Feb. 17, 1970 O. J. FIEBEL ET AL 3,496,496

PRECISION COAXIAL CONNECTOR

Filed March 21, 1966

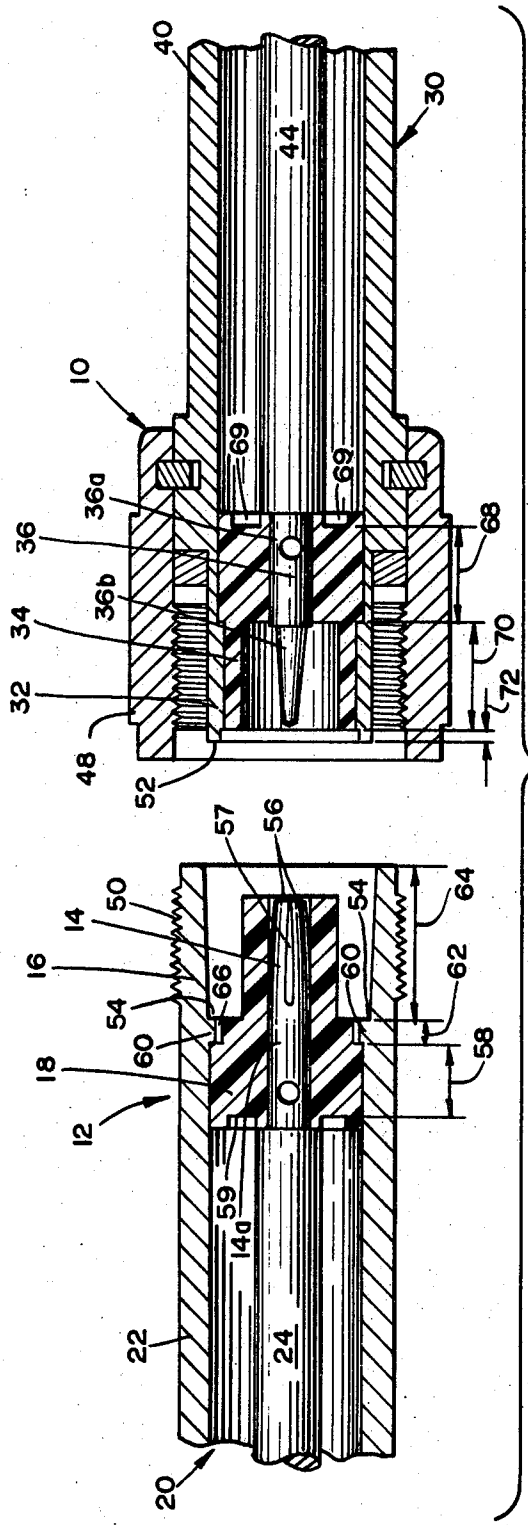


FIG. 1

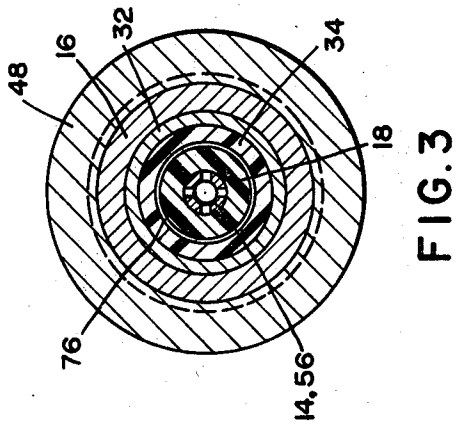


FIG. 3

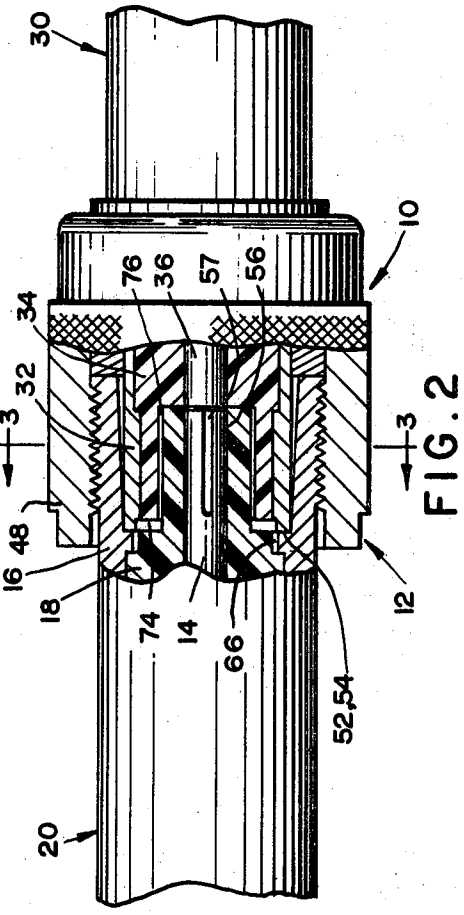


FIG. 2

INVENTORS
OTTMAR J. FIEBEL
BY FRANKLIN D. ROSEN

Blair, Buckles & Cesari
ATTORNEYS

United States Patent Office 3,496,496
Patented Feb. 17, 1970

3,496,496

PRECISION COAXIAL CONNECTOR

Ottmar J. Fiebel, Holliston, and Franklin D. Rosen, Brighton, Mass., assignors to General RF Fittings, Inc., Boston, Mass.

Filed Mar. 21, 1966, Ser. No. 535,768
Int. Cl. H03h 7/38
U.S. Cl. 333—33 11 Claims

ABSTRACT OF THE DISCLOSURE

A transmission line connection characterized by a low standing wave ratio has a reduced outer conductor diameter in the region of inner conductor overlap. In other sections the insulating spacers between the inner and outer conductors are cut away to provide partial air dielectrics compensating for different outer conductor diameters.

This invention relates to a connector for coaxial transmission lines. More particularly, it provides a radio frequency coaxial connector having a new transmission line structure that markedly reduces impedance discontinuities encountered in prior coaxial connectors of the same type. Due to this new structure, the connector can easily provide, on a production basis, superior impedance characteristics as were heretofore approached only in costly hand-finished connectors.

The invention is concerned primarily with connectors in which both the inner conductors and the outer conductors of the mating connector portions telescope together. This is in contrast to connections wherein the outer conductors meet in a face-to-face relation and have flanges that are bolted together to secure the connection.

Coaxial connectors are conventional devices—in common use since at least the 1940's—used to interconnect radio frequency devices such as antennas, receivers, transmitters and test equipment having coaxial transmission line ports.

The principal function of a coaxial connector is reliably to conduct signals between the interconnected transmission lines without introducing a transmission discontinuity. That is, unless the connector is required to provide an impedance transformation, it should have precisely the same electrical impedance throughout its entire length as the two interconnected transmission lines, which generally have the same impedance. When the characteristic impedance at any point in the connector differs from that of the interconnected coaxial lines, the impedance discontinuity reflects part of the signal directed to the connector back to its source, i.e., to the input transmission line. This produces in the input line a voltage standing wave whose amplitude varies along the transmission line. The standing wave ratio (SWR) of the maximum voltage in the standing wave to the minimum voltage is a measure of the impedance discontinuity: the larger the discontinuity, the larger the SWR.

It is known in the art to compensate connectors to reduce the effect of impedance discontinuities. Thus, when a connector manufacturer measures an SWR in a connector that he has designed to have as few discontinuities as reasonably possible, he can introduce additional discontinuities to cancel the effects of the discontinuities that persist. This technique can reduce the SWR of the connector. However, compensation seldom provides a completely reflection-free connector. And the compensation is generally frequency sensitive so that the connector is well matched only over a limited frequency range.

Prior to the present invention, the current laboratory standard coaxial connectors were hand-finished and hand-

compensated with the plug and jack sections specially impedance-matched to each other. These prior precision connectors have a maximum SWR generally under 1.04 at frequencies up to 9 gHz. As might be expected, they are relatively high cost connectors, being roughly 7 to 10 times more expensive than standard connectors, which have a typical SWR of 1.3 over a similar frequency range.

Accordingly, it is an object of this invention to provide a coaxial transmission line connector that can be readily manufactured to have a low standing wave ratio. A further object is to provide such a connector for manufacture with a lower SWR than heretofore available except with hand-finishing for impedance improvement. It is also an object that the connector have such a low SWR over a relatively wide range of frequencies, preferably exceeding a 10:1 range. Another object of the invention is to provide such a precision connector at a relatively low cost, particularly at a cost competitive with previously available, standard connectors from relatively high volume manufacture.

A further object of the invention is to provide a coaxial transmission line connector having a precise, low SWR without requiring impedance compensation.

A more particular object is to improve the impedance characteristics, as manufactured, of types HN, BNC, C, SC, TNC, and like connectors without detracting from their mechanical and other electrical features.

A further object of the invention is to provide connectors of the above character whose jacks and plugs are separately compatible with prior art plugs and jacks, respectively.

It is also an object of the invention to provide a coaxial transmission line connector of the type in which the inner conductor receptacle of the jack has axially-extending fingers that receive and frictionally engage the inner conductor pin of the plug, which connector has fewer impedance mismatches than its prior art counterpart.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a side sectional view of a disengaged connector embodying the invention;

FIGURE 2 is a side view, partly broken away, of the assembled connector; and

FIGURE 3 is a transverse sectional view of the assembled connector as seen along line 3—3 in FIGURE 2.

In the prior art there are many standard coaxial connector designs. Also, in the highly competitive and rapidly developing microwave industry, many assertedly new connectors are continually being announced. The new connectors claim such improvements as smaller size, compatability with new cables, lower SWR, higher breakdown voltage, lower cost and higher reliability and versatility. However, this aggressive and competitive industry has been unaware that a common connector construction introduces impedance mismatches that can be removed in a relatively simple manner.

The sources of these mismatches have now been recognized and understood to such an extent that theoretical calculations result directly—without the experimental cut-and-try refinements so commonly required to perfect

microwave devices—in almost perfect connectors. The invention thus provides structural changes in existing connectors that improve considerably their SWR, without "hand tailoring." The new precision connectors are compatible with prior connectors and are no more costly to manufacture.

Specifically, it is now recognized that the common jack inner conductor receptacle having narrow slots to form axially-extending contact fingers has a measurably smaller effective radius, for impedance purposes, than an unslotted conductor of the same outer diameter. Further, it has been established that a reduction in the inner radius of the outer conductor opposite the slotted receptacle essentially completely offsets the impedance changes the slots would otherwise introduce. In one preferred embodiment then, the invention provides a connector with a conventional slotted inner conductor receptacle, and having a reduction in the outer conductor diameter opposite the slotted inner conductor.

The connector also has other departures from prior art, as will now be described in detail.

As shown in FIGURE 1, the connector comprises a plug indicated generally at **10** and a jack indicated at **12**. The illustrated jack is identical in many respects to a conventional TNC jack and has a slotted and bored inner conductor receptacle **14** and an outer conductor **16**. An insulating sleeve **18** supports the receptacle within the outer conductor. The back end of the inner conductor receptacle **14** is connected to the inner conductor **24** of a coaxial transmission line **20**. The transmission line outer conductor **22** is joined to the back end of the connector outer conductor **16**. (The back ends of elements in the jack are their axial ends nearest where the transmission line **20** extends from the jack; their other axial ends are referred to as their front ends. The elements of the plug **10** are similarly referred to as having back and front ends.)

The connector plug **10** has a cylindrical outer conductor **32** and an insulating sleeve **34** coaxially within the outer conductor and supporting an inner conductor pin **36**. The inner conductor **44** of a coaxial line **30** extends from the back end of the pin **36**, and the transmission line outer conductor **40** connects to the plug outer conductor **32**.

Referring to FIGURES 1 and 2, the connector is assembled by threading a captive nut **48** axially retained on the plug **10** on threads **50** on the outside of the jack outer conductor **16**, as is conventional. This urges the plug and jack together with the plug outer conductor **32** telescoping under the outer conductor **16** of the jack until the front face **52** of the plug outer conductor butts against the shoulder **54** on the jack outer conductor. At the same time, the inner conductor pin **36** of the plug fits in the bore within the fingers **56** of the jack inner conductor receptacle **14**. The front edges of the fingers frictionally engage the pin forming a secure contact.

Referring again to FIGURE 1 and the construction of the jack **12**, the jack inner conductor receptacle **14**, disposed snugly within a bore in the insulating sleeve **18**, has an unslotted cylindrical portion **14***a* behind the fingers **56**. However, it has a uniform maximum outer diameter over its entire length when assembled with the plug pin **36**. Further, the bases of the slots **57** are forward of the outer conductor shoulder **54** by a short but finite distance.

The jack has a "normal" transmission line section **58** the back limit of which is the bottom of a counterbore **59** in the insulating sleeve **18** and the forward end of which is the back edge of a retaining rim **60** on the outer conductor **16**. The normal section is thus axially coextensive with the greater part of the unslotted cylindrical portion **14***a* of the receptacle **14**. Forward of the normal section **58**, for the short axial length of the outer conductor retaining rim **60**, the jack has a "retaining" section **62** the forward limit of which is the shoulder **54**. This section **62** is preferably also opposite only the unslotted receptacle portion **14***a*. Between the shoulder **54** and the front face of the outer conductor **16**, which is the front edge of the jack, the jack has an "overlapping" section **64**.

Along the length of the normal section **58** of the jack **12**, the outer surface of the sleeve **18** firmly engages the outer conductor **16**. The cylindrical inner surface of the outer conductor has a uniform diameter such that the transmission line characteristic impedance between the outer conductor and the receptacle portion **14***a* has a selected design value.

At the forward end of the jack normal section **58**, the inwardly protruding retaining rim **60** on the outer conductor engages the insulating sleeve **18** to hold the sleeve and other elements of the jack in place, as is conventional. However, the reduced radial spacing between the outer conductor rim and the inner conductor receptacle tends to decrease the characteristic impedance in the section **62** below the design value in the normal section **58**. This change in impedance would introduce an impedance discontinuity that would measurably increase the input SWR of the jack.

However, the present connector maintains the characteristic impedance in the retaining section **62** at the same value as in the normal section **58** by reducing the sleeve outer diameter to provide an air gap **66** beneath the rim **60**. This partial replacement of the insulating sleeve by air increases the impedance in the retaining section of the jack to the design value. This is because air has a smaller permittivity than the material of the insulating sleeve **18**, which may be of polytetrafluoroethylne (commercially available under the trade designation of Teflon).

With further reference to FIGURE 1, in the overlapping section **64** of the jack, the outer conductor **16** is radially enlarged and the outer diameter of the insulating sleeve **18** is greatly reduced, compared to their dimensions in the sections **58** and **62**, to provide a cylindrical gap that receives the front portion of the plug outer conductor and insulating sleeve, as shown in FIGURE 2. The shoulder **54** in the jack against which the plug outer conductor butts is at the back end of the overlapping section. Also in this section **64**, the insulating sleeve **18** preferably extends forward just beyond the end of the slotted receptacle **14** to protect the fingers **56** from damage.

In the plug **10**, the inner conductor pin **36** has a cylindrical portion **36***a* behind a tapered portion **36***b*; the diameter at the base of the tapered portion is less than the diameter of the cylindrical portion by twice the thickness of the jack receptacle fingers **56**. The outer diameter of the cylindrical portion **36***a* is usually equal to the outer diameter of the cylindrical portion **14***a* of the jack receptacle **14**.

With further reference to FIGURE 1, the connector plug has a "normal" transmission line section **68** the back end of which is the bottom of a counterbore **69** in the insulating sleeve **34** and the forward end of which is defined by the forward end of the pin cylindrical portion **36***a*.

Forward of this normal section **68**, there is a "slotted" section **70** that is substantially coextensive with the tapered portion **36***b* of the pin **36**. More particularly, as shown in FIGURE 2, the slotted section **70** is coextensive with the slots **57** in the jack inner conductor receptacle **14** when the connector is assembled.

Forward of the slotted section of the plug is an "end" section **72** where the outer conductor **32** extends beyond the inner conductor pin **36** and, in the assembled connector, extends into the jack for the axial distance from the base of the slots **57** to the jack outer conductor shoulder **54**.

In the normal section **68** of the connector plug, the pin outer diameter and the outer conductor inner diameter are usually selected to provide the same design impedance as in the jack normal section **58** and hence have the same values as the corresponding diameters of the jack receptacle **14** and outer conductor **16**. The inner conductor

sleeve **34** snugly fits between these coaxial conductors in the section **68**.

Considering the end section **72** of the plug **10**, in the assembled connector, it is opposite the cylindrical portion **14***a* of the jack receptacle **14**. Accordingly, to provide the same characteristic impedance as in the adjoining jack sections **58** and **62** (which have the same inner conductor diameter as the plug end section in the asssembled connector), the inner diameter of the plug outer conductor **32** would be expected to be identical to one of the outer conductor diameters in these jack sections **58** and **62**. However, this is not the case, as will now be discussed.

In assembling the plug, the insulating sleeve **34** and the outer conductor **32** are slid onto each other and therefore the sleeve cannot have a larger outer diameter in the region of the end section **72** than it has in the region of the slotted section **70**. It has therefore been determined that the sleeve **34** not extend forward beyond the slotted section **70**; other arrangements can be employed, but this one is preferred for mechanical and electrical reasons. This leaves an air gap **74** in the assembled connector radially between the plug outer conductor **32** and the jack insulating sleeve **18**. The net permittivity of the resultant combination of sleeve **18** and the air gap **74** between the assembled coaxial conductors in the plug end section **72** is generally different from the permittivity elsewhere in the connector. Accordingly, to provide the design value of characteristic impedance, the inner diameter of the plug outer conductor in the section **72** generally has a value different from the outer conductor diameters in the other sections of the connector. Specifically, because the illustrated air gap **74** is thicker than the air gap **66** in the section **62** of the jack **12**, the inner diameter of the illustrated plug outer conductor in the section **72** is smaller than the outer conductor diameters in the connector sections **58**, **62** or **68**.

In the slotted section **70** of the plug, the inner diameter of the insulating sleeve **34** is enlarged to provide a cylindrical space for receiving the front part of the jack inner conductor receptacle and insulating sleeve with a minimal air space **76** (FIGURE 3) radially between the two assembled sleeves **18** and **34**. This step in the inner diameter of the insulating sleeve **34** is preferably radially in-line wtih the forward end of the cylindrical portion **36***a* of the inner conductor pin **36**.

Further, the inner diameter of the outer conductor **32**, which is a circumferentially-continuous cylinder, is measurably smaller in the slotted section **70** than in the normal section **68**. For the reason now to be explained, this reduced outer conductor diameter in the slotted section **70** provides the same characteristic impedance, when the plug is assembled with the jack, as the larger, usually equal, outer conductor diameters in the plug normal section **68** and in the jack normal section **58**.

In the assembled connector, FIGURE 2, the inner conductor portion opposite the outer conductor in the plug section **70** is the slotted portion of the jack receptacle **14**. Due to the slots **57**, the effective outer diameter for impedance purposes of this portion of the receptacle is less than the physical outer diameter thereof. When the reduced diameter in the slots, which as shown in FIGURE 3 is the diameter at the base of the tapered section **36***b* of the plug inner conductor pin, is taken into account, the effective radius, r_{eff}, of the connector inner conductor in the plug section **70** can be shown to have the following value

$$r_{eff}=r_a-\frac{2l}{\pi}\left(1-\frac{r_b}{r_a}\right) \tag{1}$$

where:

r_a is the outer radius of the fingers **56** in the assembled connector, and hence is the outer radius of the cylindrical portion **14***a* of the jack receptacle **14**;

r_b is the largest radius of the pin tapered portion **36***b*; and

l is the width of each of the slots **57**.

Equation 1 neglects second and higher order effects; however they are relatively small.

The inner radius, R, of the plug outer conductor **32** in the section **70** is determined for the design characteristic impedance, Z_0, from the conventional equation

$$Z_0=\frac{60}{\sqrt{\epsilon_{net}}}\,1n\left(\frac{R}{r}\right) \tag{2}$$

using as the inner conductor radius r the value of r_{eff} determined in accordance with Eq. 1. The permittivity ϵ_{net} in Eq. 2 is the effective value determined according to conventional techniques from the permittivities of the sleeves **18** and **34** and of the gas in the narrow cylindrical space **76** (FIGURE 3) between the overlapping sleeves. Where the two sleeves have the same permittivity ϵ_1, and the gas in this space has a permittivity ϵ_2, (ϵ_{net}) for use in Eq. 2, can generally be calculated with sufficient accuracy as follows:

$$\epsilon_{net}=\epsilon_1-\epsilon_2\left(\frac{2\times d}{R^2-r_a{}^2}\right) \tag{3}$$

where:

d is the thickness of the cylindrical space **76**; and

x is the radius to the middle of the space **76**.

The effect of the permittivity in the slots **57** is usually so small that it can be neglected, and hence omitted from Eq. 3.

Substituting Eq. 1 into Eq. 2 provides the following expression for the value of the inner radius R of the plug outer conductor **32** in the section **70**.

$$R=\left[r_a\left(\frac{2l}{\pi}\right)\left(1-\frac{r_b}{r_a}\right)\right]\text{Exp.}\,\frac{Z_0\sqrt{\epsilon_{net}}}{60} \tag{4}$$

The radii thus calculated from the approximated Eqs. 1–4 have been found to be within ¼% of the optimum values as determined by actual test.

The foregoing connector construction provides a marked reduction in SWR as contrasted with conventional prior connectors. In fact, a conventional TNC connector, for example, has the same outer conductor diameter opposite the slotted inner conductor as it has opposite the unslotted inner conductor. The resultant impedance discontinuity between the slotted and unslotted sections typically introduces a maximum SWR close to 1.1. Further, the prior TNC connector does not have the gaps **66** and **74** provided in the present construction and it lacks a section equivalent to the present plug end section **72**. Moreover, the outer conductor of the conventional TNC plug, corresponding to the present conductor **32**, has contact fingers that engage the inner surface of the jack outer conductor; it does not have the butt connection of the present connector between the plug outer conductor face **52** and the jack shoulder **54**. As a result of this construction, the maximum SWR of the complete standard TNC connector is at least as high as 1.2 between 1 gHz. and 10 gHz. The *SWR* of the improved construction described above, on the other hand, is generally below 1.03 over this 10:1 frequency range, and does not exceed 1.05. Indeed, connectors constructed in accordance with the invention often do not manifest a measurable standing wave. That is, any signal reflected from impedance discontinuities in the connector are too small to be distinguished from the noise in the measuring system.

The present connector construction provides this remarkable impedance match with only conventional manufacturing techniques whereby all connectors are substantially alike. They do not require hand-finishing, tailored to each connector, as required in the prior art to attain equivalent impedance characteristics. As a result, the present connectors can readily be manufactured at the same cost as the conventional prior connectors of the same type.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described the invention, what is claimed as new and secure by Letters Patent is:

1. A coaxial transmission line connector for mating with another connector to provide a connection having a substantially constant characteristic impedance, said connector having

(i) an outer conductor (**22**) and an insulating sleeve (**18**),

(ii) first, second and third contiguous axially consecutive sections with said second section being closer to the front end of the connector than said first end and said third end being closer to said front end than said second end, and

(iii) an inner conductor-receiving central bore extending through said insulating sleeve in said sections,

said connector being characterized in that

(A) in said first section (**58**)

(1) said outer conductor has a first inner diameter, and

(2) the outer surface of said insulating sleeve adjoins said outer conductor,

(B) in said second section (**62**)

(1) said outer conductor has a second inner diameter smaller than said first diameter to form an inwardly protruding retaining rim (**60**) engaged with a radial surface of said insulating sleeve,

(2) a second insulating material having a smaller permittivity than the material of said insulating sleeve extends for a sufficient part of the radial distance between said outer conductor rim and said bore of said sleeve to provide substantially the same characteristic, impedance in said second section as in said first section, and

(1) said outer conductor has a third inner diameter larger than said second diameter thereof, and

(2) said insulating sleeve has a fourth outer diameter considerably smaller than said second diameter thereby forming a cylindrical space between said outer conductor and said insulating sleeve for receiving the outer conductor of a mating connector.

2. A connector according to claim **1** further comprising an inner conductor receptacle (**14**) disposed in said bore coaxial with said outer conductor and having a portion (**14***a*) axially extending along said first and second sections, said receptacle portion having a substantially continuous cylindrical outer surface of uniform diameter in said first and second sections.

3. A coaxial transmission line connector jack having a front end at which it receives a mating connector plug and a back end axially removed therefrom, said jack comprising

(A) a cylindrical inner conductor receptacle having a first outer diameter and being axially slotted, from its end closest to said front end of said jack, for a portion of its length to form a plurality of axially-extending, pin-receiving, contact fingers,

(B) a cylindrical insulating sleeve

(1) having a central axial bore in which said receptacle is disposed,

(2) having a first axial section that is at least partially coextensive with said slots in said receptacle and that has a second outer diameter,

(3) having a second axial section that is contiguous with the end of said first section nearest said back end of the jack and that has a third outer diameter larger than said second diameter, and

(4) having a third axial section that is contiguous with the end of said second section nearest the back end of the jack and that has a fourth outer diameter larger than said third diameter, and

(C) an outer conductor

(1) having a cylindrical inner surface at least axially coextensive with first, second and third sections of said insulating sleeve,

(2) having a fifth axial section that is exactly coextensive with said second axial section of said cylindrical sleeve and that has a sixth inner diameter greater than said third diameter of said sleeve so that there is a gap radially between said sleeve and said outer conductor,

(3) having a fourth axial section that is contiguous with the end of said fifth section nearest said front end of the jack and that has a seventh inner diameter larger than said sixth diameter thereof, and

(4) having a sixth axial section contiguous with the end of said fifth section nearest the back end of the jack and having an inner diameter substantially equal to said fourth diameter of insulating sleeve.

4. A coaxial transmission line connector for connection with a mating connector, said connectors being arranged to couple transmission lines having the same characteristic impedance, said transmission line connector being arranged for a low standing wave ratio and having

(i) an outer conductor (**48**) coaxial and at least partly coextensive with an inner conductor (**36**) and with an insulating sleeve (**34**) between said conductors,

(ii) first and second contiguous axially consecutive sections (**68, 70**) with said second section (**70**) being closer to the front end thereof that connects with a mating connector, and

(iii) a central bore extending through said insulating sleeve in both said sections,

said connector being characterized in that

(A) in said first section

(1) said inner conductor has a cylindrical part (**36***a*) with a first outer diameter,

(2) the inner diameter of said outer conductor has a second value, and

(3) the inner diameter of said sleeve is substantially equal to said first diameter and the outer diameter of said sleeve is substantially equal to said second value, and

(B) in said second section

(1) said inner conductor has a connecting part (**36***b*) joined to said cylindrical part, said connecting part being arranged to fit within an inner conductor receptacle in said mating connector, said receptacle being slotted in the axial direction to form a plurality of fingers that fit over and frictionally engage said connecting part (**36***b*),

(2) the inner diameter of said outer conductor has a third value less than said second value, said third value being substantially twice the radius R_3 determined from the following equation

$$R_3=\left[r_a-\left(\frac{2l}{\pi}\right)\left(1-\frac{r_b}{r_a}\right)\right]\text{Exp}\,\frac{Z_0\sqrt{\epsilon}}{60}$$

where:

r_a is the radius to the outer surface of a finger of said receptacle when assembled with said connecting part (**36***b*);

r_b is substantially equal to r_a less the radial thickness of said fingers at said slot;

l is the width of the slots between adjacent fingers of said receptacle;

Z_0 is the design characteristic impedance in said second section of said connector when assembled with said further mating connector; and

ϵ is the net permittivity of the insulating material between said outer conductor and said receptacle when said connectors are assembled together; and

(3) the outer diameter of said sleeve is substantially equal to said third value.

5. A coaxial transmission line connector for connection with a mating connector, said connectors being arranged to couple transmission lines having the same characteristic impedance, said transmission line connector being arranged for a low standing wave ratio and having

(i) an outer conductor (**48**) coaxial and at least partly coextensive with an inner conductor (**36**) and with an insulating sleeve (**34**) between said conductors,

(ii) first, second and third contiguous axially consecutive sections (**68, 70, 72**) with said third section (**72**) being closest to the front end of said connector that connects with said mating connector, and said second section (**70**) being between said first and third sections, and

(iii) a central bore extending through said insulating sleeve in all said sections,

said connector being characterized in that

(A) in said first section

(1) said inner conductor has a cylindrical part (**36***a*) with a first outer diameter,

(2) the inner diameter of said outer conductor has a second value, and

(3) the inner diameter of said sleeve is substantially equal to said first diameter and the outer diameter of said sleeve is substantially equal to said second value, and

(B) in said second section

(1) said inner conductor has a connecting part (**36***b*) joined to said cylindrical part,

(2) the inner diameter of said outer conductor has a third value less than said second diameter, and

(3) the outer diameter of said sleeve is substantially equal to said third value,

(C) in said third section said outer conductor has a fourth inner diameter greater than said third inner diameter value, and

(D) said insulating sleeve terminates at the end of said second section contiguous with said third section so as not to extend into said third section.

6. A conductor according to claim **5** in which said fourth outer conductor diameter is intermediate said second and third outer conductor diameters.

7. A connection between two coaxial transmission lines, said connection comprising

(A) a first generally cylindrical inner conductor member,

(B) a second generally cylindrical inner conductor member

(1) having a first axial end,

(2) connected at said first end to said first inner conductor member,

(3) having means forming a plurality of slots, each having a width (l), axially extending therein from said first end and forming a plurality of axially extending contact fingers, said fingers being circumferentially spaced apart by said slots and engaging said first inner conductor member at their inner surfaces,

(4) said second inner conductor member having a radius (r_a) to the outer surface of said fingers and having a radius (r_b) to the inner surface of said fingers at said first end, and

(C) an outer conductor having a generally cyclindrical inner surface coaxial with and at least partly coextensive with the slots in said second inner conductor member and having an inner radius (R) related to the dimensions of said second inner conductor member by the following equation

$$R=\left[r_a-\left(\frac{2l}{\pi}\right)\left(1-\frac{r_b}{r_a}\right)\right]\text{Exp}\,\frac{Z_0\sqrt{\epsilon}}{60}$$

where:

Z_0 is the design value of the characteristic impedance between said outer conductor member and said inner conductor members at said slots, and

ϵ is the net permittivity of the material between said outer conductor member and said slotted length of said second inner conductor member.

8. A coaxial transmission line connection consisting of a plug assembled with a jack, said connection comprising

(A) a first inner conductor member (**36**) having a connecting part (**36***b*) joined to a cylindrical part (**36***a*) that has a first outer radius,

(B) a second inner conductor member (**14**) having

(1) a first end,

(2) a cylindrical part (**14***a*) that has said first outer radius,

(3) a generally-cylindrical slotted part (**56, 57**)

(a) joined with said cylindrical part thereof and extending therefrom to said first end,

(b) having a plurality of fingers (**56**) axially extending to said first end and separated by slots (**57**) and telescopically receiving between them and frictionally engaging said connecting part of said first inner conductor member,

(c) having said first radius to the outer surface of said fingers, and

(C) a first outer conductor member (**32**) having a cylindrical inner bore coaxial with said first and second inner conductor members having

(1) a first section (**70**) coextensive with said slotted part of said second inner conductor member and having a second inner radius, and

(2) a second section (**68**) contiguous with said first section thereof and at least partly coextensive with said cylindrical part of said first inner conductor member and having a third inner radius larger than said second radius.

9. A connection according to claim **8** further comprising

(A) a second outer conductor member (**16**) having a cylindrical inner bore

(1) coaxial with said first and second inner conductor members, and

(2) having a first section (**58**)

(a) at least partly coextensive with said cylindrical part (**14***a*) of said second inner conductor member, and

(b) having a radius equal to said third inner radius.

10. A connection according to claim **9** in which

(A) said cylindrical inner bore of said second outer conductor member has a second section (**60**)

(1) axially contiquous with said first section thereof and being closer than said first section to said first end of said second inner conductor member,

(2) around said cylindrical part of said second inner conductor member, and

(3) having a fourth inner radius less than said third radius,

(B) a cylindrical insulating sleeve (**18**)

(1) disposed between said second inner conductor member and said second outer conductor member and at least coextensive with said first and second sections of said second outer conductor member,

(2) having an inner radius substantially equal to said first radius,

(3) having an outer radius substantially equal to said third radius along the length thereof coextensive with said first section of said second outer conductor member, and

(4) having an outer radius less than said fourth radius along the length thereof coextensive with said second section of said second outer conductor member.

11. A connection according to claim **12** in which

(A) said cylindrical inner bore of said first outer conductor member has a third section (**72**)

(1) axially extending from and contiguous with the end of said first section thereof remote from said second section thereof, and

(2) having a fifth inner radius intermediate said second and third radii, and

(B) a hollow, cylindrical insulating sleeve (**34**) is

(1) between and coaxial with said first outer conductor member and both said slotted part of said second inner conductor member and said cylindrical part of said first inner conductor member, and

(2) absent from the space within said third section of said first outer conductor member, and

(C) means forming an annular air gap is provided between said first outer conductor member and the inner conductor member coextensive therewith over the entire axial length of said third section of said first outer conductor member.

References Cited

UNITED STATES PATENTS

3,022,482	2/1962	Waterfield	333—97
3,245,027	4/1966	Ziegler	333—97
3,295,076	12/1966	Kraus	174—75.2
3,323,083	5/1967	Ziegler	333—97
3,350,666	10/1967	Ziegler	333—97

FOREIGN PATENTS

637,579	3/1962	Canada.

HERMAN K. SAALBACH, Primary Examiner

L. ALLAHUT, Assistant Examiner

U.S. Cl. X.R.

333—97; 339—177