same E_r (see Equation 1), the only problem is to equate the aforementioned ratios. To this end we have found that to linearly increase the outer diameter from b_1 to b_2 and at the same time abruptly increase the inner diameter a_1 to a_2 at the midpoint of said linear increase, provides a satisfactory substantially reflection free transition. It is noted, of course, that the ratio b_1/a_1 is numerically equal to b_2/a_2. Furthermore, the abrupt change in a_1 takes place at a distance $L/2$ which is defined as one half the horizontal distance L. A similar design is employed in the pack assembly of FIGURE 7 with dielectric insert **33** and functions in the same way.

Contact pins **18** and **32** provide the abrupt change from diameter a_1 to a_2. This change takes place at the distance $L/2$ and the possibility of error is obviated because the recess in insert **27** terminates at the midpoint of its taper. Trimmed center conductor **23** passes through insert **27**, but dielectric **22** abuts the wall of said recess. Contact pin **18**, having an external diameter a_2, is affixed to conductor **23** whereby it touches the end face of dielectric **22** at the midpoint $L/2$.

Insert **27** is secured in position in the connector body by means of crimping at **41** in FIGURE 6. Contact fingers **29** are secured to and spaced around the outer surface of dielectric **27** and provide frictional engagement with the inner surface of sleeve **30** of the jack shown in FIGURE 7. Positioned within the cavity defined by member **16** the elastomer ring **28** which becomes compressed when the connector plug is in locking engagement with jack and provides a watertight seal therebetween.

Referring next to FIGURES 7 and 9 the jack assembly is shown. Female contact pin **32** is soldered to the center conductor **23** of another coaxial cable. Contact pin **32** is adapted to mate with contact pin **18**. Dielectric **33** is journaled into the cavity defined by sleeve **30** and is fixed therein by crimping at points **34**. When the plug and jack are mated dielectric inserts **27** and **33** take the form of one continuous dielectric section.

Projecting from sleeve **30** are bayonet prongs **31** for locking engagement in guideways **24** of member **16**. Sleeve **31** is both internally and externally threaded. The sleeve's internal threads cooperate with collar **39** exactly as was done in the connector plug body with collar **11** and sleeve **15**.

The jack body may be adapted for panel mounting and in that case sleeve **30** is provided with an outward radial flange **38**. A rubber washer **37** seated in hexagonal flange **38** abuts the inner wall of said panel. Washer **36** and nut **35** are passed over the left end of the jack and engaged to the outer threads of sleeve **30** to secure the jack, which has been passed through an opening in the panel, to the equipment. By tightening nut **35**, a watertight seal is created between the jack and the panel.

We have made radio frequency connector pairs in accordance with the teachings of the instant invention for 0.200 inch outer diameter coaxial line exhibiting a low voltage standing wave ratio of less than 1.32 for frequencies under 5,000 megacycles. Both plug and jack

were made from brass stock except for spring fingers **29** and contact **32** which were made of beryllium copper. Both the connector plug and jack attached were approximately ¾ inch in length and when coupled together measured about 1.33 inches. The units were gold flashed over a silver plating on the order of 0.0002 inch.

Because of the special cable clamping technique in the design of the instant invention, a discontinuity free path from the cable to the plug body is achieved. In addition to a naturally formed water seal, the connector assembly has good gripping action and is reusable.

In one embodiment, the clamp withstood a static load of seventy pounds for over fifteen minutes and failed after more than one thousand, ninety degree flexures with a five pound load. The failure noted in the flexure test was not in the connector gripping area, but due to a severance of the outer braid at the rear of collar **11**.

From the foregoing, it is noted that we have provided a connector having good radio frequency performance, ease of assembly and with excellent cable gripping properties which represents a considerable advance over the prior art.

It will be understood that the invention can be practiced otherwise than has been specifically described and is limited only by the scope of the appended claims. For example, the connector may be utilized to secure other forms of current carrying elements. Also, the connector may be used for splicing cables together as well as connection to panel mountings.

I claim:

1. An impedance matching device between coaxial lines of different physical dimensions having substantially equal impedances, comprising in combination: a coaxial line having a center and outer conductor wherein the outer diameter of said center conductor is a_1 and the inner diameter of said outer conductor is b_1; another coaxial line having a center conductor and an outer conductor wherein the outer diameter of said center conductor is a_2 and the inner diameter of said outer conductor is b_2; coaxial wave conducting means interposed between and connected to the outer conductors of said lines, respectively, having a linear taper from diameter b_1 to diameter b_2; and second wave conducting means connected to the center conductors of said lines, respectively, causing an abrupt transition from diameter a_1 to diameter a_2 wherein said abrupt transition occurs substantially at the midpoint of said taper along the axis thereof and is spaced therefrom.

2. In the device of claim **1** wherein: the ratio of b_1 to a_1 is equal to the ratio of b_2 to a_2.

3. In the device of claim **2** wherein: a dielectric having a relative dielectric constant substantially equal to that of a dielectric used in said lines, fills the space between said first and second wave conducting means.

4. A coaxial impedance matching device for coupling between coaxial lines of unequal physical dimensions having substantially equal impedances comprising in combination: hollow conductive means interposed between and connected to outer conductors of said lines and having a frusto-conical surface; and a second conductive means connected to the center conductors of said lines and having an external diameter equal to the external diameter of the center conductor of the larger of the coaxial lines, said second conductive means extending from about the midpoint of said conical section to the larger of said center conductors along the axis thereof and spaced therefrom.

5. An impedance matching device between coaxial lines of different physical dimensions having substantially equal impedances comprising in combination: a coaxial line having a center and outer conductor wherein the outer diameter of said center conductor is a_1 and the inner diameter of said outer conductor is b_1; another coaxial line having a center conductor and an outer conductor wherein the outer diameter of said center conductor is a_2 and the inner diameter of said outer conductor is b_2; coaxial wave-conducting means interposed between and connected to the outer conductors of said lines, respectively, having a linear taper from diameter b_1 to diameter b_2; and second wave-conducting means connected to the center conductors of said lines, respectively, said second wave-conducting means including a portion thereof having a diameter substantially equal to a_1 and disposed coaxially with that portion of said coaxial wave-conducting means extending from said outer conductor having an inner diameter of b_1 and a second portion thereof having a diameter substantially equal to a_2 and disposed coaxially with that portion of said coaxial wave-conducting means extending from said outer conductor having an inner diameter of b_2, said portion and said second portion being joined in an abrupt transition from diameter a_1 to diameter a_2 whereby the impedance of said impedance matching device is substantially equal to the impedance of said coaxial lines.

6. An electrical connector adapted for use with a multiconductor cable, said cable having a center and an outer conductor wherein the outer diameter of said center conductor is a_1 and the inner diameter of said outer conductor is b_1, said connector comprising: a conductive connector sleeve having a clamp portion adapted to conductively engage said outer conductor, a second portion with an inner diameter b_2, and a coaxial wave-conducting portion therebetween having a linearly tapered inner surface varying from a diameter b_1 at said clamp portion to a diameter b_2 at said second portion; inner conductor means having a first portion of diameter a_1 extending from said second conductor into said wave-conducting portion and a second portion of diameter a_2 coaxial and coextensive with the second portion of said sleeve and extending into said coaxial wave-conducting portion, said first and second portions of said inner conductor means being joined together in an abrupt transistion from diameter a_1 to diameter a_2 and the ration a_1/b_1 being equal to the ration a_2/b_2 whereby the impedance of said electrical connector is substantially equal to the impedance of said cable; and dielectric means disposed between said connector sleeve and said inner conductor means.

7. An electrical connector adapted for use with a multiconductor cable, said cable having a center and an outer conductor wherein the outer diameter of said center conductor is a_1 and the inner diameter of said outer conductor is b_1, said connector comprising: a conductive connector sleeve having a clamp portion adapted to conductively engage said outer conductor, a second portion with an inner diameter b_2, and a coaxial wave-conducting portion therebetween having a tapered inner surface varying from a diameter b_1 at said clamp portion to a diameter b_2 at said second portion; inner conductor means including a pin having a diameter a_2 and extending into said tapered coaxial wave-conducting portion to substantially the midpoint thereof, said pin being adapted for securement to said center conductor; and dielectric means disposed between said connector sleeve and said inner conductor means.

8. An electrical connector adapted for use with a multiconductor cable, said cable having a center and an outer conductor wherein the outer diameter of said center conductor is a_1 and the inner diameter of said outer conductor is b_1, said connector comprising: a conductive connector sleeve having a clamp portion to conductively engage said outer conductor, a second portion with an inner diameter b_2, and a coaxial wave-conducting portion therebetween having a tapered inner surface varying from a diameter b_1 at said clamp portion to a diameter b_2 at said second portion; inner conductor means including a pin having a diameter a_2 and extending into said tapered coaxial wave-conducting portion to an intermediate point thereof, said intermediate point being at above the midpoint of said tapered coaxial wave-conducting portion whereby the impedance of said electrical con-

nector is substantially equal to the impedance of said multiconductor cable; and dielectric means disposed between said connector sleeve and said inner conductor means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,209,287 September 28, 1965

Edwin S. Oxner

It is hereby certified that error appears in the above numbered patent requiring correction and that the said letters Patent should read as corrected below.

Column 3, line 35, for "jacket" read -- jack --; line 69, for "enter" read -- center --; column 4, line 27, for "pack" read -- jack --; line 52, for "definied" read -- defined --; column 6, lines 38 and 39, for "ration", each occurrence, read -- ratio --; line 73, for "above" read -- about --.

Signed and sealed this 10th day of May 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Acting Officer

EDWARD J. BRENNER
Commissioner of Patents