Guidance on using Precision Coaxial Connectors in Measurement

Photograph Nick Ridler NPL

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For this edition the sections on the various connectors have been revised. The section on torque spanners and connector gauging has been expanded. The opportunity has also been taken to make some editorial revisions.

This guide covers common precision and related connectors used at DC, Low Frequency, Radio Frequency, Microwave and Millimetre-wave Frequencies.

Every effort has been made to ensure that this guide contains accurate information obtained from many sources that are acknowledged where possible. However the NPL, ANAMET and the Compiler cannot accept liability for any errors, omissions or misleading statements in the information. The Compiler would also like to thank all those members of ANAMET who have supplied information, commented on and given advice on the preparation of this document.

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GUIDANCE ON USING PRECISION COAXIAL CONNECTORS IN MEASUREMENT

1. INTRODUCTION

The importance of the correct use of coaxial connectors not only applies at radio and microwave frequencies but also at DC and low frequency. The requirement for ‘Traceability to National Standards’ for measurements throughout industry may depend on several different calibration systems ‘seeing’ the same values for the parameters presented by a device at its coaxial terminals. It is not possible to include all the many different types of connectors in this guide and the selection has been made on those connectors used on measuring instruments and for metrology use.

It is of vital importance to note that mechanical damage can be inflicted on a connector when a connection and disconnection is made at any time during its use.

The common types of precision and general-purpose coaxial connectors that are in volume use worldwide are the Type N, 3.5mm, Type K, 7/16, TNC, BNC, and SMA connectors. These connectors are employed for interconnection of components and cables in military, space, industrial and domestic applications.

The simple concept of a coaxial connector comprises an outer conductor contact, an inner conductor contact, and means for mechanical coupling to a cable and/or to another connector. Most connectors, in particular the general-purpose types, comprise of a pin and socket construction.

There are basically two types of coaxial connectors in use and they are known as Laboratory Precision Connectors (LPC) using only air dielectric or General Precision connectors (GPC) having a self contained, low reflection dielectric support. There is also a number of general purpose connectors in use within the GPC group but they are not recommended for metrology use e.g. some versions of Type N

Some connectors are hermaphroditic (non-sexed), particularly some of the laboratory precision types, and any two connectors may be joined together. They have planar butt contacts and are principally employed for use on measurement standards and on equipment and calibration systems where the best possible uncertainty of measurement is essential. Most of the non-sexed connectors have a reference plane that is common to both the outer and inner conductors. The mechanical and electrical reference planes coincide and, in the case of the precision connectors, a physically realised reference plane is clearly defined. Hermaphroditic connectors are used where the electrical length and the characteristic impedance is required at the highest accuracy. The 14mm, 7mm connectors are examples of this type of construction and they are expensive.

Laboratory Precision Connectors and General precision connectors of the plug and socket construction look similar but the materials used in the construction are often completely different. The best quality connectors are more robust are often made of materials like stainless steel and the mechanical tolerances are more precise. It is important to be clear on the quality of the connector being used. The general precision connector types in common use are the, Type 7/16, Type N 7mm, 3.5mm, Type K 2.92mm, 2.4mm,Type V 1.85mm and 1.0mm Connectors

The choice of connectors, from the range of established designs, must be appropriate to the proposed function and specification of the device or measurement system. Often a user requirement is for a long life quality connector with minimum effect on the performance of the device it is used on and the repeatability of the connection is generally one of the most important parameters.

Coaxial line sizes

Some coaxial line sizes for establishing a characteristic impedance of 50Ω are shown in Table 1. They are chosen to achieve the desired performance over their individual operating frequency range up to 110GHz for the 1mm connector.

Inside diameter of the outer conductor in mm (nominal)	16	14.29	7.00	3.50	2.92	2.40	1.85	1.00
Rated minimum upper frequency limit in GHz	7.5	8.5	18.0	33.0	40.0	50.0	65.0	110.0
Theoretical limit in GHz for the onset of the TE_{11} (H_{11}) mode	-	9.5	19.4	38.8	46.5	56.5	73.3	135.7

Table 1 Coaxial line sizes for 50Ω characteristic impedance

2. CONNECTOR REPEATABILITY

Connectors in use on test apparatus and measuring instruments at all levels need to be maintained in pristine condition in order to retain the performance of the test apparatus. The connector repeatability is a key contribution to the performance of a measurement system.

Connector repeatability can be greatly impaired because of careless assembly, misalignment, over-tightening, inappropriate handling, poor storage, and unclean working conditions. In extreme cases, permanent damage can be caused to the connectors concerned and possibly to other originally sound connectors to which they are coupled.

Connectors should never be rotated relative to one another when being connected and disconnected. Special care should be taken to avoid rotating the mating plane surfaces against one another.

Handling of airlines

When handling or using airlines and similar devices used in automatic network analyser, calibration and verification kits it is extremely important to avoid contamination of the component parts due to moisture and finger marks on the lines. Protective lint free cotton gloves should always be worn. The failure to follow this advice may significantly reduce performance and useful life of the airlines.

Assessment of connector repeatability

In a particular calibration or measurement system, repeatability of the coaxial interconnections can be assessed from measurements made after repeatedly disconnecting and reconnecting the device. It is clearly necessary to ensure that all the other conditions likely to influence the alignment are maintained as constant as possible.

In some measurement situations it is important that the number of repeat connections made uses the same positional alignment of the connectors.

In other situations it is best to rotate one connector relative to the other between connections and reconnections. For example, when calibrating or using devices fitted with Type N connectors (e.g. power sensors or attenuator pads) three rotations (approximately 120°) or five rotations (approximately 72°) are made. However, it is important to remember to make the rotation before making the contact.

The repeatability determination will normally be carried out when trying to achieve the best measurement capability on a particular device, or when initially calibrating a measuring system. The number of reconnections and rotations can then be recommended in the measurement procedure.

Repeatability of the insertion loss of coaxial connectors introduces a major contribution to the Type A component of uncertainty in a measurement process. If a measurement involving connectors is repeated several times, the Type A uncertainty contribution deduced from the results will include that arising from the connector repeatability provided that the connection concerned is broken and remade at each repetition.

It should be remembered that a connection has to be made at least once when connecting an item under test to the test equipment and this gives rise to a contribution to the Type A associated with the connector repeatability.

Experience has shown that there is little difference in performance between precision and ordinary connectors (when new) so far as the repeatability of connection is concerned, but with many connections and disconnections the ordinary connector performance will become progressively inferior when compared with the precision connector.

3. COAXIAL CONNECTOR SPECIFICATIONS

The following specifications are some of those that provide information and define the parameters of established designs of coaxial connectors and they should be consulted for full information on electrical performance, mechanical dimensions and mechanical tolerances.

Connector Standards

IEEE Standard 287 for Precision Coaxial Connectors (DC to 110GHz). New version 2007.
Highly Recommended reference document.
IEC Publication 457
MIL-STD-348A incorporates MIL-STD-39012C
IEC Publication 169
CECC 22000
British Standard 9210
DIN 47223

Users of coaxial connectors should also take in to account any manufacturer's performance specifications relating to a particular connector type in use.

4. INTERFACE DIMENSIONS AND GAUGING

It is of the utmost importance that connectors do not damage the test equipment interfaces to which they are offered for calibration. Poor performance of many coaxial devices and cable assemblies can often be traced to poor construction and non-compliance with the mechanical specifications. The mechanical gauging of connectors is essential to ensure correct fit and to achieve the best performance. This means that all coaxial connectors fitted on all equipment, cables and terminations etc. should be gauged on a routine basis in order to detect any out of tolerance conditions that may impair the electrical performance.

Gauging connectors

A connector should be gauged before it is used for the very first time or if someone else has used the device on which it is fitted.

If the connector is to be used on another item of equipment, the connector on the equipment to be tested should also be gauged.

Connectors should never be forced together when making a connection since forcing often indicates incorrectness and incompatibility. Many connector screw coupling mechanisms, for instance, rarely need to be more than finger tight for electrical calibration purposes; most coaxial connectors usually function satisfactorily, giving adequately repeatable results, unless damaged. There are some dimensions that are critical for the mechanical integrity, non-destructive mating and electrical performance of the connector.

Connector gauge kits are available for many connector types but it is also easy to manufacture simple low cost test pieces for use with a micrometer depth gauge or other device to ensure that the important dimensions can be measured or verified.

The mechanical gauging of coaxial connectors will detect and prevent the following problems:

Inner conductor protrusion

This may result in buckling of the socket contacts or damage to the internal structure of a device due to the axial forces generated.

Inner conductor recession

This will result in poor voltage reflection coefficient, possibly unreliable contact and could even cause breakdown under peak power conditions.

Appendix A shows a list of the most common types of coaxial connector in use.

Appendix B gives information on the various connector types including the critical mechanical dimensions that need to be measured for the selected connector types.

Inner conductor Gap

A mated connector pair normally has a discontinuity or gap at the inner conductor junction. This gap is the result of finite mechanical tolerances that are used to manufacture the connectors. The electrical performance of a connector pair can degrade significantly if this gap is too large. Discontinuities in coaxial transmission lines have been studied by various authors, including MacKenzie and Sanderson, Moreno, Somlo, Whinnery and Jamieson. The results from the studies are slightly different depending on how the gap is modelled. The IEEE 287 standard describes the measurements made and includes a number of connectors such as the 14mm, 7mm, Type N 7mm, 3.5mm, 2.92mm, and 2.4mm. For further information consult the relevant part of the IEEE P287 standard

Inner conductor slotted contact.

A study was undertaken to determine the errors associated with the use of slotted contacts in pin and socket connectors. Modelling techniques were used to obtain values of return loss performance characteristics for slotted socket contacts when exposed to pin shank diameters that varied according to the tolerances specified in the standard. The study was conducted by two members of the P287 subcommittee namely Paul Watson of Hewlett-Packard and John Juroshek of NIST. Different modelling techniques were used to obtain return loss values for the connector types used in this study, which included: Type N, 3.5mm, 2.92mm, 2.4mm 1.85mm and 1.0mm. For further information consult the relevant part of the IEEE P287 standard

5. CONNECTOR CLEANING

To ensure a long and reliable connector life, careful and regular inspection of connectors is necessary and cleaning of connectors is essential to maintaining good performance. Awareness of the advantage of ensuring good connector repeatability and its effect on the overall uncertainty of a measurement procedure should encourage careful inspection, interface gauging and handling of coaxial connectors.

Visual inspection

Prior to use, connectors including new ones and those fitted to cables should be inspected for dents, raised edges, and scratches on the mating surfaces and other physical damage. Connectors that have dents on the mating surfaces will also have raised edges around them and will make less than perfect contact; further to this, raised edges on mating interfaces will make dents and damage to other connectors to which they are mated. Connectors should always be replaced unless the damage is very slight.

A visual examination should be made of a connector or adaptor, particularly for concentricity of the centre contacts and for dirt on the PTFE dielectric. It is essential that the axial position of the centre contact of all items offered for calibration should be gauged because the butting surfaces of mated centre contacts must not touch. If the centre contacts do touch, there could be damage to the connector or possibly to other parts of the device to which the connector is fitted. For precision hermaphroditic connectors the two centre conductor spring loaded petals do butt up and the dimensions are critical for safe connections.

Connector Cleaning Procedure

The items required for the satisfactory cleaning of connectors are listed below and the cleaning procedure to be followed is also described

a. Low pressure compressed air (solvent free).
b. Cotton cleaning swabs and other similar swabs e.g. Microtabs can be obtained for this purpose.
c. Lint free cleaning cloth.
d. Isopropanol.
e. Illuminated magnifier or a jewellers eye glass
f. Soft wooden pointed cocktail stick
g. Lint free gloves or similar types
h. Grounding wrist strap (for static sensitive devices)

Note:
Isopropanol that contains additives should not be used for cleaning connectors as it may cause damage to plastic dielectric support beads in coaxial and microwave connectors. It is important to take any necessary safety precautions when using chemicals or solvents.

First Step

Remove loose particles on the mating surfaces and threads etc. by using low-pressure compressed air. Small particles, usually of metal, are often found on the inside connector mating planes, threads, and on the dielectric. They should be removed to prevent damage to the connector surfaces. A wooden cocktail stick can be used to ***carefully*** remove any small particles that the compressed air does not remove.

Second Step

Clean surfaces using Isopropanol on cotton swabs or lint free cloth. Use only sufficient solvent to clean the surface. When using swabs or lint free cloth, use the least possible pressure to avoid damaging connector surfaces. Do not spray solvents directly on to connector surfaces or dielectrics. Do not use contaminated solvents.

Third Step

Use the low-pressure compressed air once again to remove any remaining small particles and to dry the surfaces of the connector to complete the cleaning process before using the connector.

Cleaning connectors on static sensitive devices

Special care is required when cleaning connectors on test equipment containing static sensitive devices. When cleaning such connectors always wear a grounded wrist strap and observe correct procedures. The cleaning should be carried out in a special handling area. These precautions will prevent electrostatic discharge (ESD) and possible damage to circuits.

6. CONNECTOR LIFE

The number of times that a connector can be used is very difficult to predict and it is quite clear that the number of connections and disconnections that can be achieved is dependent on the use, environmental conditions and the care taken when making a connection. Some connector bodies such as those used on the Type N connector are made using stainless steel and are generally more rugged, have a superior mechanical performance and a longer useable life. The inner connections are often gold plated to give improved electrical performance.

For many connector types the manufacturer's specification will quote the number of connections and disconnections that can be made. The figure quoted may be as high as >5000 times but this figure assumes that the connectors are maintained in pristine condition and correctly used. For example, the Type SMA connector was developed for making interconnections within equipment and its connector life is therefore relatively short in repetitive use situations.

However, by following the guidance given in this document it should be possible to maximise the lifetime of a connector used in the laboratory.

7. ADAPTORS

Buffer adaptors or 'connector savers' can be made use of in order to reduce possible damage to output connectors on signal sources and other similar devices. However, it should be remembered that the use of buffer adaptors and so called "connector savers" may have an adverse effect on the performance of a measurement system and may result in significant contributions to uncertainty budgets.

Adaptors are often used for the following reasons:

1. To reduce wear on expensive or difficult to replace connectors on measuring instruments where the reduction in performance can be tolerated.
2. When measuring a coaxial device that is fitted with an SMA connector.

8. CONNECTOR RECESSION

The ideal connector pair would be constructed in such a way in order to eliminate any discontinuities in the transmission line system into which the connector pair is connected. In practice, due to the mechanical tolerances there will almost always be a small gap between the mated plug and socket connectors. This small gap is often referred to as "recession".

It may be that both of the connectors will have some recession because of the mechanical tolerances and the combined effect of the recession is to produce a very small section of transmission line that will have different characteristic impedance than the remainder of the line causing a discontinuity.

The effect of the recession could be calculated but there are a number of other effects present in the mechanical construction of connectors that could make the result unreliable. Some practical experimental work has been carried out at Agilent Technologies on the effect of recession. For more information a reference is given in Appendix F to an ANAMET paper where the results of some practical measurements have been published.

The connector specifications give limit values for the recession of the plug and socket connectors when joined (see, for example, Appendix B for the Type N connector). The effects on the electrical performance caused by recession in connectors is a subject of special interest to users of network analysers and more experimental work needs to be carried out. The IEEE Standard 287 Annex B describes study work the discontinuities in coaxial lines carried out by various authors. The results of the studies differ depending how the gap is modelled.

9. CONCLUSIONS

The importance of the interconnections in measurement work should never be under estimated and the replacement of a connector may enable the Type A uncertainty contribution in a measurement process to be reduced significantly. Careful consideration must be given, when choosing a connector, to select the correct connector for the measurement task. In modern measuring instruments, such as power meters, spectrum analysers and signal generators, the coaxial connector socket on the front panel is often an integral part of a complex subassembly and any damage to this connector may result in a very expensive repair.

It is particularly important when using coaxial cables, with connectors that are locally fitted or repaired that they are tested before use to ensure that the connector complies with the relevant mechanical specification limits. All cables, even those obtained from specialist manufacturers, should be tested before use. Any connector that does not pass the relevant mechanical tests should be rejected and replaced.

Further information on coaxial connectors can be obtained direct from manufacturers. Many connector manufacturers have a web site and there are other manufacturers, documents and specifications that can be found by using a search engine such as www.google.com and searching by connector type.

For more information on the evolution, development and history of connectors the following document is recommended from the Maury Microwave Corporation.

Mario A Maury, Jr Microwave Coaxial Connector Technology: A continuing Evolution Maury Microwave Corporation 13 December 2005. Maury Connector guide. PDF

Appendix A

Frequency range of some common coaxial connectors

The tables below list common types of coaxial connectors used on measurement systems showing the frequency range over which they are often used and the approximate upper frequency limit for the various line sizes.

Title	Line Size	Impedance	Upper Frequency Range (for normal use)	Upper Frequency Limit (approximate value)
GR900	**14.2875mm**	**50Ω**	**8.5GHz**	**9.5GHz**
GPC14	**14.2875mm**	**75Ω**	**3.0GHz***	**-**
7mm	**7.0mm**	**50Ω**	**18GHz**	**19.4GHz**

Table A.1. Precision non-sexed connectors

Title	Line Size	Impedance	Upper Frequency Range (for normal use)	Upper Frequency Limit (approximate value)
Type N	**7.0 mm**	**50Ω**	**18GHz**	**19.4GHz**
3.5mm	**3.5mm**	**50Ω**	**33GHz**	**38.8GHz**
Type K	**2.92mm**	**50Ω**	**40GHz**	**46.5GHz**
Type Q	**2.4mm**	**50Ω**	**50GHz**	**60GHz**
Type V	**1.85mm**	**50Ω**	**65GHz**	**73.3GHz**
1.0mm	**1.0mm**	**50Ω**	**110GHz**	**135.7GHz**

Table A 2. Precision sexed connectors

Title	Line Size	Impedance	Upper Frequency Range for normal use
Type N	**7.0mm**	**50Ω**	**18GHz**
Type N	**7.0mm**	**75Ω**	**3GHz***
7/16	**16.0mm**	**50Ω**	**7.5GHz**
SMA	**3.5mm**	**50Ω**	**26.5GHz**

Table A.3. General purpose connectors

** Measurements made in 75Ω impedance system are normally restricted to an upper frequency limit of 3GHz*

Appendix B

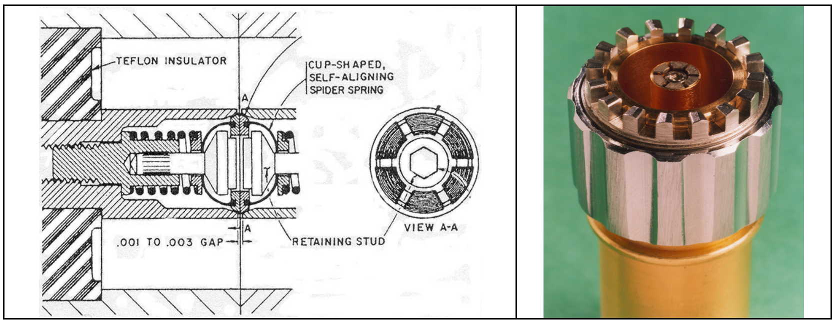
B.1. 14 mm precision connector

The 14mm precision connector was developed in the early 1960s by the General Radio Company and is known as the GR900 connector. It has seen limited usage and is mainly used in primary standards laboratories and in military metrology. It is probably the best coaxial connector ever built in terms of its performance and it has low insertion loss, low reflection and extremely good repeatability. However, it is bulky and expensive. The interface dimensions for the GPC 14mm connector are given in IEEE Standard 287 and IEC Publication 457. There are 50Ω and 75Ω versions of the GR900 connector available. The GR900 14mm connector is made in two types.

LPC	**Laboratory precision connector**	**Air dielectric**
GPC	**General precision connector**	**Dielectric bead support**

The LPC version is usually fitted to devices such as precision airlines for use in calibration and verification kits for automatic network analysers and reflectometers.

Before use, a visual examination, particularly of the centre contacts, should be made. Contact in the centre is made through sprung inserts and these should be examined carefully. A flat smooth disc pressed against the interface can be used to verify correct functioning of the centre contact. The disc must fit inside the castellated coupling ring that protects the end surface of the outer connector and ensures correct alignment of the two connectors when mated. The inner connector should be gauged with the collet removed. A special tool kit is available for use with GR900 connectors. There is also another version of the 14mm connector designated the GR890. The GR890 connector has a much reduced specified frequency range of operation limited to approximately 3GHz and it can be identified by the different marking on the locking ring as shown in Figure1b.



Photograph NPL

Figure 1a GR 900 14mm connector

Photograph Doug Skinner

Figure 1b GR890 connector locking ring

B.2. 7 mm precision connector

This connector series was developed to meet the need for precision connectors for use in laboratory measurements over the frequency range DC to 18GHz. This connector is known as the Type 7mm connector and it is designed as a hermaphroditic connector with an elaborate coupling mechanism. The connector interface features a butt co-planar contact for the inner and outer contacts, with both the mechanical and electrical interfaces at the same location. A feature of the 7mm connector is its ruggedness and good repeatability over multiple connections in a laboratory environment.

The connector is made in two types.

GPC	**General precision connector**	**Dielectric support**
LPC	**Laboratory precision connector**	**Air dielectric**

The LPC version is usually fitted to devices such as precision airlines for use in calibration and verification kits for automatic network analysers and reflectometers.

The interface dimensions for the 7mm connector are given in IEEE Standard 287 and IEC 457. The most common connector of this type in the UK has a centre contact comprising a slotted resilient insert within a fixed centre conductor. The solid part of the centre conductor must not protrude beyond the planar connector reference plane, although the resilient inserts must protrude beyond the reference plane. However, the inserts must be capable of taking up co-planar position under pressure. A flat, smooth plate or disc, pressed against the interfaces can verify correct functioning of the centre contact.

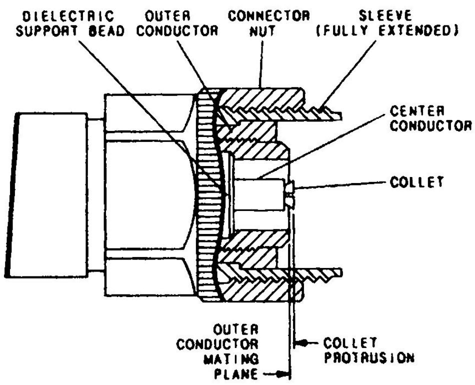
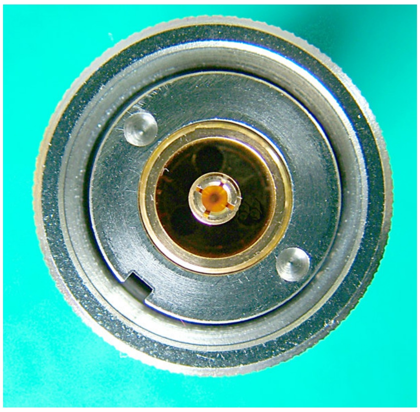
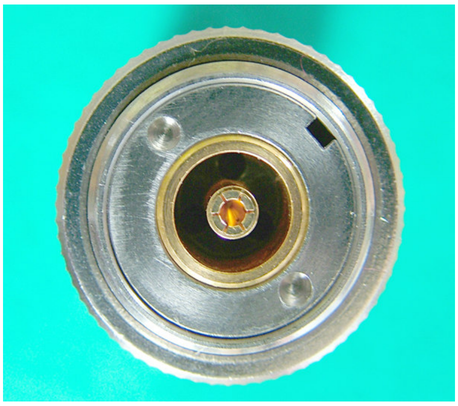


Figure 2.1 7mm connector

Figure 2.1 shows the construction of the 7mm Connector and the location of the outer conductor mating plane. The use of the 7mm connector is normally restricted to making precision measurements in calibration laboratories and special applications





Photograph Doug Skinner

Figure 2.2a 7mm 4 slot collet ***Figure 2.2b 7mm 6 slot collet***

There are two versions of the collet for this connector one that has 4 slots see Figure 2.2a and the other with 6 slots as in Figure 2.2b. For best performance it is good practice to replace the 4-slot version with the 6-slot type. The 4 collet version should not be used above 10GHz

Connection and disconnection of 7mm connectors

It is important to use the correct procedure when connecting or disconnecting 7mm connectors to prevent damage, to ensure a long working life and a consistent electrical performance. The following procedure is recommended for use with 7mm connectors.

Connection

1. On one connector, retract the coupling sleeve by turning the coupling nut until the sleeve and the nut become disengaged. The coupling nut can then be spun freely with no motion of the coupling sleeve.
2. On the other connector, the coupling sleeve should be fully extended by turning the coupling nut in the appropriate direction. Once again the coupling nut can be spun freely with no motion of the coupling sleeve.
3. Put the connectors together carefully but firmly, and thread the coupling nut of the connector with the retracted sleeve over the extended sleeve. Finally tighten using a torque spanner set to the correct torque (see appendix D).

Disconnection

1. Loosen the fixed coupling nut of the connector showing the wide gold band behind the coupling nut. This is the one that had the coupling sleeve fully retracted when connected.
2. Part the connectors carefully to prevent damage to the inner conductor collet.

It is a common but bad practice with hermaphroditic connectors, to screw the second coupling ring against the first in the belief that there should be no loose parts in the coupled pair. This reduces the pressure between the two outer contacts of the connectors, leading to higher contact resistance and less reliable contact.

To avoid damage, connectors with retractable sleeves (e.g. 7mm) should not be placed face down on their reference plane on work surfaces. When not in use withdraw the threaded sleeve from under the coupling nut and fit the plastic protective caps

When connecting any mating surfaces together it is important not to allow the reference plane surfaces rub against each other because the mating surfaces will be severely damaged and the life of the connector will be considerably reduced. Hold the connector surfaces together lightly but firmly in one position and tighten using a torque spanner

.

B.3. Type N 7 mm connector

The Type N connector is a rugged connector that is often used on portable equipment and military systems because of its large size and robust nature. The design of the connector makes it relatively immune to accidental damage due to misalignment during mating (subject to it being made and aligned correctly). The Type N connector is made in both 50Ω and 75Ω versions and both types are in common use.

Figure 3 Type N plug

Figure 3.2 Type N Socket slotless

Figure 3.3 Type N Socket slotted

Photographs NPL

Two different types of inner sockets are at present available for Type N socket connectors. They are referred to as "slotted" or "slotless" sockets. The slotted Type N normally has either four or six slots cut along the inner conductor axis to form the socket. The diameter and therefore the characteristic impedance, is determined by the diameter of the mating pin and it easy to damage or distort the slotted socket and can add a discontinuity to the line impedance. Compensation of this impedance change cannot be easily achieved. The slotted inner is normally only fitted to general purpose versions of the Type N connector. The development of the slotless socket by Julius Botka of Hewlett Packard (Agilent) in 1988 see Figure 3.2.a provided a solid inner conductor with internal contacts and so it eliminated the effect of the mating pin distortion and therefore provided an improved and more consistent performance. There are also slotless versions for the 3.5mm and 2.4mm connectors. The slotless socket was patented by Hewlett Packard in 1988.

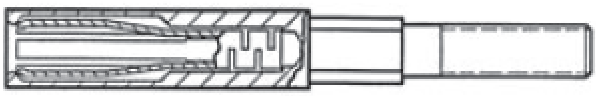


Figure 3.2.a Slotless socket for the Type N Connector

The reference plane for the Type N connector is the junction surface of the outer conductors. Unlike some other pin and socket connectors the junction surface of the inner connector is offset from the reference plane by 5.258mm (0.207 in). The offset is designed this way in order to reduce the possibility of mechanical damage due to misalignment during the connection process. The construction and mechanical gauging requirements for the Type N connector are shown in Figure 3.4. The offset specifications can vary and the different values shown in the table below show various values depending on the specification used. The electrical performance of a beadless airline is particularly dependent upon the size of the gap at the inner connector junction due to manufacturing tolerances in both the airline and the test port connectors. Therefore for the best performance it is important minimize the gap to significantly improve the electrical performance. It is important to note the manufacturer's specification for any particular Type N connector being used. To meet the present MIL-STD-348A requirement the minimum recession on the pin centre contact is 5.283 mm (0.208 in).

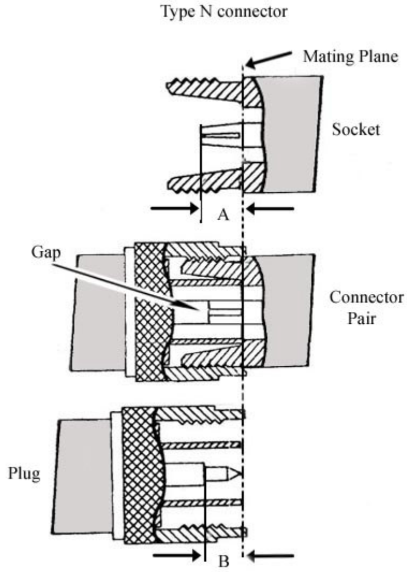


Figure 3.4 Type N connector

For some applications Type N connectors need only be connected finger tight but torque settings are given in appendix D that should be used in metrology applications. The gauging limits are listed in Table 3 and apply to both 50Ω and 75Ω connector types. For the convenience of users the dimensions are given in Imperial and Metric Units. The metric values are shown in brackets.

Type N	**Dimensions in inches (*mm*)**		**Gap between mated centre contacts**		
Specification	**Socket**	**Plug**	**Min**	**Nom**	**Max**
MMC Precision also HP Precision	**0.000 (*0.000*) 0.207 (*5.2578*) –0.003 (*–0.0762*)**	**+ 0.003 (*+0.0762*) 0.207 (*5.2578*) 0.000 (*0.0000*)**	**0.000 (*0.000*)**	**0.000 (*0.000*)**	**0.006 (*0.1524*)**
MIL-STD-348A Standard Test	**0.000 (*0.0000*) 0.207 (*5.2578*) – 0.003 (*–0.0762*)**	**+ 0.003 (*+0.0762*) 0.208 (*5.2832*) 0.000 (*0.0000*)**	**0.001 (*0.0254*)**	**0.001 (*0.0254*)**	**0.007 (*0.1778*)**
MIL-STD-348A Class 2 Present Type N	**0.207 max (*5.2578*)**	**0.208 min (*5.2832*)**	**–**	**0.001 (*0.0254*)**	**–**
MMC Type N equivalent to MIL-C-71B	**+ 0.005 (*+0.1270*) 0.197 (*5.0038*) – 0.005 (*– 0.1270*)**	**+ 0.005 (*+0.1270*) 0.223 (*5.6642*) – 0.005 (*– 0.1270*)**	**0.016 (*0.4064*)**	**0.026 (*0.6604*)**	**0.036 (*0.9144*)**
MIL-C-71B Old Type N	**+ 0.010 (*+0.254*) 0.197 (*5.0038*) – 0.010 (*– 0.2540*)**	**+ 0.010 (*+0.2540*) 0.223 (*5.6642*) – 0.010 (*– 0.2540*)**	**0.006 (*0.1524*)**	**0.026 (*0.6604*)**	**0.046 (*1.1684*)**

Table 3 Type N connector

The Type N connector has been designed to operate up to 18GHz but special versions are available that can operate up to 22GHz and also to 26.5GHz. However, traceability of measurement is not at present available for devices fitted with 7mm connectors above 18GHz.

This paragraph is repeated here as it is important for a long life of type N connectors as they are the most common metrology connector used many calibration laboratories. When connecting any mating surfaces together it is important not to allow the reference plane surfaces rub against each other because the mating surfaces will be severely damaged and the life of the connector will be considerably reduced. Hold the connector surfaces together lightly but firmly in one position and tighten using a torque spanner.

Gauging a plug Type N connector

When gauging a plug Type N connector a clockwise deflection of the gauge pointer (a “plus”) indicates that the shoulder of the plug contact pin is recessed less than the minimum recession of 0.207 inches behind the outer conductor mating plane. This will cause damage to other connectors to which it is mated.

Gauging a socket Type N connector

When gauging a socket Type N connector a clockwise deflection of the gauge pointer (a “plus”) indicates that the tip of the socket mating fingers are protruding more than the maximum of 0.207 inches in front of the outer conductor mating plane. This will cause damage to other connectors to which it is mated.

75Ω Type N Connectors

The 75Ω version of the Type N coaxial connector is a similar design to the Type N 50Ω connector except that the centre conductor is of a smaller diameter. This is necessary to give the correct impedance of 75Ω for the same inner diameter of the outer conductor

Warning

On the 75Ω connector the centre contact of the socket can be physically destroyed by a 50Ω pin centre contact so that cross coupling of 50Ω and 75Ω connectors is not admissible

Special adaptors can be purchased, which are commonly known as ‘short transitions’; to enable the connection to be made if necessary, but these transitions should be used with caution. If possible it is best to use a minimum loss attenuation pad to change the impedance to another value.

In order to prevent accidental damage it is useful to adopt a local colour coding system to quickly identify 75Ω connectors, adaptors and cables

B.4. 7/16 connector

The 7/16 precision coaxial connector was developed in Germany during the 1960s during an era when such connectors were beginning to become standardised. It is experiencing a resurgence of interest due to its particular suitability for certain applications in high performance military systems and cellular base station installations; including high power 3G systems. The 7/16 connector is designed to a DIN specification number 47223.

The name of the connector comes from the nominal values of 16 mm at the interface for the internal diameter of the outer conductor, and 7 mm for the diameter of the centre conductor. The exact ratio is chosen such that it gives a nominal impedance of 50 ohms.

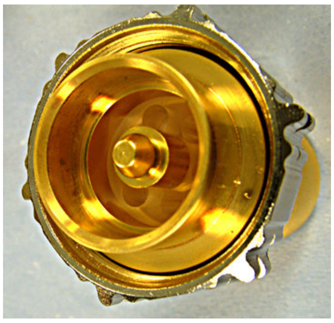
This connector is now being widely used in the telecommunications industry and it has a frequency range covering from DC to 7.5 GHz. It has an excellent electrical performance including low insertion and return loss, good connection repeatability and high power handling capability. It is mechanically robust and exhibits low Passive Inter-Modulation (PIM).

High quality devices fitted with 7-16 connectors are available for use as standards for calibrating Vector Network Analysers, reflection analysers and other similar measuring instruments.

In response to the growing demand for assurance of measurements of devices in this connector type the UK National Physical Laboratory has set up calibration service with traceability to UK National Standards (and hence to the international system of units SI). At present only impedance (i.e. complex *S*-parameters) and antenna measurements are available but attenuation and power measurement services will soon be introduced. A calibration service providing measurements of characteristic impedance of precision air lines in this line size is also available.

A range of push on adaptors is available to eliminate the time consuming need for tightening, and disconnecting using a torque spanner.

Terminations, mismatches, open and short circuits are available and back to back, plug to plug, socket to plug and socket to socket adaptors are also made.



Photographs Doug Skinner

Figure 4 7/16 Connector

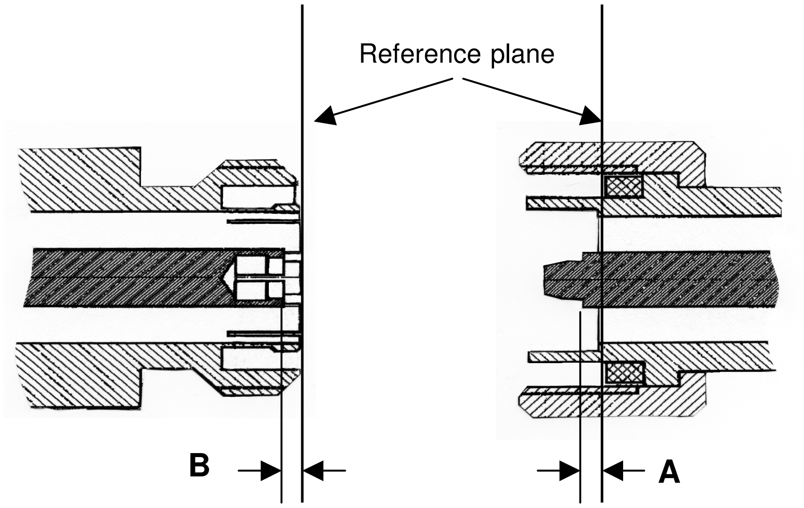


Figure 4.1 7/16 socket connector ***Figure 4.2 7/16 plug connector***

The mechanical gauging requirements for the 7/16 connector are shown in the table below.

7-16	Dimensions							
Specification	**A**				**B**			
	Plug - Inches		**Plug - mm**		**socket - Inches**		**socket - mm**	
GPC	**0.0697** +0.000 -0.010		**1.77** *+0.00* *-0.25*		**0.0697** +0.012 -0.000		**1.77** *+0.30* *-0.00*	
LPC	**0.0697** +0.0000 -0.0015		**1.77** *-0.000* *-0.038*		**0.0697** +0.0000 -0.0015		**1.77** *+0.038* *-0.000*	
European 7/16	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
General purpose	0.0579	0.0697	*1.47*	*1.77*	0.0697	0.0815	*1.77*	*2.07*
Reference/ test	0.06811	0.06890	*1.73*	*1.75*	0.07047	0.07126	*1.79*	*1.81*

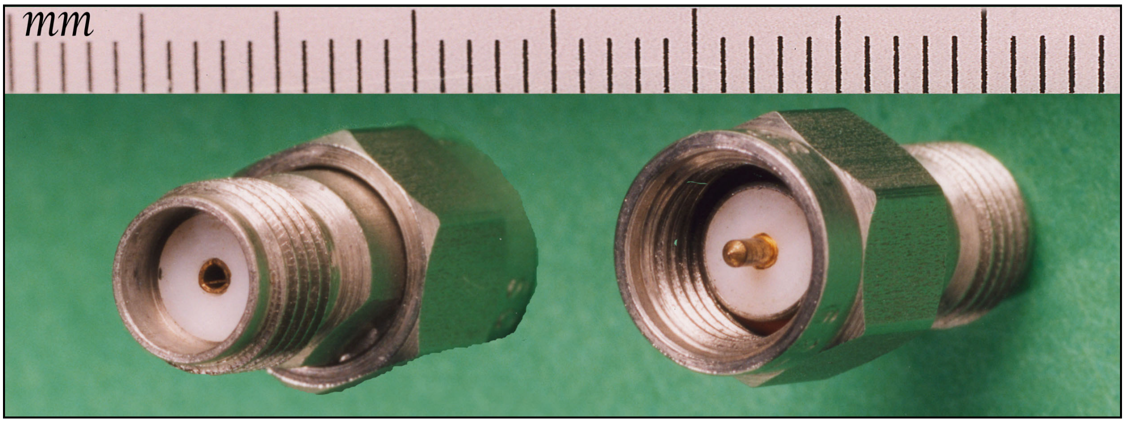
Table 4 7/16 Connector

For further information on the 7/16 connector the article by Paynter and Smith is recommended. This article describes the 7/16 connector and discusses whether to use Type N connector technology or to replace it with the 7/16 DIN 47223 interface for use in mobile radio GSM base stations.

B.5. SMA connector

The interface dimensions for SMA connectors are listed in MIL-STD 348A.

BS 9210 N0006 Part 2 published primarily for manufacturers and inspectorates, also gives details for the SMA interface but some of the requirements and specification details differ. For example, wall thickness may be a little thinner and hence a little weaker. However, MIL-STD-348A does not preclude thin walls in connectors meeting this specification although the physical requirements and arrangements will probably ensure that thicker walls are used for both specifications.



Photograph NPL

Figure 5 SMA Connector

The SMA connector is **a semi-precision** connector and should be carefully gauged and inspected before use as the tolerances and quality can vary between manufacturers. The user should be aware of the SMA connector's limitations and look for possible problems with the solid plastic dielectric and any damage to the plug pin. In a good quality SMA connector the tolerances are fairly tight. However the SMA connector is not designed for repeated connections and they can wear out quickly, be out of specification, and potentially destructive to other connectors. The SMA connector is widely used in many applications as it is a very cost-effective connector and suitable for many purposes however, precision metrology is not normally possible using SMA connectors?

Connector users are advised that manufacturers' specifications vary in the value of coupling torque needed to make a good connection. Unsatisfactory performance with hand tightening can indicate damage or dirty connector interfaces. It is common but bad practice to use ordinary spanners to tighten SMA connectors however, excessive tightening (>15 lb. in) can easily cause collapse of the tubular portion of the pin connector.

Destructive interference may result if the contacts protrude beyond the outer conductor mating planes; this may cause buckling of the socket contact fingers or damage to associated equipment during mating.

The dielectric interface is also critical since protrusion beyond the outer conductor-mating plane may prevent proper electrical contact, whereas an excessively recessed condition can introduce unwanted reflections in a mated pair.

The critical axial interface of SMA type connectors is shown in Figures 5.2, 5.3 and Table 5 where the dimensions are given in inches, with the equivalent in millimetres shown in brackets.

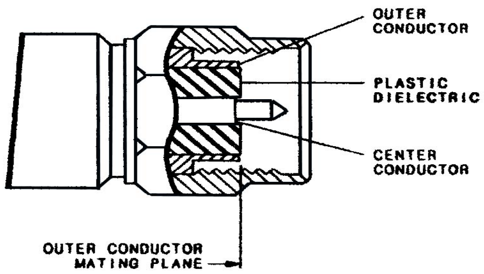


Figure 5.2 SMA plug connector

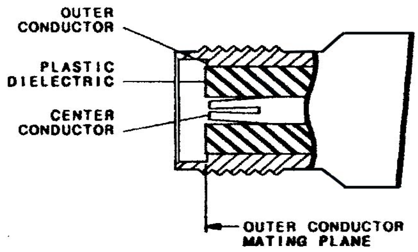


Figure 5.3 SMA socket connector

SMA	Dimensions inches (*mm*)			
Specification	Socket Pin	Socket dielectric	Plug Pin	Plug dielectric
MIL-STD-348A Class 2	+ 0.030 (*0.7620*) 0.000 (*0.000*) 0.000 (*0.000*)	-0.002 Maximum	0.000 (*0.000*) min	-0.002 Maximum
MMC Standard	+ 0.005 (*0.1270*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.002 (*0.0508*) 0.000 (*0.000*) – 0.002 (*– 0.0508*)	+ 0.005 (*0.1270*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.002 (*0.0508*) 0.000 (*0.000*) – 0.002 (*– 0.0508*)
MMC Precision	+ 0.005 (*0.1270*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.002 (*0.0508*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.005 (*0.1270*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.002 (*0.0508*) 0.000 (*0.000*) 0.000 (*0.000*)
MIL-STD-348A- Standard Test	+ 0.003 (*0.0762*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.002 (*0.0508*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.003 (*0.0762*) 0.000 (*0.000*) 0.000 (*0.000*)	+ 0.002 (*0.0508*) 0.000 (*0.000*) 0.000 (*0.000*)

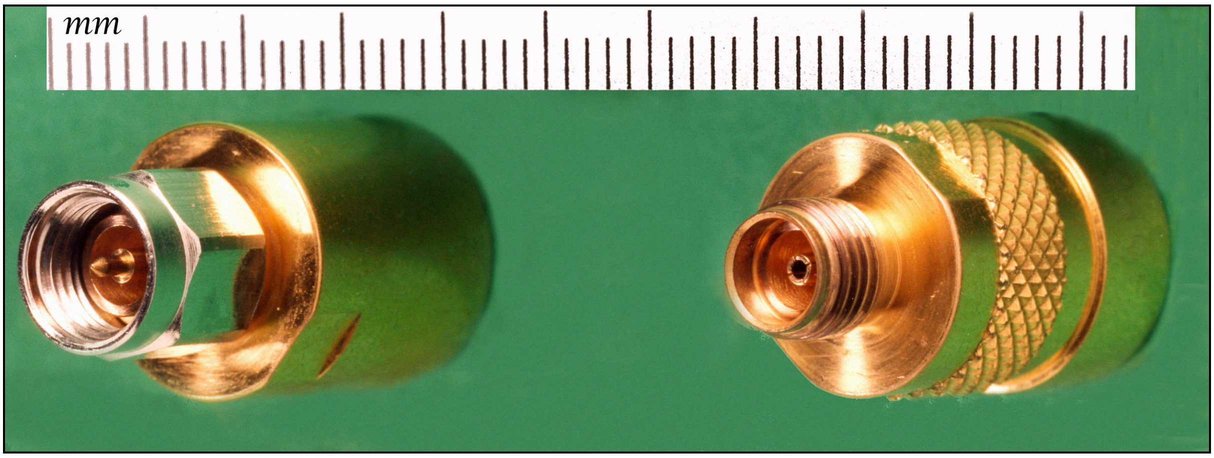
Table 5 SMA Connector

The specification allows dielectric to protrude past the outer conductor-mating plane to 0.002 inches (0.0508mm) max. However, there is some doubt if the SMA standards permit the dielectric to protrude beyond the reference plane. There is a high voltage version that does allow the dielectric to protrude beyond the reference plane, but it does not claim to be compatible with the SMA standard.

B.6. 3.5 mm connector

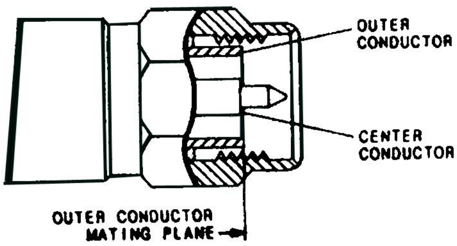
This connector is physically compatible with the SMA connector and is known as the 3.5mm connector. It has an air dielectric interface and closely controlled centre conductor support bead providing mechanical interface tolerances similar to hermaphroditic connectors. However, although in some ways planar, it is not an IEEE 287 precision connector. There is a discontinuity capacitance when coupled with SMA connectors.

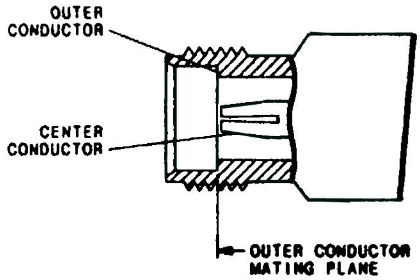
A special version of the 3.5mm connector has been designed. The design incorporates a shortened plug pin and allows the centre conductors to be pre-aligned before contact thus considerably reducing the likelihood of damage when connecting or disconnecting the 3.5mm connector. Figure 6.1 shows the plug and socket types of 3.5mm connector and Table 6 shows the gauging dimensions.



Photograph NPL

Figure 6.1 3.5mm plug and socket connector





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3.5mm	**Pin Depth Specifications inches (*mm*)**	
Specification	**Socket**	**Plug**
LPC	**0 to + 0.0005 (*+0.0127*)**	**0 to + 0.0005 (*+0.0127*)**
GPC	**0 to + 0.002 (*+0.0508*)**	**0 to +0.002 (*+0.0508*)**

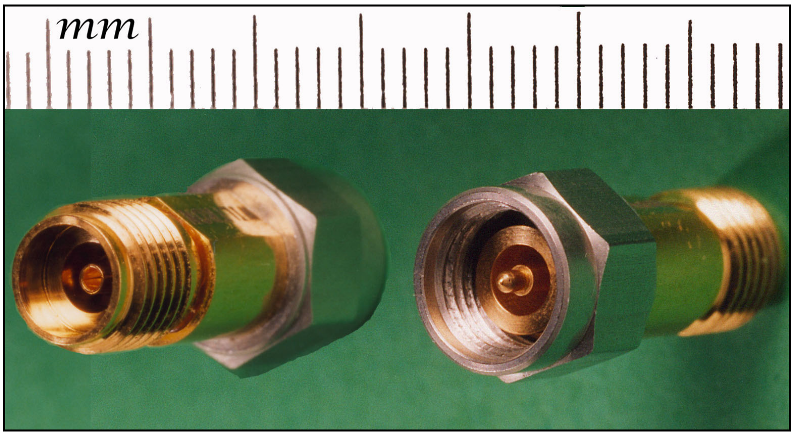
Table 6 3.5 mm connector

A Plus + tolerance indicates a recessed condition below the outer conductor mating plane.

B.7. 2.92 mm connector

The 2.92mm connector is a reliable connector that operates up to 46GHz and it is used in measurement systems and on high performance components, calibration and verification standards. It is also known as the Type K connector. The K connector interfaces mechanically with 3.5mm and SMA connectors. However, when mated with the 3.5mm or SMA connector the junction creates a discontinuity that must be accounted for in use.

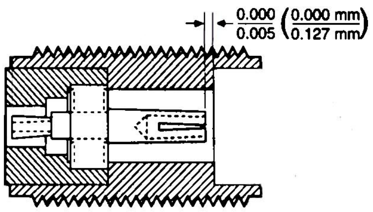
Compared to the 3.5mm and the SMA connector the 2.92mm connector has a shorter pin that allows the outer conductor alignment before the pin encounters the socket contact when mating a connector pair. The type K connector is therefore less prone to damage in industrial use.



Photograph NPL

Figure 7 Type K plug and socket connector

Figure 7.1 and 7.2 shows the diagram of the Type K connector and Table 7 gives the important gauging dimensions.



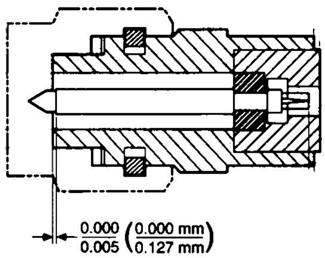


Figure 7.1 Type K socket connector

Figure 7.2 Type K plug connector

2.92 mm	**Pin Depth Specifications inches (*mm*)**	
Specification	**Socket**	**Plug**
LPC	**0 to 0.0005 (*0.0127*)**	**0 to 0.0005 (*0.0127*)**
GPC	**0 to 0.002 (*0.0508*)**	**0 to 0.002 (*0.0508*)**

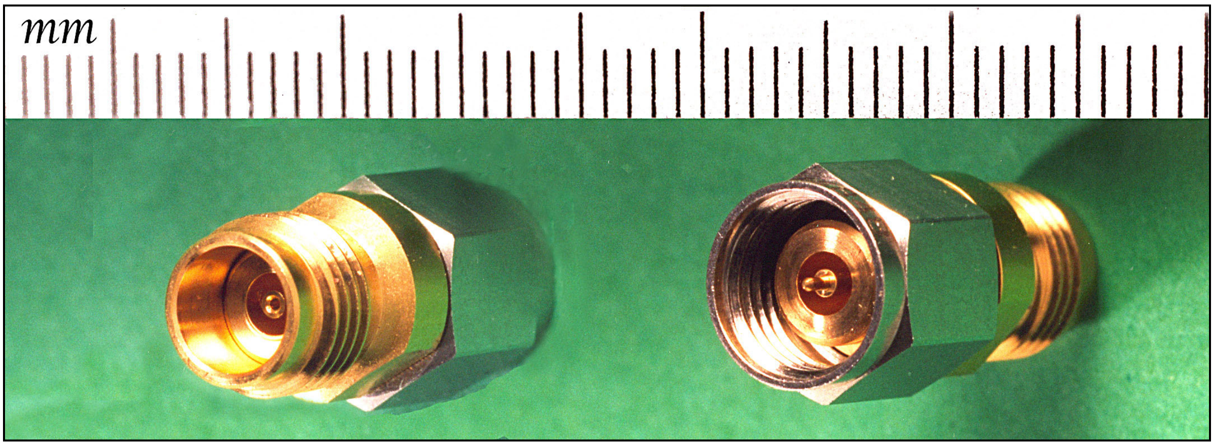
Table 7 Type K connector

A Plus + tolerance indicates a recessed condition below the outer conductor mating plane.

B.8. 2.4 mm connector

The 2.4mm connector was designed by the Hewlett Packard Company (now Agilent Technologies) and the connector assures mode free operation up to 60GHz. It is also known as the Type Q connector. The 2.4mm connector is a pin and socket type connector that utilises an air dielectric filled interface. The 2.4mm interface is also mechanically compatible with the 1.85mm connector. Figure 8 shows a photograph of the 2.4mm connector

No patent applications were filed to protect the design of the connector and Hewlett Packard allows free use of the interface by everyone. This means that any manufacturer of connectors can make their own version of the 2.4mm connector. It is important to note that a U.S. patent number 4,648,683 has been granted on the design of 2.4mm constant impedance contact. The constant impedance contact, used on the metrology grade LPC standards helps to provide traceability to NIST through mechanical measurement.



Photograph NPL

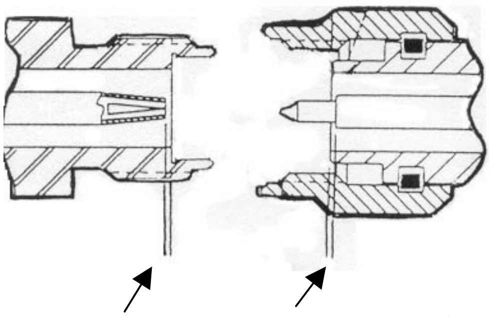
Figure 8. 2.4mm socket and plug connector

Note

The manufacturers of small coaxial connectors have agreed the mechanical dimensions so that they can be mated non-destructively. This has lead to the use of the term "mechanically compatible" because both lines are nominally 50Ω it has been assumed that "mechanically compatible" equates to electrical compatibility. The effect of the electrical compatibility of mechanically mateable coaxial lines is discussed in ANAlyse Note No.3 January 1994 included in the list of further reading at the end of this guide.

As for other connectors of this type the coupling engagement of the outer conductors is designed to insure that the outer conductors are coupled together before the inner conductors can engage to prevent damage to the inner conductor.

Figure 8.1 shows the diagram of the 2.4mm connector and Table 8 gives the important gauging dimensions.



0.000 (0.000) to + 0.002 (+ 0.0508)

Figure 8.1 2.4mm socket and plug connector

2.4 mm	**Pin Depth Specifications inches (*mm*)**	
Specification	**Socket**	**Plug**
LPC	**0 to+ 0.0005 (+ *0.0127*)**	**0 to + 0.0005 (+ *0.0127*)**
GPC	**0 to + 0.002 (+ *0.0508*)**	**0 to +0.002 (+ *0.0508*)**

Table 8 Type 2.4mm connector

A Plus + tolerance indicates a recessed condition below the outer conductor mating plane.

B.9. 1.85 mm connector

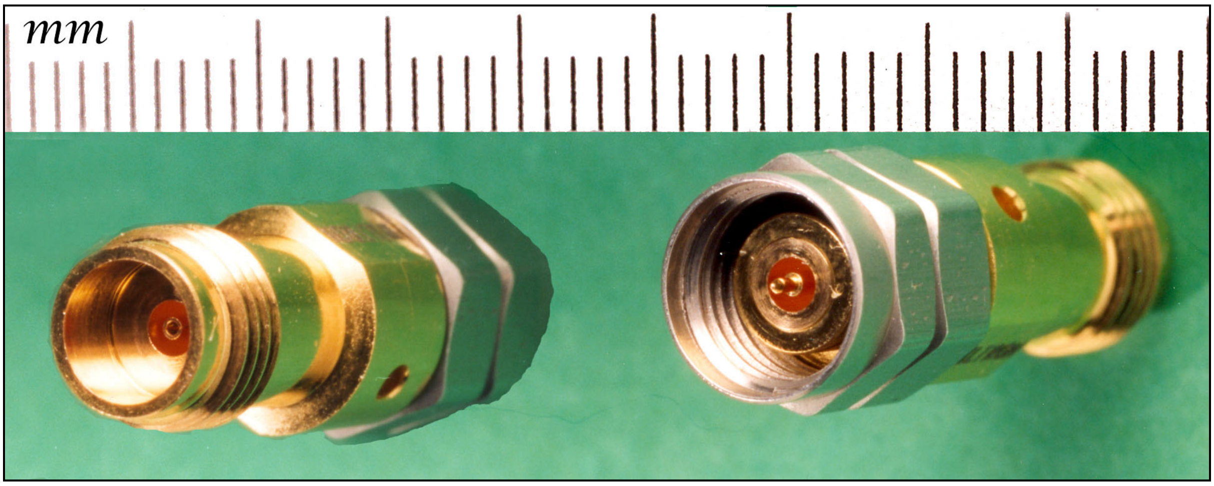
The 1.85mm connector was first proposed and introduced by Hewlett Packard back in 1986, before Anritsu commercialised it and used on their Vector Network Analysers in 1989 and the connector assures mode free operation up to 65GHz. It is also known as the Type V connector. The 1.85mm connector is a pin and socket type connector that uses an air dielectric filled interface.

No patent applications were filed to protect the design of the connector and Hewlett Packard allows free use of the interface by everyone. This means that any manufacturer of connectors can make their own version of the 1.85mm connector. It is important to note that a patent application has been filed to protect the design of 1.85mm constant impedance contact. The constant impedance contact, used on the metrology grade LPC standards helps to provide traceability to NIST through mechanical measurement.

The coupling engagement of the outer conductors is designed to insure that the outer conductors are coupled before the inner conductors can engage to ensure a damage free fit.

Since the introduction of the precision 1.85mm connector about 20 years ago it has become more commercialised and there has been an increasing need to have reliable quality assurance techniques for measurements of devices fitted with this connector.

For most other types of precision coaxial connector traceability has been available. However, traceability has remained elusive for the 1.85mm connector mainly due to the small geometric sizes of the critical electromagnetic component parts of this connector line size. In recent years the availability of beadless air lines in the 1.85mm line size has meant traceability to national standards is now available from the UK National Physical Laboratory[1] to provide traceable S-parameters measurements of devices fitted with 1.85mm precision connectors. A photograph of the connector is shown in Figure 9.



Photograph

NPL

[1] N M Ridler, "Traceability to National Standards for S-parameter Measurements of devices fitted with Precision 1.85mm Coaxial Connectors. National Physical Laboratory, Hampton Road, Teddington, Middlesex TW11 0LW, United Kingdom and was presented at the 68th ARFTG Meeting 2006

Figure 9 1.85mm Connector

Figure 9.1 shows the diagram of the 1.85mm connector and Table 9 shows the important gauging dimensions.

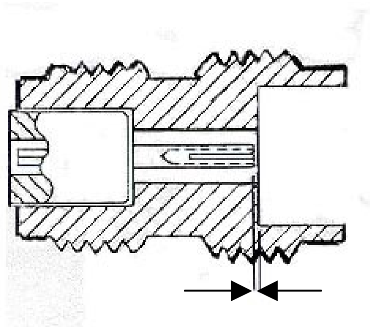


Figure 9.1 Type V socket connector.

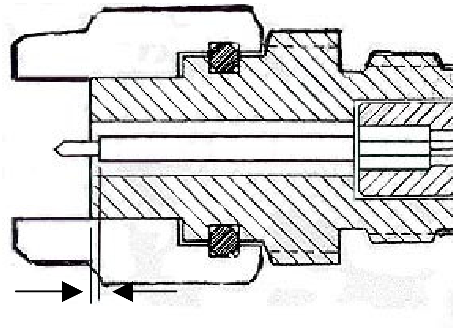


Figure 9.2 Type V plug connector

1.85 mm	**Pin Depth Specifications inches (*mm*)**	
Specification	**Socket**	**Plug**
LPC	**0 to + 0.0005 (+ *0.0127*)**	**0 to + 0.0005 (+*0.0127*)**
GPC	**0 to + 0.002 (+ *0.0508*)**	**0 to + 0.002 (+*0.0508*)**

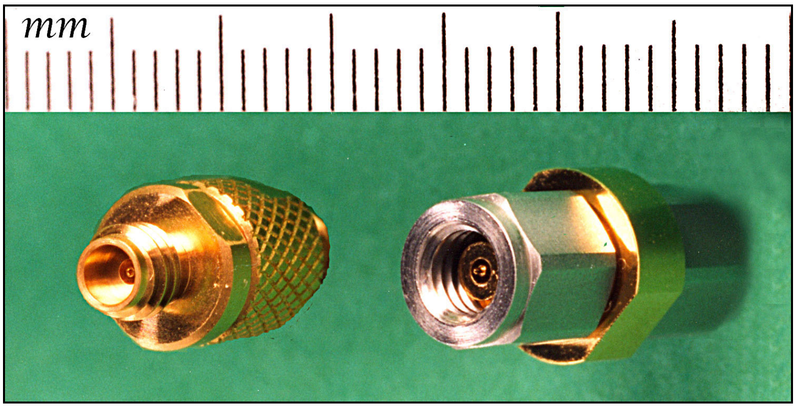
Table 9 Type 1.85mm connector

A Plus + tolerance indicates a recessed condition below the outer conductor mating plane.

B10. 1.0 mm connector

The 1.0 mm connector was designed by Hewlett Packard (now Agilent Technologies) and in is described in IEEE 287 Standard. The connector assures mode free operation up to 110GHz. The 1.0 mm connector is a pin and socket type connector that utilises an air dielectric filled interface. The coupling diameter and thread size are chosen to maximise strength, and increase durability. The coupling engagement of the outer conductors is designed to ensure that the outer conductors are coupled together before the inner conductors can engage to ensure a damage free fit.

Figures 10.1 and 10.2 show two versions of the 1.0 mm connector that are available from Agilent Technologies and the Anritsu Company. They are based on the dimensions shown in IEEE 287.



Photograph NPL

Figure 10.1 Agilent 1.0 mm socket and plug connector

Anritsu

Figure 10.2 Anritsu 1.0mm socket and plug connector

Figure 10.3 is a view of Anritsu's 1.0 mm connector based on the dimensions in the IEEE 287 standard.

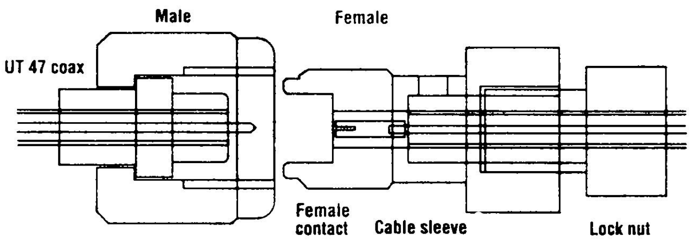


Figure 10.3 diagram of the 1.0mm plug and socket arrangement

Table 10 below shows the important gauging dimensions for 1.0 mm Connector

1.00 mm	**Pin Depth Specifications inches** *(mm)*	
Specification	**Socket**	**Plug**
LPC	**0 to+ 0.0005** *(+0.0127)*	**0 to + 0.0005** *(+0.0127)*
GPC	**0 to+ 0.002** *(+0.0508)*	**0 to + 0.002** *(+0.0508)*

Table 10 Maximum pin depth for the 1.0 mm connector

A Plus + tolerance indicates a recessed condition below the outer conductor mating plane.

No patent applications were filed to protect the design of the 1.0 connector. It is intended by Agilent to allow free use of the interface by everyone. Any manufacturer of connectors is free to manufacture its own version of the 1mm connector.

Appendix C

Repeatability of connector-pair insertion loss

The values shown in Table C1 show some insertion loss repeatability (dB) figures provided that the connector-pairs are in good mechanical condition and clean; further, that in use, they are not subjected to stresses and strains due to misalignment or transverse loads. For any particular measurement process the connector repeatability in the uncertainty budget is calculated in the same units of the final measurements. For example, when measuring the Calibration Factor of a power sensor the repeatability is measured in percent. Graph 1 shows a graph of repeatability figures for the calibration factor of a group of microwave power sensors.

These **guidance** figures will serve two purposes:

1. They show limits for connector repeatability for normal use in uncertainty estimates where unknown connectors may be involved;
2. Provide a measure against which a "real" repeatability assessment can be judged.

The Figures in Table C1 are based on practical measurement experience at NPL, SESC, and in UKAS Calibration Laboratories. In practice, connector repeatability is an important contribution to measurement uncertainties and should be carefully determined when verifying measurement systems or calculated for each set of measurements made. In some cases with great care better values with than those shown in table C1 can be obtained.

Connector	Connector Insertion loss repeatability dB		
GR900 - 14mm	**0.001 (DC to 0.5GHz)**	**0.002 (0.5 to 8.5GHz)**	
7mm	**0.001 (DC to 2GHz)**	**0.004 (2GHz to 8GHz)**	**0.006 (8 to 18GHz)**
Type N - 7mm	**0.001 (DC to 1 GHz)**	**0.004 (1 to 12GHz)**	**0.008 (12 to 18GHz)**
3.5mm	**0.002 (DC to 1GHz)**	**0.006 (1 to 12GHz)**	
SMA 3.5mm	**0.002(DC to 1GHz)**	**0.006 (1 to 12GHz)**	

Table C1 Connector insertion loss repeatability.

Automatic Network Analyser Connector Repeatability

When using Automatic Network Analysers and other similar equipment the connector repeatability is typically of the order of those shown in table C2. The results shown in table C2 give the mean of the ten measurements for a 7mm connector pair. In addition the standard deviation and standard uncertainty have been calculated. The results are shown in the table, and they were calculated using the procedure described in the UKAS Guide M3003 Edition 2. The values can be used in an uncertainty budget. In practice the measurement uncertainty contribution for the connector repeatability should be determined for each measurement procedure.

For references for further reading on connector repeatability see Appendix F

Freq	Run Number										Mean	Std	Std
GHz	1	2	3	4	5	6	7	8	9	10	Value	Dev	Uncert
1	0.000	-0.001	0.001	-0.001	0.000	-0.001	0.003	-0.002	0.000	0.000	-0.0001	0.0014	0.0004
2	-0.002	-0.001	-0.001	0.000	-0.001	0.000	0.004	-0.001	0.000	0.002	0.0000	0.0018	0.0006
3	-0.001	-0.001	0.001	-0.001	0.000	-0.001	0.004	-0.002	0.000	0.002	0.0001	0.0018	0.0006
4	-0.001	0.000	0.001	-0.001	0.000	0.000	0.005	-0.002	0.000	0.002	0.0004	0.0020	0.0006
5	-0.004	-0.001	0.002	-0.001	-0.001	0.001	0.006	-0.003	0.000	0.003	0.0002	0.0029	0.0009
6	-0.001	-0.001	0.001	-0.001	-0.001	-0.001	0.006	-0.003	0.000	0.004	0.0003	0.0027	0.0009
7	-0.003	-0.002	0.002	-0.003	-0.001	-0.001	0.007	-0.004	0.000	0.004	-0.0001	0.0035	0.0011
8	-0.003	-0.003	0.002	-0.003	-0.001	0.000	0.007	-0.003	-0.001	0.004	-0.0001	0.0034	0.0011
9	-0.001	-0.002	0.002	-0.001	-0.001	0.000	0.007	-0.003	0.000	0.006	0.0007	0.0033	0.0011
10	-0.005	-0.002	0.003	-0.002	-0.002	-0.004	0.008	-0.005	-0.001	0.003	-0.0007	0.0042	0.0013
11	-0.003	-0.003	0.003	-0.001	-0.007	0.003	0.009	-0.005	0.000	0.008	0.0004	0.0053	0.0017
12	-0.001	-0.006	0.003	-0.003	-0.004	0.002	0.005	0.002	0.003	0.007	0.0008	0.0042	0.0013
13	-0.002	0.000	0.004	-0.002	-0.002	-0.002	0.010	-0.005	0.000	0.008	0.0009	0.0049	0.0015
14	-0.003	-0.003	0.004	-0.002	0.001	0.000	0.012	-0.005	0.000	0.008	0.0012	0.0053	0.0017
15	-0.001	-0.003	0.004	-0.002	0.000	-0.001	0.011	-0.003	0.002	0.007	0.0014	0.0046	0.0015
16	-0.004	-0.004	0.003	-0.003	-0.003	-0.004	0.010	-0.004	0.001	0.009	0.0001	0.0055	0.0017
17	-0.002	-0.004	0.005	-0.002	-0.005	0.000	0.012	-0.004	-0.002	0.009	0.0007	0.0059	0.0019
18	0.000	-0.006	0.004	-0.001	-0.004	-0.002	0.012	-0.003	-0.002	0.009	0.0007	0.0058	0.0018

Table C2 A typical example of 7mm connector repeatability using an ANA

Freq	Run Number										Mean	Std	Std
GHz	1	2	3	4	5	6	7	8	9	10	Value	Dev	Uncert
1	0.002	0.001	-0.002	-0.001	0.000	0.000	0.000	-0.001	0.001	-0.002	-0.0002	0.0013	0.0004
2	0.002	0.001	-0.002	-0.001	0.001	0.000	0.001	-0.001	0.002	-0.002	0.0001	0.0015	0.0005
3	0.004	-0.002	-0.005	-0.001	0.001	-0.001	0.001	0.000	0.001	-0.004	-0.0006	0.0026	0.0008
4	0.005	0.000	-0.005	-0.001	0.001	-0.001	0.001	-0.004	0.003	-0.001	-0.0002	0.0030	0.0009
5	0.004	-0.003	-0.007	-0.001	0.002	-0.001	0.001	-0.002	0.004	-0.003	-0.0006	0.0034	0.0011
6	0.006	-0.002	-0.008	-0.001	0.002	-0.001	0.001	-0.003	0.004	-0.004	-0.0006	0.0041	0.0013
7	0.004	-0.003	-0.008	-0.003	0.004	-0.002	0.002	-0.002	0.004	-0.006	-0.0010	0.0043	0.0014
8	0.007	-0.003	-0.010	-0.001	0.003	-0.002	0.003	-0.002	0.004	-0.004	-0.0005	0.0049	0.0015
9	0.005	-0.004	-0.010	-0.001	0.003	-0.003	0.004	-0.004	0.004	-0.004	-0.0010	0.0049	0.0015
10	0.005	-0.005	-0.010	-0.001	0.002	-0.004	0.008	-0.002	0.001	-0.005	-0.0011	0.0053	0.0017
11	0.004	-0.003	-0.010	-0.001	0.001	-0.003	0.006	-0.003	0.002	0.001	-0.0006	0.0045	0.0014
12	0.004	-0.008	-0.012	-0.008	0.009	-0.003	0.011	-0.005	0.001	-0.003	-0.0014	0.0076	0.0024
13	0.006	-0.007	-0.011	-0.001	0.000	-0.003	0.011	-0.006	0.002	-0.002	-0.0011	0.0064	0.0020
14	0.004	-0.007	-0.012	0.001	-0.002	-0.003	0.015	-0.007	0.002	0.003	-0.0006	0.0075	0.0024
15	0.004	-0.005	-0.011	0.001	0.000	-0.004	0.014	-0.006	-0.002	0.001	-0.0008	0.0067	0.0021
16	0.004	-0.008	-0.013	0.001	-0.001	-0.006	0.016	-0.009	0.003	0.003	-0.0010	0.0084	0.0026
17	0.004	-0.008	-0.014	0.001	0.000	-0.006	0.017	-0.008	0.002	0.003	-0.0009	0.0086	0.0027
18	0.001	-0.014	-0.017	0.004	-0.006	-0.008	0.024	-0.011	0.003	0.005	-0.0019	0.0120	0.0038

Table C3 A typical example of Type N connector repeatability using an ANA

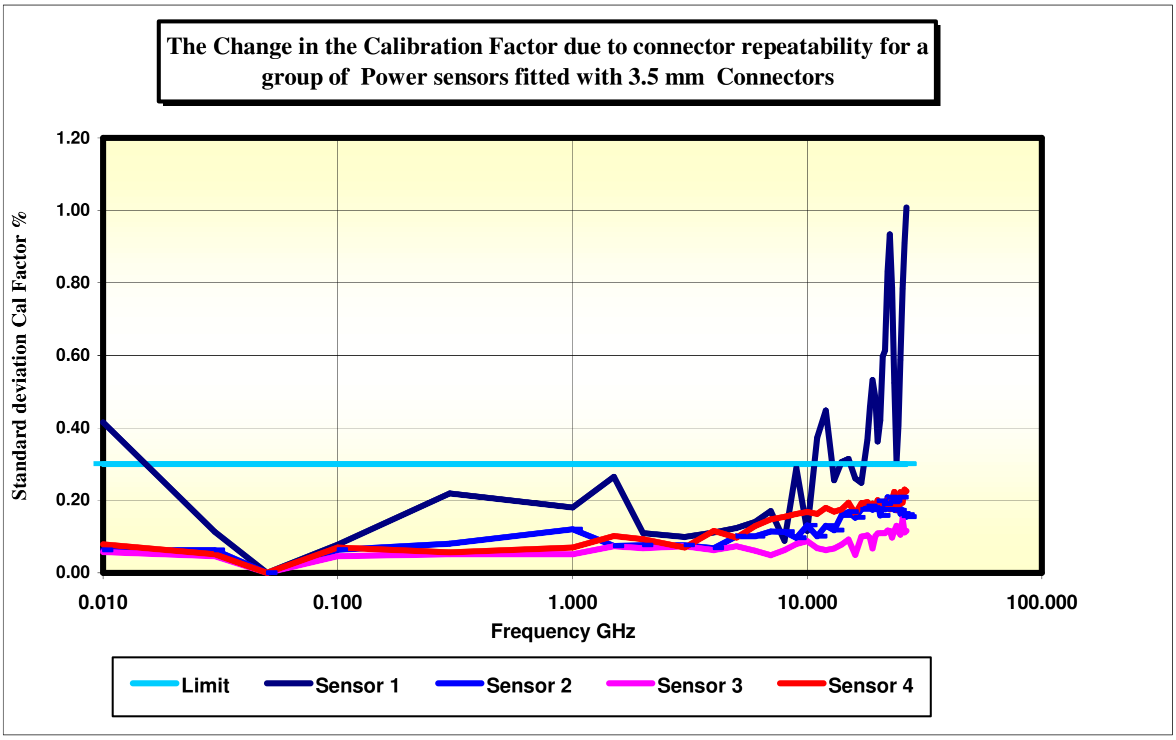
Connector repeatability for a group of Power Sensors

The power sensors used in the test are numbered 1 to 4

The power sensors used for these measurements were not new but they are power sensors that are in general use in the laboratory. Power sensor 1 was chosen because it is a well used power sensor that has been in use for a long time. The difference between sensor 1 and the sensors 2, 3 and 4 that are fairly new is clear.

The method used to obtain the results was to make ten calibrations runs of calibration factor in % for each sensor. Each sensor was disconnected and reconnected between each measurement. One reference calibration at 50MHz 1mW was made for each set of measurements. All the connectors were inspected, cleaned and gauged for mechanical compliance before use.

The graph below shows how a worn connector may cause the power sensor calibration factor standard deviation to deteriorate with age and use. Also notice that in this test the performance tends to get worse at the high frequencies.



Graph 1 Results of connector repeatability measurement for a group of power sensors

Appendix D

Torque wrenches

Types of torque wrenches

There are a number of different types of torque wrenches available for use with coaxial connectors and some examples are shown in the photographs below. Some torque wrenches are adjustable but others are preset when manufactured and the setting is shown on a label also one manufacturer uses a different coloured handle to identify each torque setting.

Figure D1 7mm and N Connector 12 in-lb

Figure D2 7-16 Connector 20 in-lb

Figures D1 to D4 N Ridler NPL

Figure D3 3.5mm connector 8 in-lb ruggedised

Figure D4 3.5 mm connector 8 in-lb

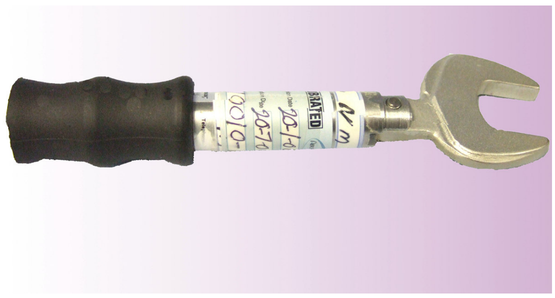


Figure D5 to D6 Doug Skinner

Figure D5 3.5mm 8 in-lb Click type

Figure D6 7mm Type N 12in-lb

The torque wrench shown in Figure D5 is of the click type. They should be used with great care because it is possible to apply extra torque by continuing to apply pressure after the click action.

Figures D1 to D4 N Ridler NPL

Figure D7 14mm GR900 12in-lb

This torque wrench shown Figure D7 is a custom made wrench for use with the 14mm GR900 connector and it was designed at the RSRE Malvern to be used when making connector repeatability measurements for the 14mm GR900 connector. This torque wrench is not available commercially and it is included here to show that custom made torque wrenches can be used.

Torque wrench setting values for use with coaxial connectors

Table D1 gives a list of recommended connector tightening torque values to be used for metrology purposes for each connector type.

This list is based on the best available information from various sources and should be used with care. Some manufacturers recommend slightly different values for the torque settings in their published performance data. Where this is the case the manufacturers' data should be used. With all torque spanners, it is possible to get substantially the wrong torque by twisting the handle axially and by a variety of other incorrect methods of using the torque spanner.

There are also some differences on the torque settings used when making a permanent connection (within an instrument) rather than for metrology purposes and this information is also normally shown on the connector data sheet.

Connector data sheets also show a maximum torque value that should not be exceeded.

For combinations of 3.5mm and SMA connectors the torque should be set to a lower value of 5 in-lb.

On some torque spanners the handles are colour coded to represent the torque value set for ease of identification e.g. 12 in-lb (1.36 N-m) blue and 8 in-lb (0.90 N-m) red. However, for safety, always check the torque setting before use.

The torque spanners used should be regularly calibrated, and set to the correct torque settings for the connector in use and clearly marked.

Connector		**Torque**	
Type	**Size** *mm*	**in-lb**	***N-m***
GR900	*14*	**12**	*1.36*
7mm	*7*	**12**	*1.36*
N	*7*	**12**	*1.36*
7/16	*16.5*	**20**	*2.26*
3.5mm	*3.5*	**8**	*0.90*
SMA	*3.5*	**5**	*0.56*
K	*2.92*	**5 – 8**	*0.56 – 0. 90*
Q	*2.4*	**8**	*0.90*
V	*1.85*	**8**	*0.90*
W	*1.0*	**3**	*0.34*

Table D1 Torque spanner setting values

Torque Spanners can be easily calibrated in a Mechanical Calibration Laboratory but some users may prefer to have their own torque wrench calibration device.

Appendix E

E. Calibrating dial gauges and test pieces

There are a number of different types of dial gauges and gauge calibration blocks used for gauging connectors. They require regular calibration to ensure that they are performing correctly. There is a British Standard BS 907: "Specification for dial gauges for linear measurement" dated 1965 that covers the procedure for the calibration of dial gauges and this should be used. However, the calibration of the gauge calibration blocks is not covered by a British Standard, but they can be measured in a mechanical metrology laboratory. It is important to use the correct gauge for each connector type to avoid damage to the connector under test. Some gauges have a very strong gauge plunger springs that, if used on the wrong connector, can push the centre block through the connector resulting in damage. Also if gauges are used incorrectly they can compress the centre conductor collet in precision 7mm connectors, during a measurement, resulting in inaccurate readings when measuring the collet protrusion.

Connector gauge measurement resolution

Because of connector gauge measurement resolution uncertainties (one small division on the dial) and variations in measurement technique from user to user connector dimensions may be difficult to measure. Dirt and contamination can cause differences of 0.0001-inch (0.00254 mm) and in addition the way that the gauge is used can result in larger variations. When using a gauge system for mechanical compliance testing of connectors carry out the following procedure each time.

1. Carefully inspect the connector to be tested and clean if necessary.
2. Clean and inspect the dial gauge, and the gauge calibration block.
3. Carefully zero the dial gauge with the gauge calibration block in place.
4. Remove the gauge calibration block.
5. Measure the connector using the dial gauge and note the reading.
6. Repeat the process at least once or more times as necessary.

Types of dial gauges

Gauges used for the testing of connectors for correct mechanical compliance are basically of two main types:

Push on type

The push on type is used for measuring the general-purpose type of connectors. For sexed connectors, two gauges are normally used (one plug and one socket) or a single gauge with plug and socket adaptor bushings. It normally has a mechanical dial indicator.

The diagram in Figure E2 shows a SMA dial gauge of the push on type with its gauge calibration block.

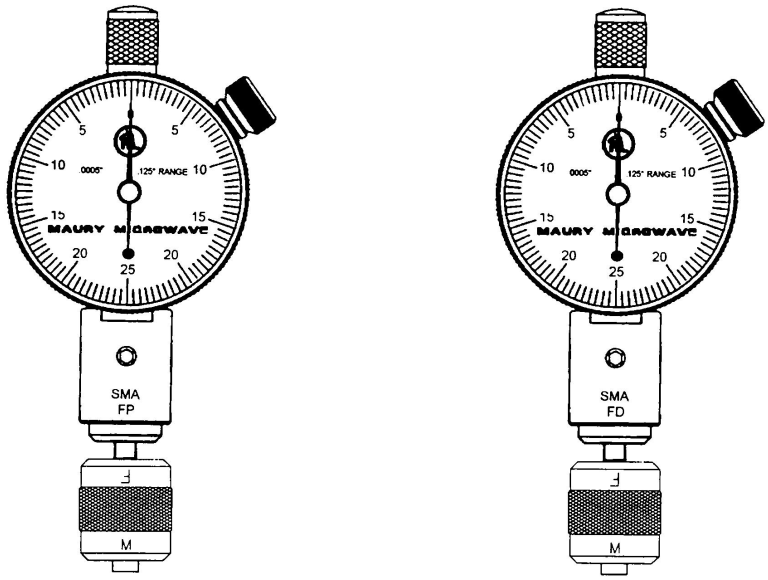


Figure E2 Type SMA push –on gauge

Calibration Gauge blocks

Every connector gauge of the push–on type normally has a gauge calibration block that is used to zero the gauge to a pre-set value before use. When the Dial indicator is calibrated it is good practice to have the calibration block calibrated at the same time.

Doug Skinner

Figure E3 Calibration gauge block for type N connectors

Screw on type

The screw-on type is mainly used (except GR 900) in calibration kits for network analysers and reflectometers. They are used for the 7mm and sexed connectors and for the latter they are made in both plug and socket versions. The screw-on type is made in the form of a connector of the opposite sex to one being measured. This type of connector gauge set may use a mechanical type dial indicator or be a digital indicator as shown in Figure E4 and it is available from Maury Microwave Corporation.

Note that there is a torque wrench included in the box with the calibration kit so that the calibration piece can be tightened to the correct torque to initially zero the digital dial indicator.

Maury Microwave Corporation

Figure E4 Digital readout connector gauge set

The diagram in Figure E5 shows a pair of dial gauges and gauge calibration blocks for a Type N connector screw on type gauge.

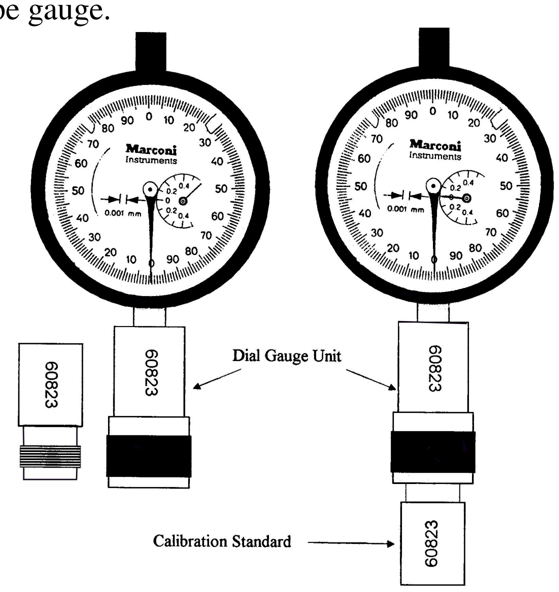


Figure E5. Type N screw-on dial gauge and calibration block

Appendix F

Coaxial connectors – some further reading.

Microwave Measurements Edition 3

Edited by Richard Collier and A Douglas Skinner. Published by the Institution of Engineering and Technology. www.theiet.org

Uncertainties of Measurement

UKAS M3003 - The Expression of Uncertainty and Confidence in Measurement (Edition 2, January 2007). Available as a download from the UKAS web site.

http://www.ukas.com/Library/downloads/publications/M3003.pd

General Connector Paper

Mario A Maury, Jr Microwave Coaxial Connector Technology: A continuing Evolution Maury Microwave Corporation 13 December 2005. Maury Connector guide. PDF

ANAMET publications relating to coaxial connectors

ANAMET Reports[1]

N M Ridler and J C Medley, "ANAMET-962: dial gauge comparison exercise", *ANAMET Report*, Number 001, July 1996.

N M Ridler and J C Medley, "Live dial gauge comparison exercise: ANAMET-963", *ANAMET Report*, Number 007, May 1997.

N M Ridler and C Graham, "An investigation into the variation of torque values obtained using coaxial connector torque spanners", *ANAMET Report*, Number 018, September 1998.

G J French, "ANAMET-982: live torque comparison exercise", *ANAMET Report*, Number 022, February 1999.

N M Ridler and A G Morgan, "ANAMET-032: "live" dial gauge measurement investigation using Type-N connectors", *ANAMET Report*, Number 041, November 2003.

[1] Other reports which are fore-runners of the 2nd edition of the ANAMET Connector Guide were:

A D Skinner, "Guidance on using coaxial connectors in measurement – draft for comment", ANAMET Report, Number 015, February 1998.

A D Skinner, "ANAMET connector guide", ANAMET Report, Number 032, January 2001.

ANAlyse Notes

J P Ide, "A study of the electrical compatibility of mechanically mateable coaxial lines", *ANAlyse Note*, Number 3, January 1994.

N M Ridler, “How much variation should we expect from coaxial connector dial gauge measurements? *ANAlyse Note*, Number 14, February 1996.

ANA Tips Notes

A J A Smith and N M Ridler, “Gauge compatibility for the smaller coaxial line sizes”, *ANA-tips Note*, Number 1, October 1999.

P D Woolliams and N M Ridler, “Tips on using coaxial connector torque spanners”, *ANA-tips Note*, Number 2, January 2000.

ANAMET News articles

J P Ide, “Are two collets better than one? *ANAMET News*, Issue 2, p 3, Spring 1994.

J P Ide, “Masters of the microverse”, *ANAMET News*, Issue 2, p 2, Spring 1994.

J P Ide, “More from the gotcha! files: out of my depth”, *ANAMET News*, Issue 9, p 9, Autumn 1997.

I Instone, “The effects of port recession on ANA accuracy”, *ANAMET News*, Issue 11, pp 4-6, Autumn 1998.

Note
The first three items in this list are short, amusing, articles (albeit containing important and useful information).

Publications on connectors from other sources see:

N M Ridler, “Connectors, air lines and RF impedance”, notes to accompany the IEE training course on Microwave Measurements see IET Microwave Measurements book Edition 3

N M Ridler, “Traceability to National Standards for S-parameter Measurements of devices fitted with Precision 1.85mm Coaxial Connectors. National Physical Laboratory, Hampton Road, Teddington TW11 0LW, United Kingdom presented at the 68th ARFTG Meeting.

Connector Repeatability

Dietrich Bergfield and Helmut Fischer. Insertion Loss Repeatability versus Life of Some Coaxial Connectors. IEEE Transactions on Instrumentation and Measurement Vol. Im-19, No4, pp 349 – 353 November 1970.

Type 7/16 Coaxial Connector

Jeffery D. Paynter and Richard Smith: Coaxial Connectors: 7/16 DIN and Type N Mobile Radio Technology Magazine April 1995 Intertech Publishing Corp a copy is available on http//www.andrew.ru/products/article/cmkr0003.asp