(12) UK Patent Application (19) GB (11) 2 417 618 (13) A

(43) Date of A Publication 01.03.2006

(21) Application No: **0419303.3**

(22) Date of Filing: **31.08.2004**

(71) Applicant(s):
ITT Manufacturing Enterprises, Inc.
(Incorporated in USA - Delaware)
1105 North Market Street, Suite 1217,
Wilmington, Delaware 19801,
United States of America

(72) Inventor(s):
Robert Craig Hosler

(74) Agent and/or Address for Service:
Elkington and Fife LLP
Prospect House, 8 Pembroke Road,
SEVENOAKS, Kent, TN13 1XR,
United Kingdom

(51) INT CL:
H01R 24/02 (2006.01) **H01R 13/646** (2006.01)

(52) UK CL (Edition X):
H2E ECR

(56) Documents Cited:
GB 2019665 A **US 6402550 B2**
US 20040018771 A1

(58) Field of Search:
INT CL^7 **H01R**
Other: **Online: WPI, EPODOC, JAPIO**

(54) Abstract Title: **Coaxial connector**

(57) A radio frequency coaxial connector is designed to terminate a coaxial cable having a centre conductor 3, a dielectric material 5 surrounding the central conductor, a conductive foil 7a surrounding the dielectric material and optionally a conductive braid 7b surrounding the foil. The connector comprises a substantially tubular metallic connector body arrangement 19 having a first end for receiving the coaxial cable and a second end for interfacing with a complementary connector, and a substantially tubular insulator 21 in the connector body between the first and second ends and coaxial with the connector body. The first end 19a of the connector body arrangement is an open end having a bore extending from the open end to the insulator for receiving the centre conductor, dielectric material and conductive foil of the cable. An inner diameter of the bore reduces across a portion of the bore between the open end and the insulator to provide an interference fit with the conductive foil. This avoids a gap (see Fig 2b) which would cause return loss and resonance.

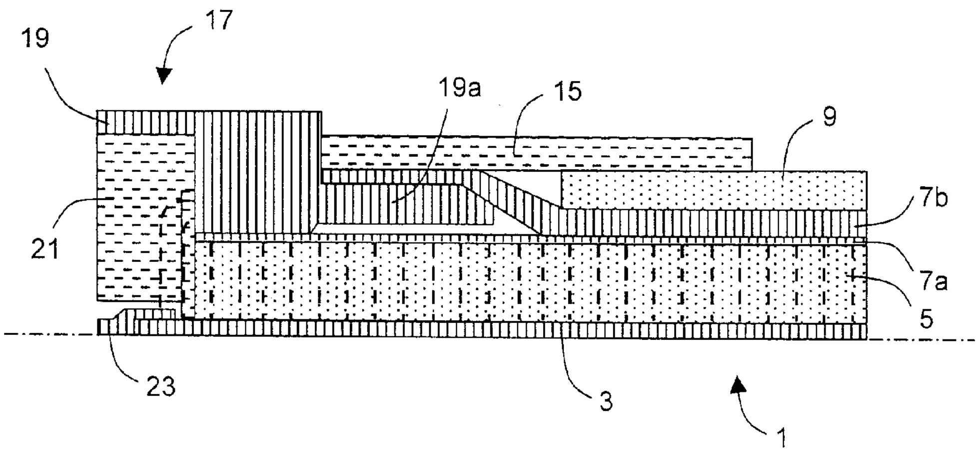


Fig. 5

GB 2 417 618 A

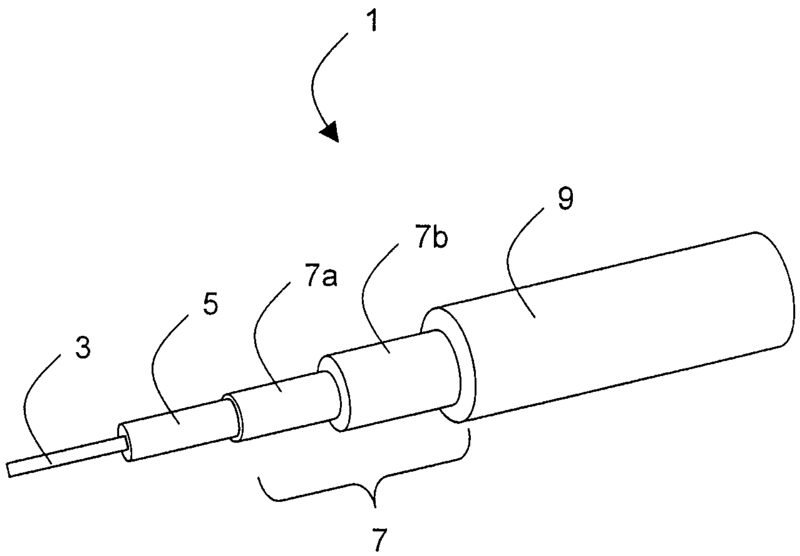


Fig. 1

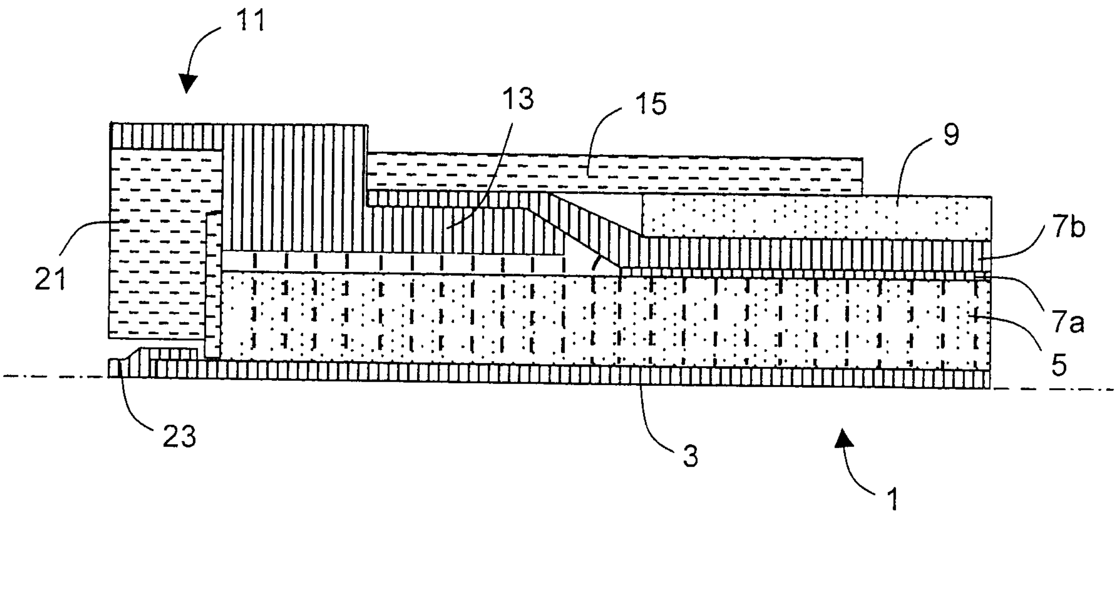


Fig. 2a

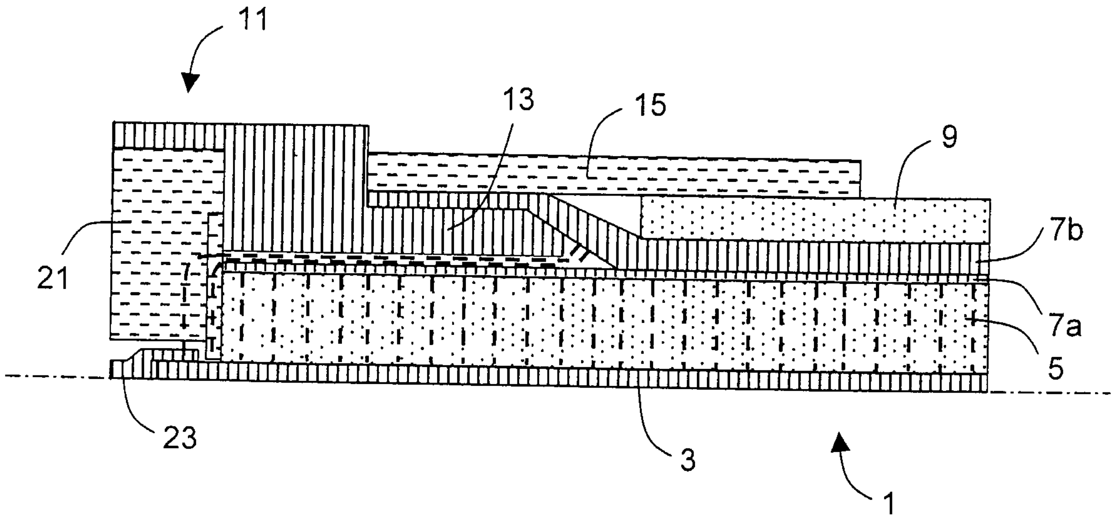


Fig. 2b

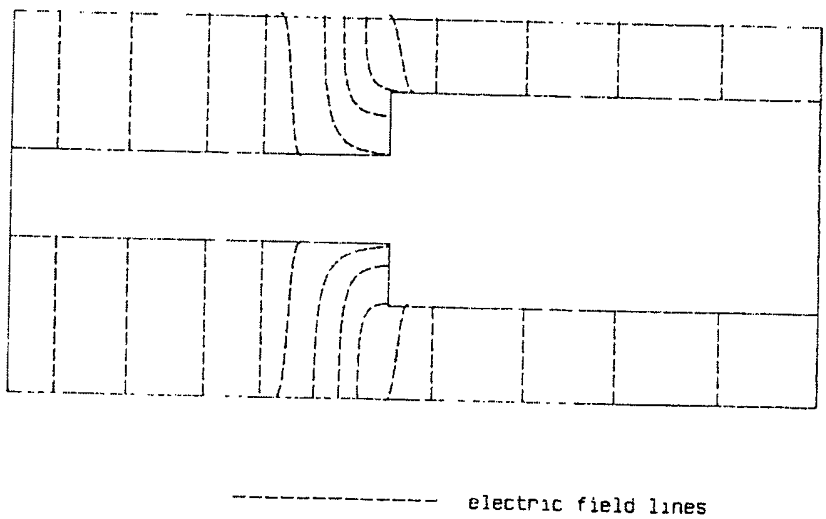


Fig. 3

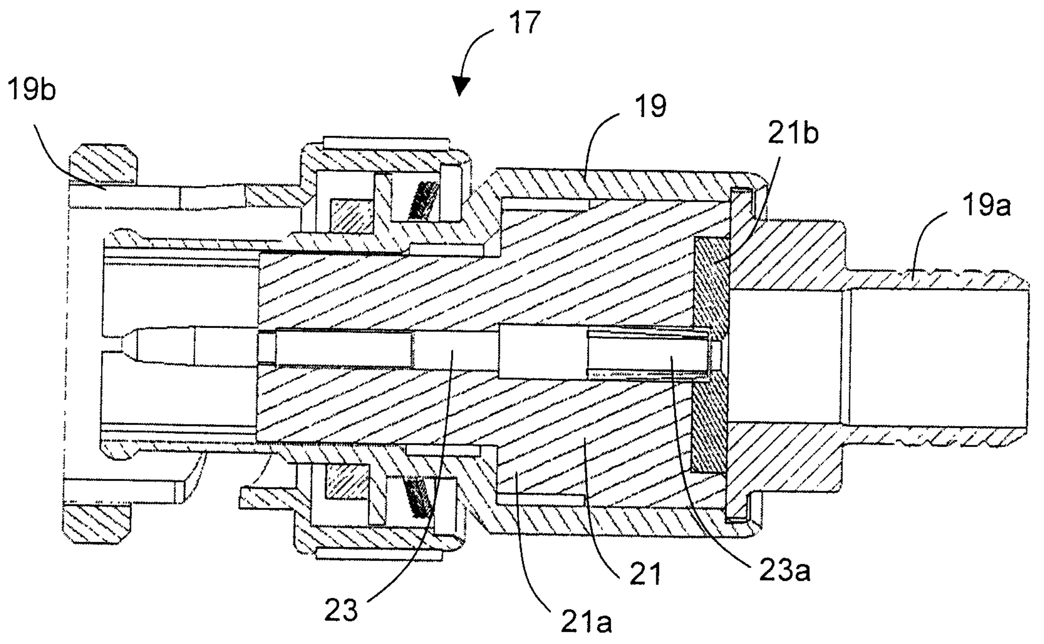


Fig. 4

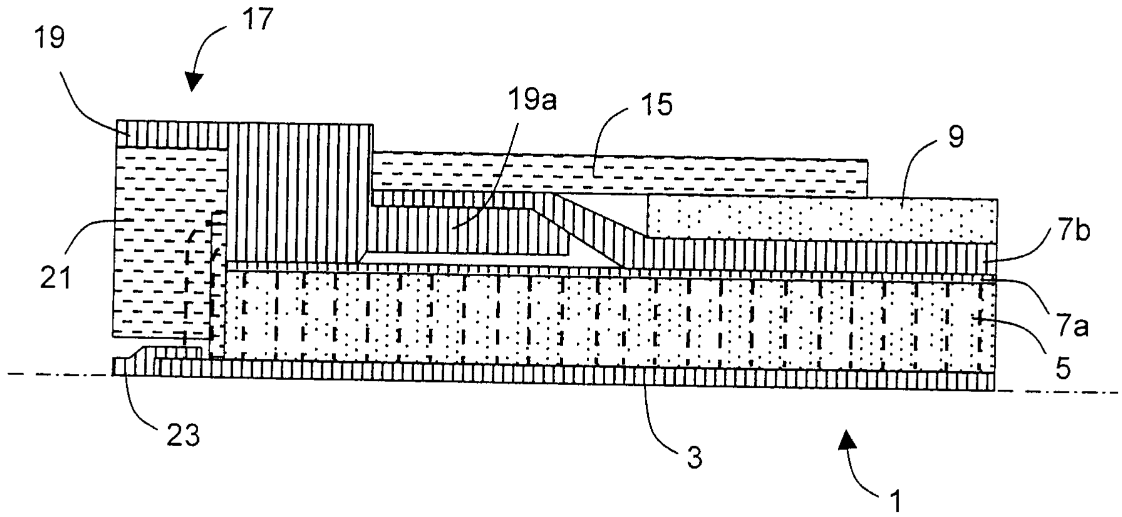


Fig. 5

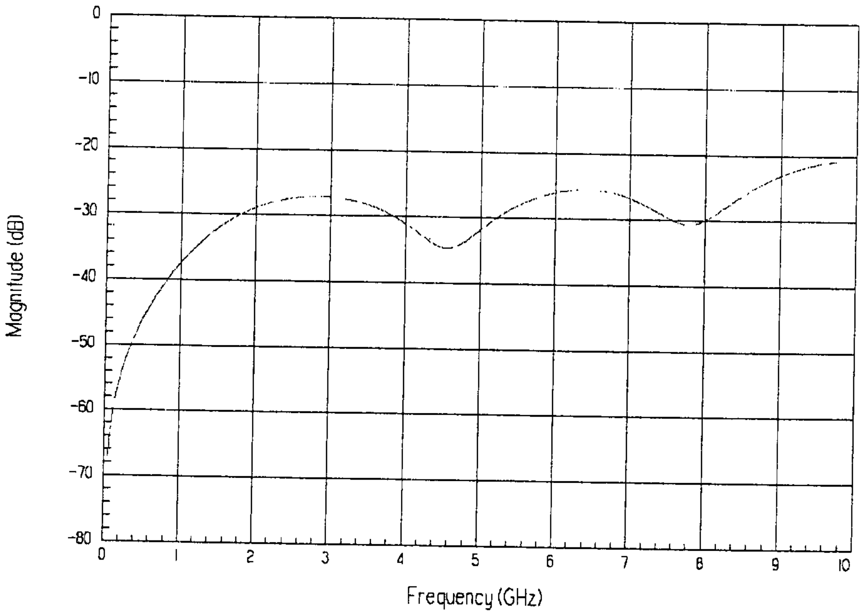

0
-10
-20
-30
-40
-50
-60
-70
-80
Magnitude (dB)
0
1
2
3
4
5
6
7
8
9
10
Frequency (GHz)

Fig. 6a

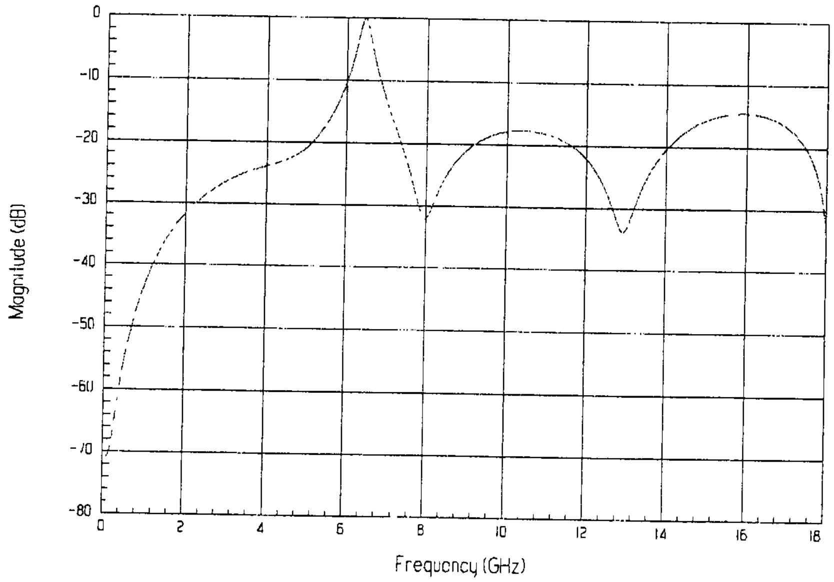

0
-10
-20
-30
-40
-50
-60
-70
-80
Magnitude (dB)
0
2
4
6
8
10
12
14
16
18
Frequency (GHz)

Fig. 6b

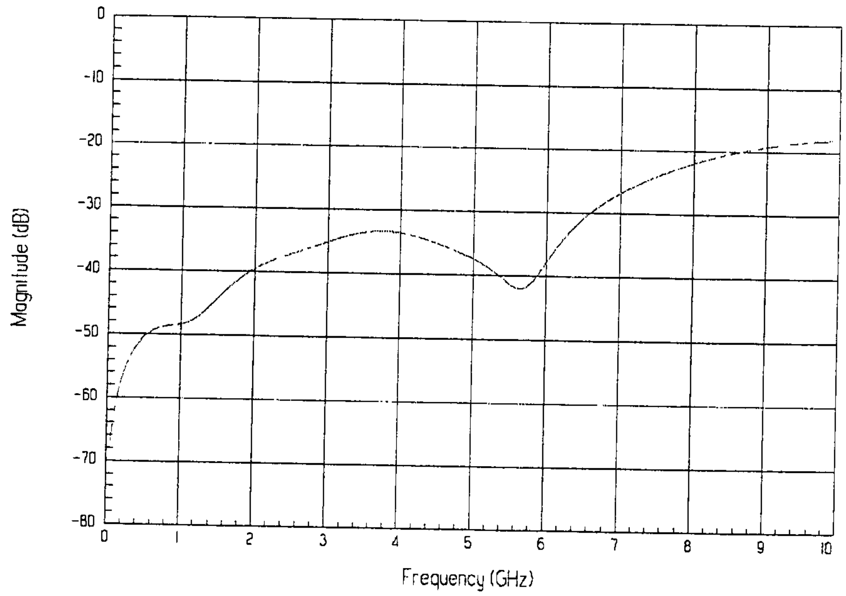

0
-10
-20
-30
-40
-50
-60
-70
-80
Magnitude (dB)
0
1
2
3
4
5
6
7
8
9
10
Frequency (GHz)

Fig. 6c

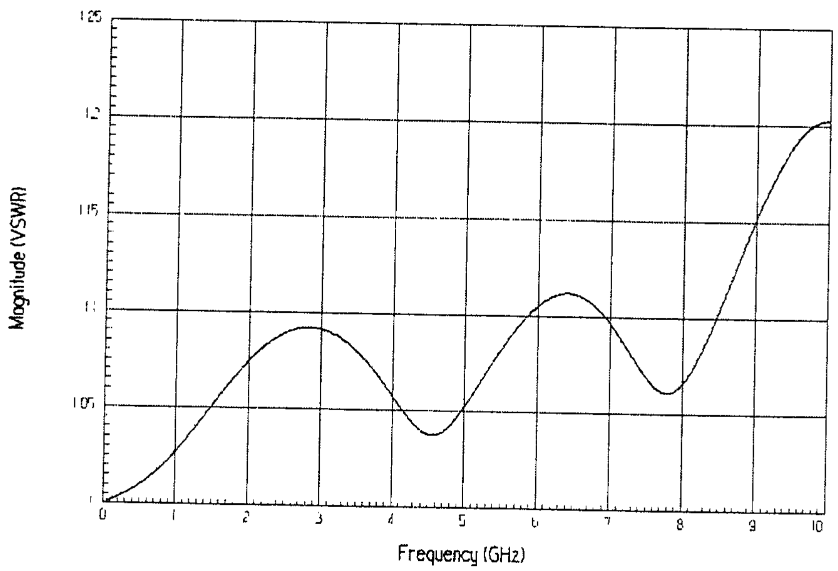
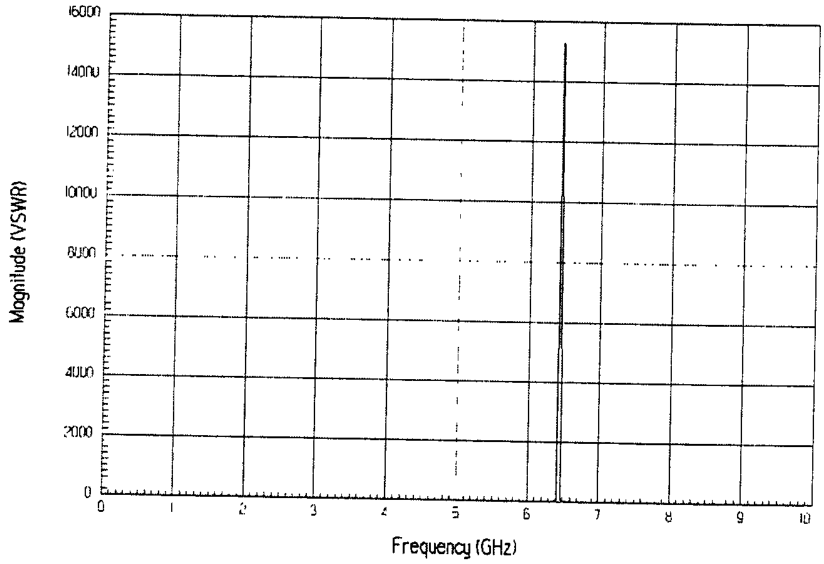
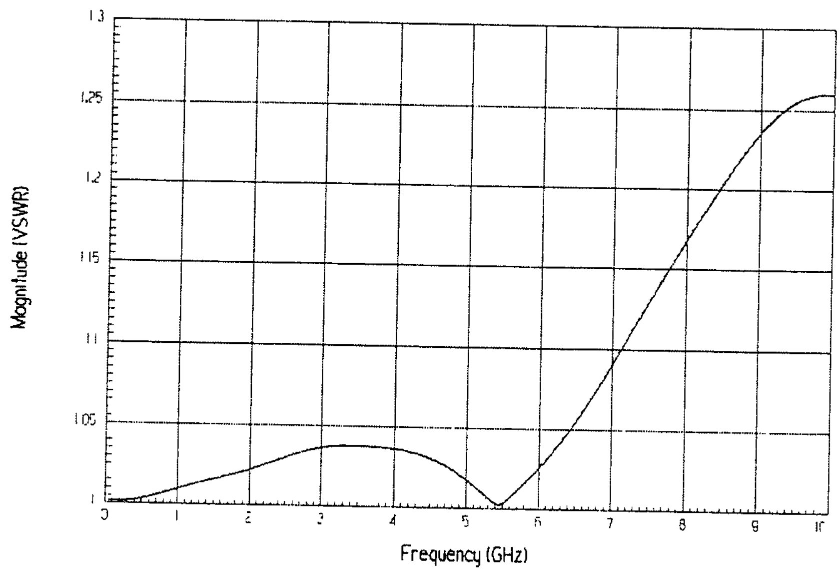

Magnitude (VSWR)
Frequency (GHz)

Fig. 7a



16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
5
6
7
8
9
10
Magnitude (VSWR)
Frequency (GHz)

Fig. 7b



1.3
1.25
1.2
1.15
1.1
1.05
1
0
1
2
3
4
5
6
7
8
9
10
Magnitude (VSWR)
Frequency (GHz)

Fig. 7c

2417618

Coaxial connector

This invention relates to radio frequency (RF) coaxial cable connector. In particular, this invention relates to an RF coaxial connector for terminating high performance coaxial cables having wrapped conductive shields.

Coaxial cables are commonly used in transmission line designs to transmit electrical signals from one location to another. Generally, a coaxial cable includes a solid or stranded inner conductor surrounded by a layer of polymer dielectric material. The dielectric material is precisely centred within a woven braid outer conductor, and the cable has an outer jacket of polymer material. In coaxial cables, the outer conductor defines a ground return path necessary for microwave signal transmission.

High performance, low loss coaxial cables have been developed to transmit higher frequencies with minimal impedance discontinuities. With low loss dielectrics, these cables may transmit higher power levels with minimal attenuation. The high performance cables generally comprise an inner conductor surrounded by a low loss dielectric material such as cellular polyethylene, a thin wrapped metallic outer shield such as a conductive foil, a woven plated copper braid shield, and a polymer outer jacket such as polyvinyl chloride (PVC). This type of cable is desirable for use in the transmission of digital signals such as those used in the High Definition Television (HDTV) industry.

A known high performance coaxial cable 1, as described above, is shown in Figure 1 and comprises a centre conductor 3 and two outer conductors 7. The two outer conductors are a thin wrapped metallic foil 7a and a woven braid outer conductor 7b. A dielectric material 5 separates the centre conductor 3 and the outer conductors 7. The entire cable 1 is enclosed in an outer jacket 9.

Connectors for terminating coaxial cables are well known. Cables are generally prepared for termination by stripping the centre conductor, the dielectric material, the braid and the cable jacket to the strip lengths specified by the manufacture of the RF coaxial connector.

In the case of the high performance coaxial cable having the wrapped metallic shield, the metallic foil forming the shield is generally removed and stripped back approximately evenly with the jacket, as shown in Figure 2a (which will be described in detail below). The removal of the metallic foil in this way is an inconvenience for cable assembly manufacturers and cable installers because it requires the foil to be stripped back behind the braid that surrounds it. This operation is time consuming and requires special tools, and may lead to damage of the braid.

A preferred termination technique would therefore be to leave the metallic foil intact, i.e. flush with the dielectric material and/or braid. However, this presents a problem in terms of electrical performance. At lower frequencies, cables prepared and terminated in this way exhibit no electrical performance problems, with particular respect to return loss. However, at higher frequencies, a convoluted signal path occurs, and a higher than expected return loss or VSWR (voltage standing wave ratio) is consequently exhibited.

According to the invention, there is provided a radio frequency coaxial connector for terminating a coaxial cable, the coaxial cable comprising a centre conductor, a dielectric material surrounding the centre conductor and a conductive foil surrounding the dielectric material, the connector comprising: a substantially tubular metallic connector body arrangement having a first end for receiving the coaxial cable and a second end for interfacing with a complimentary connector; and a substantially tubular insulator arrangement located in the connector body between the first and second ends and coaxial with the connector body, wherein the first end of the connector body arrangement is an open end having a bore extending from the open end to the insulator arrangement for receiving the centre conductor, dielectric material and conductive foil of the cable, and wherein an inner diameter of the bore reduces across a portion of the bore between the open end and the insulator arrangement to provide an interference fit with the conductive foil. The reduced inner diameter of the bore is preferably located adjacent the insulator arrangement.

The invention provides a radio frequency coaxial connector for terminating a high performance coaxial cable, and is capable of providing very low return loss, or VSWR, in a transmission line. The connector has a bore for receiving the coaxial cable. In use, the centre conductor, dielectric material surrounding the centre conductor and the conductive foil are received into the first end of the RF coaxial connector, and the conductive braid surrounds the first end of the connector body. The cable is easily received into the first end of the connector body, but the reducing diameter of the bore provides an interference fit between the conductive foil of the cable and the inner surface of the bore. This interference fit eliminates any clearance between the conductive foil of the cable and the inner surface of the bore, and thereby eliminates the convoluted signal path between the conductive foil and the connector body.

It has been found that prevention of such a longitudinal signal path is an effective way of maintaining the transverse orientation of the electric field, thereby ensuring good electrical performance at higher frequencies.

The connector may further comprise a centre conductor contact pin arrangement located in the insulator arrangement and coaxial therewith. Alternatively, the insulator arrangement may simply have a central hole formed therein for receiving an extended length of the centre conductor of the cable.

The connector preferably further comprises a ferrule for crimping onto the first end of connector body arrangement. In use, the ferrule clamps the conductive braid of the coaxial cable onto the outer surface of the first end of the connector.

The second end of the connector body arrangement preferably includes a bayonet collar. For example, the connector may be a solder, crimp or clamp type BNC plug. Alternatively, the second end of the connector body arrangement may have a push-fit or threaded collar.

The minimum inner diameter of the bore may be 3.75mm or less, and is preferably 3.70mm or less. The minimum inner diameter may be 3.60mm or more, and is preferably 3.65mm or more.

The maximum inner diameter of the bore may be 3.80mm or more, and is preferably 3.85mm or more. The maximum inner diameter of the bore may be 4.00mm or less, and is preferably 3.95mm or less.

The first end of the connector body arrangement may have an outer diameter in the range 4.50mm to 5.50mm, and preferably in the range 4.75mm to 5.25mm.

The invention also provides a coaxial lead comprising the connector described above and a coaxial cable. The coaxial cable includes a centre conductor, a dielectric material surrounding the centre conductor, a conductive foil surrounding the dielectric material, a conductive braid surrounding the foil and an outer jacket. The centre conductor, dielectric material and conductive foil of the coaxial cable are received within the bore of the first end of the connector body arrangement such that there is an interference fit.

The outer diameter of the conductive foil may be in the range 3.7mm to 3.85mm, and preferably in the range 3.76mm to 3.79mm.

An embodiment of the invention will now be described, by way of example only, in detail with reference to the following drawings in which:

Figure 1 is a partially cut away view of a known high performance coaxial cable;

Figures 2a and 2b are cross sectional view of the known high performance coaxial cable shown in Figure 1 terminated with a known coaxial connector;

Figure 3 is a cross sectional view showing electric field lines at step discontinuities in coaxial conductors;

Figure 4 is a cross sectional view of a coaxial connector according to the invention;

Figure 5 is a cross sectional view of the high performance coaxial cable shown in Figure 1 terminated with the coaxial connector shown in Figure 4;

Figure 6a, 6b and 6c show predicted return loss for the terminated coaxial connectors shown in Figures 2a, 2b and 5 respectively; and

Figure 7a, 7b and 7c show predicted voltage standing wave ratio (VSWR) for the coaxial connectors shown in Figures 2a, 2b and 5 respectively.

The electric field lines of a high performance coaxial cable in the normal transverse electromagnetic mode of transmission are purely radial, and thus terminate perpendicular to the surfaces of the centre and outer conductors. However, at sudden transitions in the diameter of the conductors, such as a step change in the conductor diameter of a coaxial connector, the electric field lines distort so as to maintain their perpendicular relationship with the conductor surfaces, as shown in Figure 3. This distortion in the electric field lines creates higher order modes of propagation. Since the connector is not usually designed to transmit these higher order modes of propagation, they are attenuated over a very short distance, and are thus localised in the vicinity of the discontinuity. The higher modes of propagation lead to a power loss from the normal transverse electromagnetic mode, which results in a higher than expected return loss, or VSWR, at higher frequencies. The distortions upon analysis appear capacitive, and are a major source of reflections within an otherwise matched impedance connector.

It is almost impossible to avoid discontinuities in a connector design. For example, methods of terminating of a cable to a connector often result in diameter variations between the cable and the connector. These variations require changes in conductor diameters to maintain the proper impedances, thus creating discontinuities. Below 1000 MHz, these discontinuities usually have no significant effect on the resulting return loss or VSWR. However, at higher frequencies, the discontinuities have a major impact on the performance of the connector.

Figure 2a shows the known high performance coaxial cable 1 shown in Figure 1 terminated with a known coaxial connector 11. For clarity, only the part of the connector 11 that receives the cable 1 is shown in the Figure.

As shown in the Figure, the cable jacket 9 is stripped back from the centre conductor 3 and dielectric material 5 of the cable 1. The conductive foil 7a is also stripped back under the braid 7b to be flush with the cable jacket 9. The centre conductor 3 and the dielectric material 5 are received within a first end 13 of the connector 11. The exposed centre conductor 3 is also received into a centre conductor contact pin 23, and the dielectric material 5 abuts a corresponding insulator element 21 in the connector 11.

The braid 7b is received around the outer surface of the first end 13 of the connector 11. A ferrule 15 is crimped onto outer surface of the first end 13 of the connector 11 to urge the braid 7b against the first end 13 of the connector 11 and to prevent the connector 11 from detaching from the cable 1.

Figure 2a also shows the electric field lines between the centre and outer conductors 3, 7. It can be seen from the Figure that electric filed lines in the intact cable 1 are perpendicular. The electric field lines are slightly distorted in the region adjacent the open end of the first end 13 of the connector 11, where the braid is not parallel with the centre conductor. However, the slight distortion of the electric field lines in this region does not cause significant return loss. Within the first end 13 of the connector 11, the perpendicular orientation of the electric field lines is restored, with the field lines running from the centre conductor 3 to the first end 13 of the connector 11 (which is electrically connected to the braid 7b).

The terminated cable shown in Figure 2a provides acceptable performance in terms of return loss, even at high frequency applications such as high definition video cabling. However, as described above, the arrangement shown in Figure 2a requires that the end of the cable 11 be prepared by cutting the conductive foil 7a away from underneath the braid 7b, so that the end of the conductive foil 7a is approximately flush with the end of the cable jacket 9.

Figure 2b shows the known high performance coaxial cable 1 shown in Figure 1 terminated with the same known coaxial connector 11 as that shown in Figure 2a. However, in this case, only the cable jacket 9 is stripped away from the end of the cable 1, with the conductive foil 7a lying flush with the dielectric material 5. This is the preferred way of preparing the cable, as it does not require any special effort or special tools. Again, for clarity, only the part of the connector 11 that receives the cable 1 is shown in the Figure.

As shown in the Figure, the centre conductor 3, the dielectric material 5 and the conductive foil 7a are received within the first end 13 of the connector 11. The centre conductor 3 is received into the centre conductor contact pin 23 and the dielectric material 5 and the conductive foil 7a abut the insulator element 21 in the connector 11.

The braid 7b is received around the outer surface of the first end 13 of the connector 11 and the ferrule 15 is crimped onto outer surface of the first end 13 of the connector 11.

Figure 2b shows the electric field lines between the centre conductor 3 and the outer conductive foil 7a of the known high performance coaxial cable 1 shown in Figure 1. It can be seen from the Figure that, again, electric filed lines in the intact cable 1 are perpendicular to the centre conductor 3 and outer conductive foil 7a. It can also be seen that a gaped region exists between the outside surface of the conductive foil 7a and the inside surface of the bore of the first end 13 of the connector 11. Within the first end 13 of the connector 11, the electric field lines are generally perpendicular, terminating at the centre conductor 3 and the conductive foil 7a. However, electric field lines from the exposed end of the central conductor 3 do not terminate at the conductive foil

3a, and instead extend in a longitudinal direction from the end of the dielectric material 5 and conductive foil 7a and would terminate at some point within the gaped region. These longitudinal field lines are concentrated in a clearance gap formed between the conductive foil 7a and the inner surface of the first end 13 of the connector 11. The electric field lines are considerably distorted, resulting in a so-called cylindrical reentrant cavity, and thus causing the connector to resonate at a specific frequency.

The invention provides a connector for terminating high performance coaxial cables having an outer conductive foil, which does not cause a cylindrical reentrant cavity and the consequential high return loss, even at high frequencies, and without the need for the end of the cable to be specially prepared as shown in Figure 2.

Figure 4 shows a coaxial connector 17 according to the invention. The coaxial connector 17 comprises a substantially tubular metallic connector body 19, a substantially tubular insulator arrangement 21, a centre conductor contact pin 23 and a ferrule (not shown).

A first end 19a of the body 19 has an open end for receiving the coaxial cable 11. The first end 19a of the body 19 may be formed from a different component to the rest of the body 19, different sized first ends 19a being provided for different sized cables 1. A second end 19b of the body 19 provides a BNC plug for interfacing with a complimentary socket. The design of the second end 19b of the body 19 will be known to the skilled person, and will not be described further. The insulator arrangement 21 is located between the ends of the body 19 so as to be coaxial therewith 19. The insulator arrangement comprises two insulator blocks 21a, 21b through which are formed axial holes. The centre conductor pin arrangement 23 is located in the axial holes in the axial holes of the insulator arrangement 21. The pin arrangement comprises a portion 23a for receiving, via the first 19a end of the body 19, the centre conductor 3 of the coaxial cable 1.

The connector 17 may also comprise a number of other components (not shown) such as a bayonet collar, gaskets, spring washers and split washers. These components are all known from existing connectors and will not be described further.

The first end 19a of the connector body 19 has a bore extending from an open end to the insulator arrangement 21. The inner diameter of the bore steps from a first diameter at the open end to a second, smaller diameter adjacent the insulator arrangement 21. The outer surface of the first end 19a of the body 19 has a knurled surface.

In use, the high performance coaxial cable 1 is prepared in the same way as the cable shown in Figure 2b, by stripping back the dielectric material 5 and the conductive foil 7a to be flush, thereby leaving an exposed portion of centre conductor 3. The cable 1 is then received into the connector 17, as shown in Figure 5.

Referring to Figure 5, it can be seen that the centre conductor 3, the dielectric material 5 and the conductive foil 7a are received within bore of the first end 19a of the connector body 19. The exposed portion of the centre conductor 3 is also received into the centre conductor contact pin 23. The dielectric material 5 and the conductive foil 7a then abut the insulator arrangement 21 of the connector 17. The relative dimensions of the bore and the cable components are such that the dielectric material 5 and conductive foil 7a are easily received into the bore, but that the smaller second diameter of the bore provides an interference fit with the conductive foil 7a adjacent the insulator arrangement 21 of the connector 17.

In the specific example shown in the Figure, the outer diameter of the conductive foil 5 is 3.78mm and the first and second inner diameters of the bore are 3.9mm and 3.68mm respectively.

The braid 7b is received around the outer surface of the first end 19a of the connector body 19, and the ferrule is crimped over the braid.

Figure 5 shows the electric field lines between the centre and outer conductors 3, 7 of the cable. The electric field lines in the intact cable 1 are perpendicular. Within the bore, the electric field lines are perpendicular, terminating at the centre conductor 3 and the conductive foil 7a. However, in contrast to the arrangement shown in Figure 2b, there are no longitudinal electric field lines extending along the length of the first end 19a of the connector body 19. This is because the interference fit between the conductive foil 5 and the bore ensures that there are no clearance gaps to provide a path for the electric field. Instead, the electric filed lines from the exposed portion of the centre conductor terminate directly to the connector body, as shown in the Figure.

As noted above, the elimination of the longitudinal electric field lines reduces return loss and VSWR at high frequencies. Figure 6a, 6b and 6c are graphs showing predicted return loss for the terminated coaxial connectors shown in Figures 2a, 2b and 5 respectively. The graphs are directly comparable. It can be seen from the graph that the return loss for the coaxial connector of the invention (Figure 6c) is a large improvement on that shown in Figure 6b, and is similar to that shown in Figure 6a.

Figure 7a, 7b and 7c are directly comparable graphs showing predicted voltage standing wave ratio (VSWR) for the coaxial connectors shown in Figures 2a, 2b and 5 respectively. Again, it can be seen from the graph that the VSWR for the coaxial connector of the invention (Figure 7c) is a large improvement on that shown in Figure 7b, in that there is no specific resonant frequency. The VSWR for the coaxial connector of the invention is similar to that shown in Figure 7a.

Various modifications to the invention will be apparent to those skilled in the art.

For example, the connector described above is a BNC connector. However, the invention is equally applicable to other types of radio frequency coaxial connector.

In the connector described above, the bore of the first end of the connector body has two inner diameters with a step between them. However, other bore profiles are suitable. For example, the inner diameter of the bore may gradually ramp from the first diameter to the second diameter, or more than two discrete inner diameters may be provided. What is important is that an interference fit is provided between the bore and the conductive foil of the cable adjacent the insulator arrangement of the connector.

Specific dimensions of the bore are provided for the connector described above. However, the actual dimensions of the bore will vary depending on the size and type of the cable.

Claims:

1. A radio frequency coaxial connector for terminating a coaxial cable, the coaxial cable comprising a centre conductor, a dielectric material surrounding the centre conductor and a conductive foil surrounding the dielectric material, the connector comprising:

a substantially tubular metallic connector body arrangement having a first end for receiving the coaxial cable and a second end for interfacing with a complimentary connector; and

a substantially tubular insulator arrangement located in the connector body between the first and second ends and coaxial with the connector body; and

wherein the first end of the connector body arrangement is an open end having a bore extending from the open end to the insulator arrangement for receiving the centre conductor, dielectric material and conductive foil of the cable, and wherein an inner diameter of the bore reduces across a portion of the bore between the open end and the insulator arrangement to provide an interference fit with the conductive foil.

2. The conductor of claim 1, further comprising a centre conductor contact pin arrangement located in the insulator arrangement and coaxial therewith.

3. The connector of claim 1 or 2, further comprising a ferrule for crimping onto the first end of connector body arrangement.

4. The connector of any preceding claim, wherein the second end of the connector body arrangement includes a bayonet collar.

5. The connector of claim 4, wherein the connector is a BNC connector.

6. The connector of any preceding claim, wherein the minimum inner diameter of the bore is 3.75mm or less.

7. The connector of any preceding claim, wherein the maximum inner diameter of the bore is 3.80mm or more.

8. The connector of claim 2, wherein the centre conductor contact pin arrangement includes a receiving portion for receiving a central conductor of the coaxial cable.

9. The connector of any preceding claim, wherein the first end of the connector body arrangement has an outer diameter in the range 4.50mm to 5.50mm.

10. A coaxial lead comprising:

the connector of any preceding claim; and

a coaxial cable including a centre conductor, a dielectric material surrounding the centre conductor, a conductive foil surrounding the dielectric material, a conductive braid surrounding the foil and an outer jacket,

wherein there is an interference fit between the inner surface the bore of the connector and the conductive foil of the cable.

11. The lead of claim 10, wherein the centre conductor, dielectric material and conductive foil of the coaxial cable are received within the bore of the first end of the connector body arrangement.

12. The lead of claim 11, wherein the outer diameter of the conductive foil is in the range 3.76mm to 3.79mm.

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 0419303.3	**Examiner:**	Jens Skou
Claims searched:	1 - 12	**Date of search:**	25 January 2005

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
A	-	US 6402550 B2	(MATSUBARA HIROSHI) See Abstract, column 4, line 62 to column 5, line 3, and figure 2.
A	-	US 2004/0018771 A1	(TOGASHI KOJI) See section [0011] - [0013] and figure 4b.
A	-	GB 2019665 A	(BUNKER RAMO) See abstract; page 2, line 115-126 and figure 2.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category	P	Document published on or after the declared priority date but before the filing date of this invention
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X}:

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

H01R

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, JAPIO