



IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz)

IEEE Instrumentation and Measurement Society

Sponsored by the
Connectors in Measurements Committee

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(Revision of
IEEE Std 287-1968)

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IEEE Instrumentation and Measurement Society

Approved 22 March 2007

IEEE-SA Standards Board

The Chairman wishes to acknowledge his indebtedness to those who have so freely given their time and knowledge in the preparation of general requirements, test methods, detail specifications, and so on, and also to those who conducted experimental work on the various connector types to obtain the parameters for the Connector Summary Table. Special thanks go to Adele Hayes, Don Dixon, and Donna Trincia for preparing this manuscript.

Abstract: This standard presents the combined efforts of IEEE Subcommittee P287 that reflect the knowledge and experience of leading specialists in the development and measurement of precision coaxial connectors from dc to 110 GHz. It presents minimum performance requirements to standardize both hermaphroditic and pin- and socket-type connectors. It provides recommended electrical and mechanical test procedures for general and laboratory precision connectors. A bibliography provides a list of pertinent references for measurement techniques used in determining electrical, mechanical, and dimensional parameters for coaxial connectors.

Keywords: general precision connector (GPC), laboratory precision connector (LPC), minimum performance requirement, pin and socket connector, precision coaxial connector

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Introduction

This introduction is not part of IEEE 287-2007, IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz).

This standard is a minimum performance requirements standard for precision coaxial connectors developed by the IEEE Subcommittee P287 of the IEEE Instrumentation and Measurement Society. IEEE Subcommittee P287 was reactivated in 1988 by Robert C. Powell, Chairman I & M Technical Committee Four, “HF Instrumentation and Measurement,” in which the main statement of purpose was

- a) To revise IEEE Std 287-1968 so that it represents the current state of the art in precision coaxial connector technology.
- b) To standardize both laboratory precision connectors (LPCs) and general precision connectors (GPCs) in a minimum number of transmission line sizes covering the frequency range of dc to 110 GHz.
- c) To standardize the means of transferring laboratory measurements to devices with field type connectors.
- d) To produce a standard that is useful and meaningful to the manufacturers and users of precision coaxial connectors.
- e) To incorporate any other items deemed relevant and appropriate into the standard.

In Memory of

Peter Lacy, Bruno Weinschel, Peter Somlo, and Mario Maury, who were diligent participants of the IEEE Subcommittee P287

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IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz)

1. Overview

1.1 Scope

The scope of this standard is to specify coaxial connectors for precision electrical measurements to 110 GHz. The frequency range of the standard is increased from 65 GHz to 110 GHz since in the market exists a 1 mm connector with a rated upper minimum operating frequency of 110 GHz. The members of the subcommittee felt, in view of this, the scope of the project should be changed to incorporate this advantage.

1.2 Purpose

The purpose of this standard is to present minimum performance requirements for those precision connectors whose upper frequency limits range from 18 GHz to 110 GHz for five line sizes of the pin and socket type, which include 3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm, and 1.0 mm connectors. It also incorporates relevant information on the 14 mm and 7 mm connector types, includes the Type N (7 mm) connector, and introduces the performance requirements needed to standardize pin and socket type connectors. A novel feature in this standard is the use of slotless socket contacts for some pin and socket type connectors to maintain the concept of test port/device under test (DUT) independence. The standard presents updated test methods to utilize automatic vector network analyzers (VNAs) along with current state-of-the-art concepts in connector technology, and displays specification values from individual connector types in a connector summary table. A very important utility of this standard is that it serves as a user's guide. One unique feature of this standard is that it embodies the general requirements, definitions, measuring methods, and other pertinent information into one document for all eight standard connector types while making use of the "detail specifications" information from each connector type for standardization into Annex C through Annex J, which are listed as follows:

Annex C	Detail specifications for precision coaxial 14 mm connectors (DC to 8.5 GHz)
Annex D	Detail specifications for precision coaxial 7 mm connectors (DC to 18 GHz)
Annex E	Detail specifications for precision coaxial Type N connectors (DC to 18 GHz)
Annex F	Detail specifications for precision coaxial 3.5 mm connectors (DC to 33 GHz)
Annex G	Detail specifications for precision coaxial 2.92 mm connectors (DC to 40 GHz)
Annex H	Detail specifications for precision coaxial 2.4 mm connectors (DC to 50 GHz)
Annex I	Detail specifications for precision coaxial 1.85 mm connectors (DC to 65 GHz)
Annex J	Detail specifications for precision coaxial 1 mm connectors (DC to 110 GHz)

2. General requirements and definitions

2.1 Mechanical

2.1.1 Coaxial line sizes

A minimum number of coaxial line sizes of 50 Ω characteristic impedance is specified in Table 1 to achieve the desired performance over the frequency range of 0 GHz to 110 GHz.

Table 1—Coaxial line sizes of 50 Ω characteristic impedance

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

2.1.2 Types of precision connectors

All precision connectors shall have *air dielectric* in the mating space. The mating planes for inner and outer conductors coincide with the exception of Type N, and they are available as (1) general precision connectors (GPCs) having a self-contained, low reflection, dielectric support, and (2) laboratory precision connectors (LPCs) using only air dielectric. They attach directly to the transmission lines of Table 1.

In the GPC connector, the dielectric support shall be sufficiently recessed from the reference plane such that the electrical specifications are met.

Notes for Type N:

- a) The reference plane is the mating plane of the outer conductors.
- b) For the Type N precision pin connector, the following is specified:
 - 1) The location of the inner conductor shoulder, which is recessed from the reference plane.
 - 2) The inner diameter (ID) of the outer conductor from the inner conductor shoulder to the reference plane.

- c) For the Type N precision socket connector, the following is specified:
- 1) The location of the end of the inner conductor, which protrudes beyond the reference plane.
 - 2) The outer diameter (OD) of the inner conductor, when unslotted, from its end to the reference plane; when slotted, the impedance of the section between the end of the inner conductor and the reference plane shall be within specified limits when mated with the precision pin connector.

2.1.3 Characteristic impedance

For GPC connectors, stability and repeatability of impedance are prime objectives. For LPC connectors, optimum performance is the prime objective. The inner and outer conductors used in constructing a precision connector shall have diameter and eccentricity values such that their most adverse combination shall not cause an error in the nominal characteristic impedance of more than that shown in Table 2.

Table 2—Maximum permitted characteristic impedance uncertainty

Nominal inside diameter of outer conductor in mm		14.29	7.00	3.50	2.92	2.40	1.85	1.00
±%	LPC	0.05	0.1	0.2	0.3	0.4	0.5	0.6
±%	GPC	0.2	0.2	0.4	0.8	0.8	1.0	1.2

NOTE—The error due to the effective electrical conductivity of the conductors, including surface finish, shall be included in the above errors. However, due to the influence of skin effect which increases the magnitude of the characteristic impedance at low frequencies, it is impossible, even with zero tolerances, to comply with these accuracies below certain frequencies (see Harris and Spinney [B9], IEEE Std 314™-1971 [B13], Weinschel [B30], [B31], and Wong [B35]).^{1, 2}

2.1.4 Mateability and available combinations

Subclauses 2.1.4.1 through 2.1.4.4 contain mechanical requirements for both hermaphroditic and pin and socket connectors.

2.1.4.1 Outer conductors

In all line sizes, for LPC and GPC connectors, hermaphroditic and polarized outer conductors are permitted.

- a) LPC and GPC hermaphroditic connectors may have hermaphroditic or polarized outer conductors. The polarized and hermaphroditic outer conductors of precision connectors with hermaphroditic inner conductors shall be able to mate with one another directly.
- b) Pin and socket precision connectors shall mate directly with pin and socket type general-use connectors having an air dielectric in the mating space such as Type N, 3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm, and 1.0 mm (see NOTE after 2.1.4.4).

2.1.4.2 Inner conductors

In all line sizes, for LPC and GPC connectors, hermaphroditic and polarized inner conductors are permitted.

- a) The reference plane is the mating plane of the outer conductors.

¹The numbers in brackets correspond to those of the bibliography in Annex K.

²Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

- b) The reflection coefficient of a connector with a socket inner conductor shall be independent of the mating connector with a pin inner conductor. The reflection coefficient of a connector with a pin inner conductor shall be independent of the mating connector with a socket inner conductor.
- c) GPC and LPC with a hermaphroditic inner conductor need not be able to mate directly with polarized inner conductors of the same line size.
- d) If both inner and outer conductors of a GPC or LPC are polarized, their polarity shall be the same.

2.1.4.3 Hermaphroditic LPCs

Hermaphroditic connectors shall be used where the electrical length and characteristic impedance of the connector needs to be known to the highest accuracy. The inner conductor is hermaphroditic. The outer conductor can be either hermaphroditic or polarized. Provision shall be made in the inner conductor of the GPC connector to support the inner conductor of the LPC.

2.1.4.4 Pin and socket precision connectors

Pin and socket precision connectors mate directly with equivalent pin and socket general-use or field connectors (see MIL-PRF-39012 [B17]), without adapters. The properties of pin and socket precision connectors shall not vary as they are mated with any general-use or field connectors that comply with its standard tolerances in interface dimensions, mating force and torque as well as the required, but often not standardized, concentricity and surface finish.

NOTE—Many field connectors lack concentricity requirements. They may degrade or damage precision connectors.

2.1.5 Mechanical and electrical joining plane

All contact surfaces of a mated pair of connectors shall join in the same mechanical plane determined by the outer conductors. The mechanical plane shall also be coincident with the electrical reference plane. The only exception is the Type N connector of the pin and socket precision connectors, which have staggered inner and outer conductor mating planes.

2.1.6 Components captive to the connector

All components of the LPC shall be captive to the inner and outer conductor of the connector, respectively. The inner conductor alignment pin shall be retained but removable. If a polarized outer conductor is used with a hermaphroditic inner conductor, it may have the coupling means of the connectors detachable. The coupling mechanism of completely hermaphroditic types of connectors (GPC and LPC) shall be detachable.

2.1.7 Protection and maintenance of butting electric surfaces

Provision shall be made to protect the unmated butting electric surfaces. It shall also be possible to repolish, relap, or replace the butting electric surfaces of the LPC.

2.1.8 Subjection to axial forces

During and after mating, the front-end butting electrical surfaces of the inner conductors of the hermaphroditic GPC shall be subjected to axial forces only. The GPC inner conductor dielectric support shall withstand specified axial forces.

2.1.9 Torque

The detail specifications specify the range of mating torque and of the maximum torque (i.e., safety torque), which will not cause damage.

2.1.10 Attachment to transmission line

To attach the rear of the connector to a transmission line, the detail specification drawings for each line size show the form, dimensions, and tolerances for the attachment portion of the transmission line in the detail specification (see ANSI Y14.5M [B1]).

2.1.11 Connector diameter tolerances

The detail specifications list dimensional tolerances for both LPC and GPC for each standard connector. These tolerances are based on best current practice and, as such, do not yield the desired characteristic impedance accuracy in all cases. Therefore, the diameter ratio shall be selected such that the requirements for characteristic impedance are met.

2.1.12 Protrusion for hermaphroditic inner contacts

The range of protrusion of the inner conductor beyond the reference plane before mating is specified in the detail specifications.

2.1.13 Inner-conductor applied (mating) force limits

2.1.13.1 For hermaphroditic inner contacts

The detail specifications provide the maximum axial displacement of the supported inner-conductor resulting from the application of a specified axial force and duration.

2.1.13.2 For pin and socket connectors

- a) *Insertion and withdrawal force, socket inner conductor.* Use specified pin (see detail specifications for form, finish, material, and hardness). Detail specifications specify maximum insertion and withdrawal forces, depth of penetration, rate of insertion and withdrawal. Specify maximum temporary displacement during test and permanent displacement of socket center conductor.
- b) *Insertion and withdrawal force, pin center conductor.* For same axial forces as in item a), specify maximum temporary and permanent displacement.
- c) *Retention force, socket inner contact.* Using test pin prescribed by drawing, specify minimum axial force for withdrawal.

2.1.14 Connect/disconnect life

The minimum number of manual connection/disconnection operations of a connector pair under laboratory conditions that will not result in damage is given in the detail specifications. Damage is defined as noncompliance with any specification.

2.1.15 Dimensions

The critical dimensions, surface finish, and tolerances for the mating surfaces and the interface coupling mechanism are specified in the detail specifications.

2.2 Electrical

Subclauses 2.2.1 through 2.2.8 contain electrical requirements for both hermaphroditic and pin and socket connectors.

2.2.1 Reflection coefficient magnitude $|S_{11}|$ or return loss in decibels

The reflection coefficient magnitude of a mated connector pair versus frequency shall not exceed specified limits. The return loss is defined as the magnitude of the reflected signal in decibels of a connector pair when inserted into a 50 Ω measurement system.

$$RL \text{ (dB)} = -20 \log_{10} |S_{11}| \quad (1)$$

2.2.2 Insertion loss

The insertion loss of a mated connector pair shall not exceed specified limits versus frequency range. The insertion loss is defined as the loss of a connector pair when inserted into a 50 Ω measurement system.

$$IL \text{ (dB)} = -20 \log_{10} |S_{21}| \quad (2)$$

2.2.3 Direct-current contact resistance

The direct-current resistance of the inner and outer conductor joints of a mated connector pair shall not exceed their respective specified limits when tested with a four-terminal measuring system.

2.2.4 Repeatability with and without rotation

2.2.4.1 Repeatability without rotation

The repeatability of a specified parameter is defined as the maximum measured difference in the specified parameter of a connector pair between the extreme values of measurements of this parameter during the specified number of connect/disconnect cycles at fixed angular orientation. The repeatability shall not exceed the specified values for

- a) Magnitude of vectorial difference of reflection coefficient $|\Delta S_{11}|$ in decibels
- b) Insertion loss $\Delta |S_{21}|$ in decibels
- c) Insertion phase $\Delta \arg |S_{21}|$ in degrees
- d) DC resistance ΔR_{dc} in milliohms

Maximum values for these parameters are found in the detail specifications. The nonrotational repeatability shall be the maximum difference of the specified parameters during 100 complete connect/disconnect cycles of the connector for 14 mm and 7 mm lines. For sizes 3.5 mm and below, substitute 20 connect/disconnect cycles.

2.2.4.2 Repeatability with rotation

The repeatability with rotation shall be the maximum nonrepeatability for reflection coefficient magnitude, insertion loss magnitude, insertion phase, and dc resistance with rotation. Determine the extreme values during rotation of connector orientation of 16 approximately 45° increments over two complete 360° cycles. Maximum values are found in the detail specifications.

2.2.5 Shielding effectiveness

The shielding effectiveness [radio-frequency (RF) leakage] of a mated pair shall not be less than specified limits versus frequency.

2.2.6 Electrical length

The equivalent electrical length of both a single connector and a mated connector pair in air shall be specified as a function of frequency.

2.2.7 Rated minimum upper operating frequency and theoretical upper limit

The upper frequency and theoretical limit in gigahertz for each coaxial line size is shown in Table 1. Up to the rated minimum upper operating frequency, all requirements of this standard apply (see IEC 1141 [B11]). Although it may be practical to operate connectors above this frequency, the requirements of this standard do not apply. The theoretic limit of a transmission line (see Dimitrios [B4]) is determined by the cutoff frequency of the TE_{11} mode. The rated upper operating frequency results from the presence of dielectric supports that have lower TE_{11} mode cutoff frequencies (see Gilmore [B5]).

2.2.8 Detail specification parameters

2.2.8.1 Reflection coefficient magnitude $|S_{11}|$ (return loss in decibels)

The detail specifications specify the maximum reflection coefficient magnitude (return loss in decibels) versus frequency of both a mated connector pair (GPC–GPC) and a single connector (LPC–GPC) when inserted without center conductor gaps in a $50\ \Omega$ ($\Gamma_g = \Gamma_1 = 0$) system above 100 MHz.

2.2.8.2 Insertion loss

The detail specifications specify the maximum insertion loss versus frequency of both a mated connector pair and a single connector above 100 MHz.

2.2.8.3 Shielding effectiveness

The detail specifications specify the maximum leakage versus frequency of a mated connector pair, of an axial force referred to the electrical reference plane.

2.2.8.4 Electrical length

The manufacturer shall specify the electrical length versus frequency and applicable tolerance for both a mated connector pair and a single connector.

2.2.8.5 Direct-current contact resistance

The detail specifications provide separately the maximum direct-current contact resistance for both the mated inner and the outer conductors.

2.3 Environmental

2.3.1 Reference conditions

The reference conditions are 23 °C, 40% RH, 101.3 kPa air pressure. These reference conditions have no tolerances stated or implied. Reference conditions apply to both mechanical and electrical measurements.

2.3.2 Operating

The specified operating conditions are 20 ± 10 °C and 20 to 80% RH.

2.3.3 Nonoperating

The nonoperating temperature range that shall not cause damage to the connector is minus 50 °C to plus 70 °C. The nonoperating pressure range is 101.3 kPa to 0.145 Pa. Damage is defined as noncompliance with any specification under operating environmental conditions.

3. Recommended electrical test procedures for GPC and LPC

3.1 Statement

Precision connectors require careful measurements of their electrical performance to ensure full compliance to their specified parameters. Current techniques permit swept and stepped frequency and time-domain measurements over the entire frequency ranges of both GPC and LPC connectors with sufficient accuracy to satisfy these requirements. Real-time full-frequency performance display can reveal spurious responses, erratic behavior, and impedance deviations of the connectors under test.

A primary concern of the process is the accuracy and repeatability of the measurements with respect to the connector performance requirement. Care shall be taken to distinguish between the error and the repeatability of the measurement technique, and the repeatability of the connector itself. The precision connectors shall be attached to precision air lines for the measurement process, as the air lines become the impedance reference.

3.2 Reflection coefficient

The GPC and LPC shall be tested with attached air lines. Also all test methods require air lines in their configuration and calibration. For the smallest line sizes, LPC offset short circuits can be used for calibration. In both of the above situations, the air lines or short circuits shall be carefully controlled to maintain impedance values consistent with the error limit required for the connector reflection measurement. The inner and outer conductor diameters, the concentricity of the center conductor, and the conductivity and surface finish shall meet the impedance standards (see Harris and Spinney [B9], IEEE Std 314™-1971 [B13], Weinschel [B30], [B31], and Wong [B35]). The surface conductivity shall be appropriately controlled and, in some cases, corrected by calculation (see Nelson and Coryell [B20], Somlo and Hunter [B28], and Zorzy [B36]) especially at low frequencies.

3.2.1 Measurement technique

All of the following methods have the requisite accuracy and dynamic or frequency range. The first two methods are one-port measurements that can provide greater accuracy by avoiding flexible or semiflexible cables in the measurement path. These are more appropriate for the larger connectors with greater precision specified, e.g., 14 mm, 7 mm, Type N, and 3.5 mm. They also are needed for the repeatability measurements. A two-port measurement may subsequently be required for the transmission parameter measurements under certain circumstances. The third method allows all parameters except repeatability with rotation to be made with one setup. This method is more appropriate for the smaller, higher frequency connector types.

Other methods can be used, but the requisite performance shall be demonstrated.

3.2.1.1 Vector network analyzer (VNA)

- a) **Method 1—VNA, gated time domain.** This method (see Oldfield [B21] and Rytting [B22]) allows both reflection and transmission measurements. The directivity and both test port matches are

calibrated and stored in software to create a nearly ideal network analyzer. Furthermore, the proposed test method uses precision air lines on both sides of the connector pair under test as shown in Figure 1.

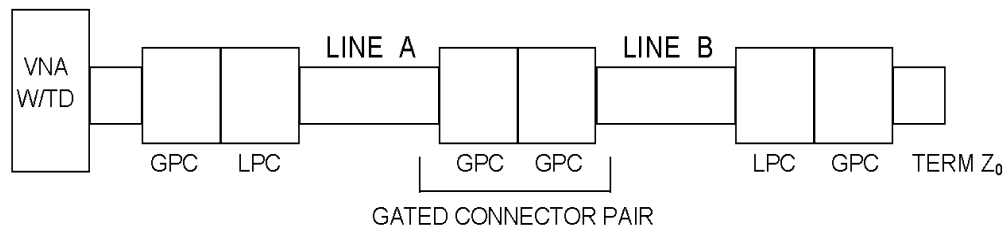


Figure 1—Reflection test setup for GPC/GPC connector pair

Lines A and B both shall have a GPC on one end and a LPC on the other end. For polarized connectors, one line will have pin connectors on each end; the other will have socket connectors on each end.

Both lines shall meet all impedance control requirements. The connector pair under test shall be configured to measure the following connector pairs: (1) GPC/GPC, (2) GPC/LPC, and (3) LPC/GPC.

The VNA is calibrated for reflection measurement using the full-frequency range of the connector type with a harmonic series of test frequencies.

Next, the data are digitally transformed to the time domain using the harmonic frequency series for the low-pass process. The frequency domain data is windowed (see Harris [B7]) by a nominal window, such as (1) truncated Gaussian at 2.5σ , (2) Kaiser-Bessel with $\alpha = 2.0$, or (3) Hamming. All of these provide 40–45 dB side lobe suppression with a main lobe width on reflection of one half a wavelength $\lambda/2$ at the maximum frequency. Both the impulse and the step response can be observed. The response display should be centered on the test connector pair position and expanded to include $5\lambda/2$ on both sides giving a total display of $10\lambda/2$.

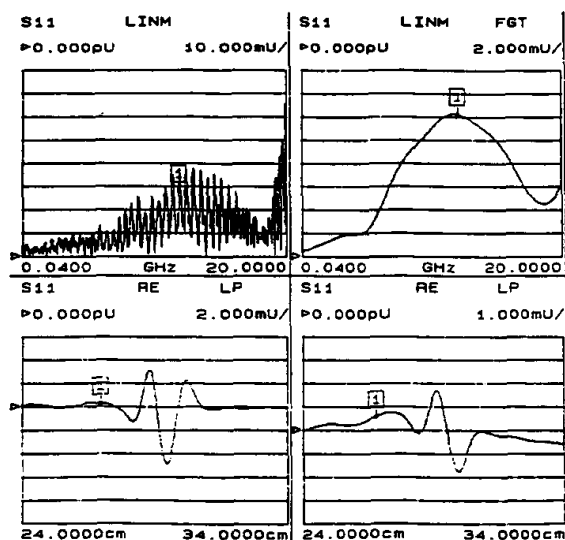
Finally, a time gate width of $5\lambda/2$ ($\pm 2.5\lambda/2$) is applied to the region around the test connector pair and then the gated time response is returned to the frequency domain. A magnitude or vector response from the test connector pair is displayed. This response is isolated from the initial test connection to the VNA and the connector and termination at the far end of the test configuration. The time domain and the gated frequency-domain responses will all be referenced to the impedance of the air line preceding the test connector pair.

Figure 2 shows the four responses discussed in Method 1 for a 7 mm GPC/GPC test connector pair.

At this time, the VNA with the time-domain transformation method tests the entire frequency range of all current and proposed connectors to 110 GHz. It provides initial scrutiny to verify connection viability and can test GPC/GPC and GPC/LPC connector pairs.

A sufficient dynamic range is 90 dB to 50 GHz and 60 dB to 110 GHz. With gated time-domain operation, the accuracy is only limited by the accuracy of the attached air lines.

The time gated frequency response can be stored and the connection broken and reestablished to study connector repeatability. The reflection of subsequent connections can be subtracted from the original stored reflection to give repeatability differences (see Botka [B2] and Harris [B7]).



Upper left:
S₁₁ full data
Lower left:
Impulse
response
Lower right:
Step response
Upper right:
Gated GPC/GPC
junction

Figure 2—Four responses for a 7 mm GPC/GPC test connector pair

- b) **Method 2—VNA with $n\lambda/2$ air lines.** This method was introduced and initially used with a slotted line measurement procedure (see Sanderson [B23]). It can be used with a VNA using an open/short/load (termination) (OSL) calibration procedure as shown in Figure 3. The termination need not be reflectionless. At the $n\lambda/2$ frequencies, the phase of the imperfect termination returns to the calibrated condition, and the end reflections of the test piece add and can be measured separate from the termination mismatch.

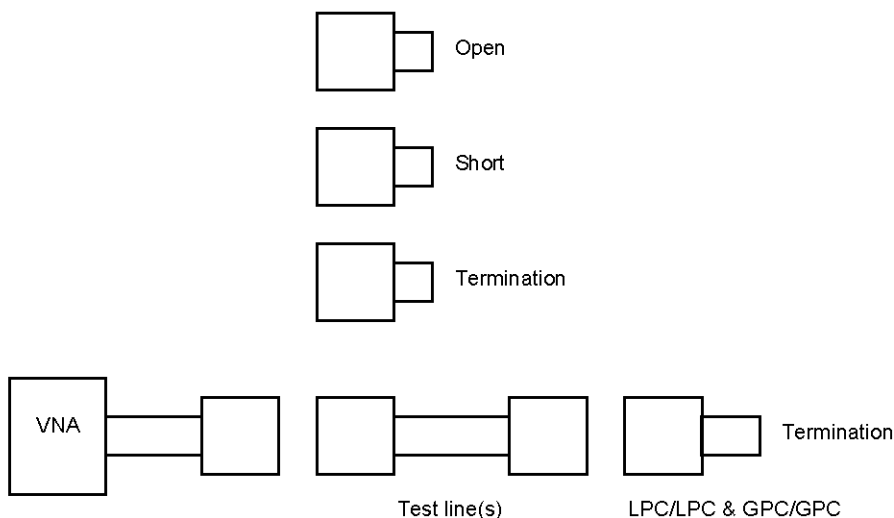


Figure 3—Test configuration for $n\lambda/2$ method

Data from a test of a pair of 2.92 mm LPC connectors are shown in Figure 4.

Sanderson (see Sanderson [B24]) analyzes some errors. The line attenuation contributes an error.

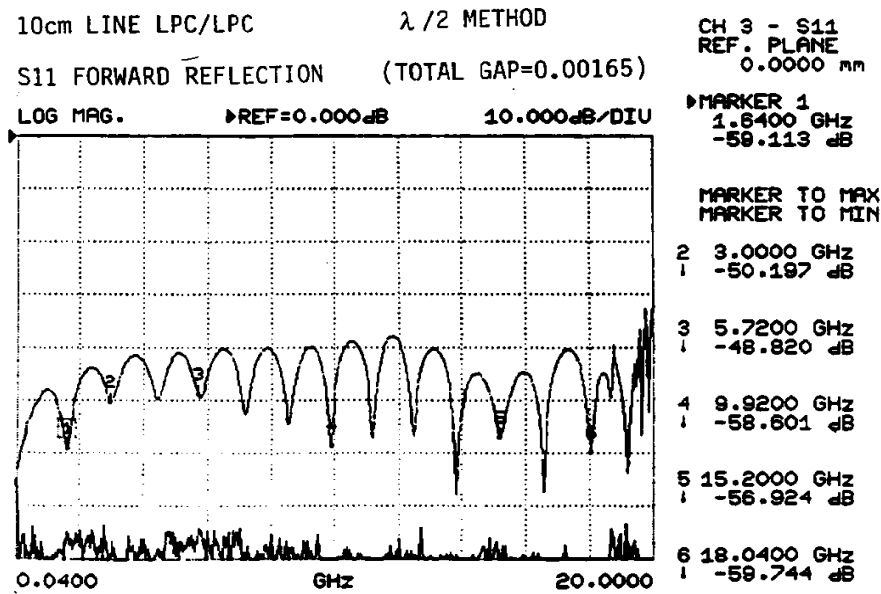


Figure 4—Response from a pair of 2.92 mm LPC connectors

- c) **Method 3—VNA, direct measurement with line, reflect, line (LRL) calibration.** The VNA using LRL calibration can achieve directivity and test port matches at ports 1 and 2 of 60 dB return loss in 7 mm. This performance is illustrated in an article by K. H. Wong [B35]. This can be used to measure a GPC connector alone (with LPC on the other end of the test line) and a GPC/GPC pair on the ends of the test lines.

This method can further be used to measure attenuation and electrical length.

3.3 Connector repeatability

The repeatability of the reflection coefficient can be determined for GPC/GPC and GPC/LPC connector pairs. It is not recommended for the LPC/LPC connector pair since the repeatability requires rotation of one connector with reference to the other, and this usually causes the connector pair to depart from axial alignment. The test configuration of Figure 5 is used for this test.

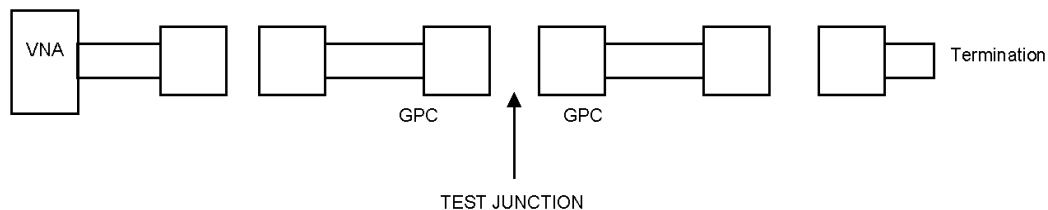


Figure 5—Test configuration for connector repeatability

An open/short/load (termination) calibration is performed at the test connector pair.

The connector pair under test is gated, and the resulting reflection coefficient S_{11} is observed. This is stored; then the connection is broken and then reconnected. The time-gated reflection response is obtained, and the difference between the new reflection and the stored reflection is obtained. This is displayed in log

magnitude format. Numeric differences at appropriate frequencies may be stored for statistical analysis. Figure 6 shows a plot of the accumulated data.

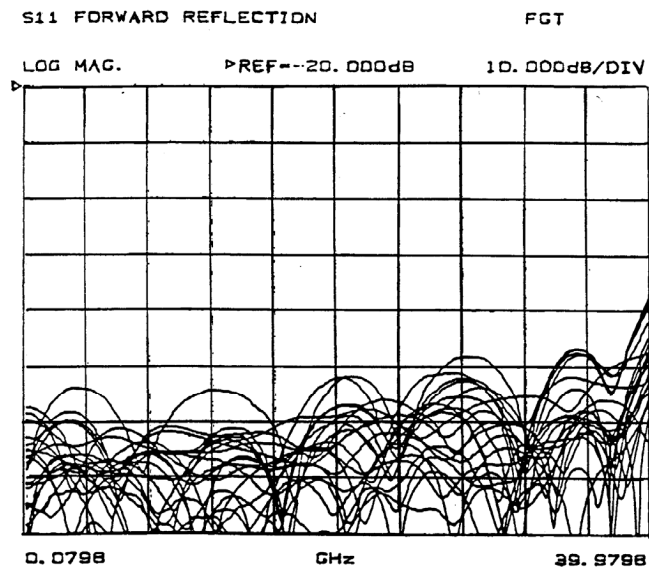


Figure 6—Repeatability of S_{11} GPC/GPC 2.92 mm connector pairs

A series of orientations are measured and displayed. A family of responses are shown in Figure 7 and Figure 8 for 3.5 mm connectors (see Botka [B2]).

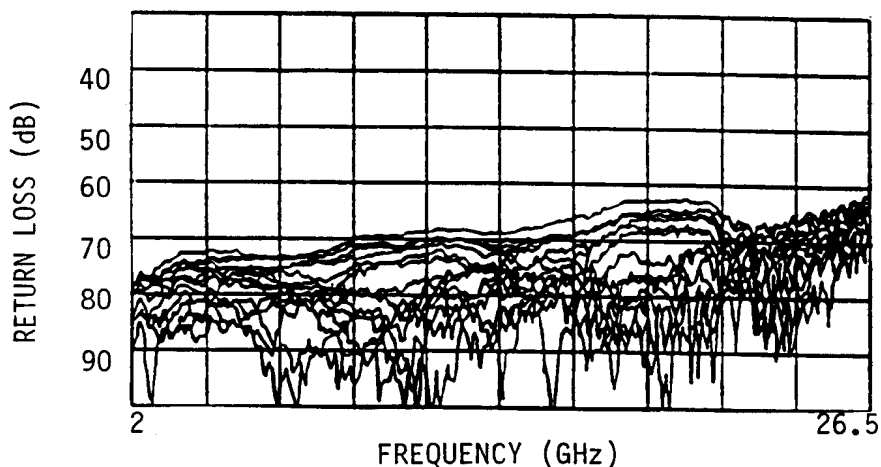


Figure 7—Family of responses for return loss repeatability of a 3.5 mm slotted socket contact

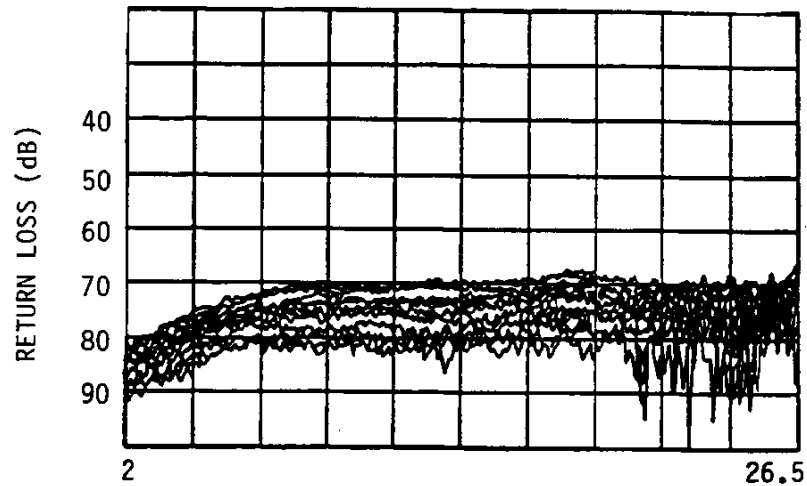


Figure 8—Family of responses for return loss repeatability of a 3.5 mm slotless socket contact

3.4 Insertion loss and phase measurement

Insertion loss and phase can be measured by either transmission or reflection techniques.

3.4.1 Transmission method

For the transmission measurement, a pair of test connectors is mounted on opposite ends of an air line whose loss and electrical length are known. The source and load shall be carefully matched. The test configuration for transmission measurement is shown in Figure 9.

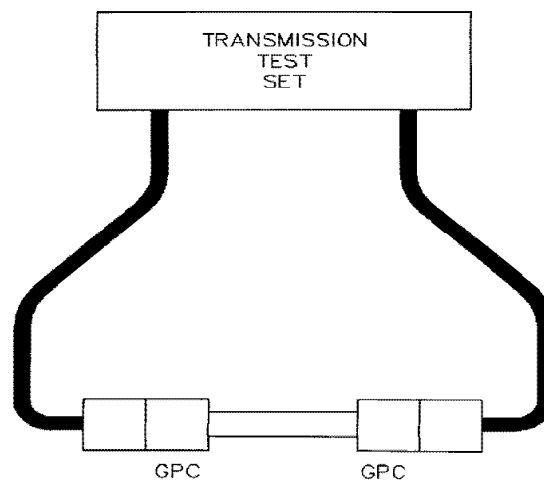


Figure 9—Test configuration for transmission measurement

The VNAs include software correction of measurement port matches with LRL calibration; however, movement of the connecting cables can affect the analyzer port matches after calibration. Care shall be taken that cable movement is minimized after calibration.

3.4.2 Reflection method, version I, VNA without time domain

Alternatively, the insertion loss of precision connectors may be determined by reflection measurements as shown in Figure 10. Again the air line with the test connector pair is used. The reflection is measured with an open and a short circuit terminating the test fixture. Series loss elements in the mechanical connector pair at the terminals will be maximum when a current maximum occurs at the connector pair. Likewise, shunt losses, usually in the support bead, will maximize when a voltage maximum (current minimum) occurs in the support bead. With high-frequency cases, the short and open are often not in the connection plane and, furthermore, the separation of the connector interface plane and the bead complicate interpretation of the test results. Note that the measurement is the sum of two transits and shall be divided by 2 to obtain the amplitude and phase difference.

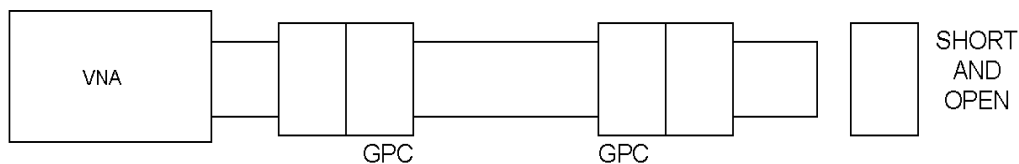


Figure 10—Test configuration for insertion loss measurement by reflection

3.4.3 Reflection method, version II, VNA with time domain

A variant on the reflection method is shown in Figure 11 and Figure 12. In this arrangement, a comparison test line is constructed such that the length of the air line section (less connectors) is the same as the sum of air lines L1 and L2 (less connectors). The comparison air line section shall carefully match the material, surface finish, and mechanical accuracy of the separate test pieces L1 and L2. The difference in insertion loss and phase is then attributed to the test connector pair.

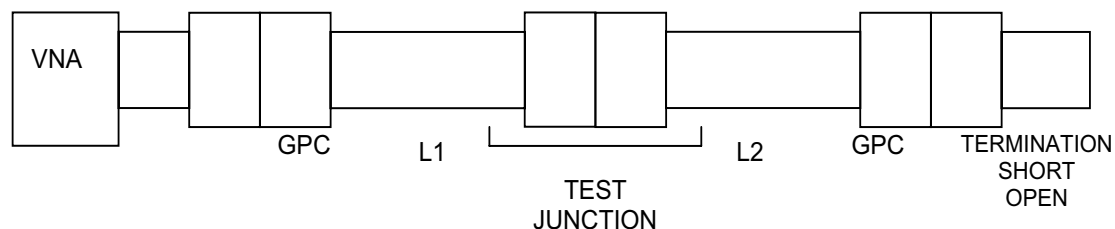


Figure 11—Test configuration

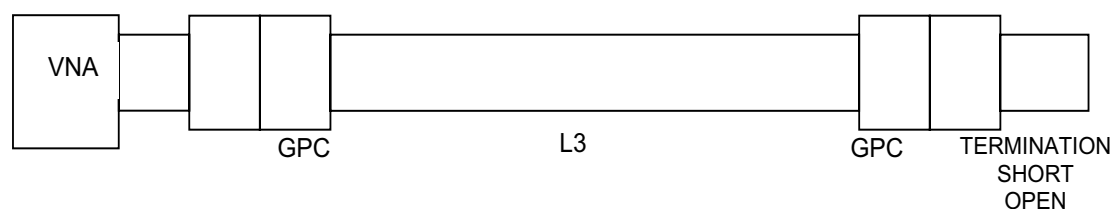
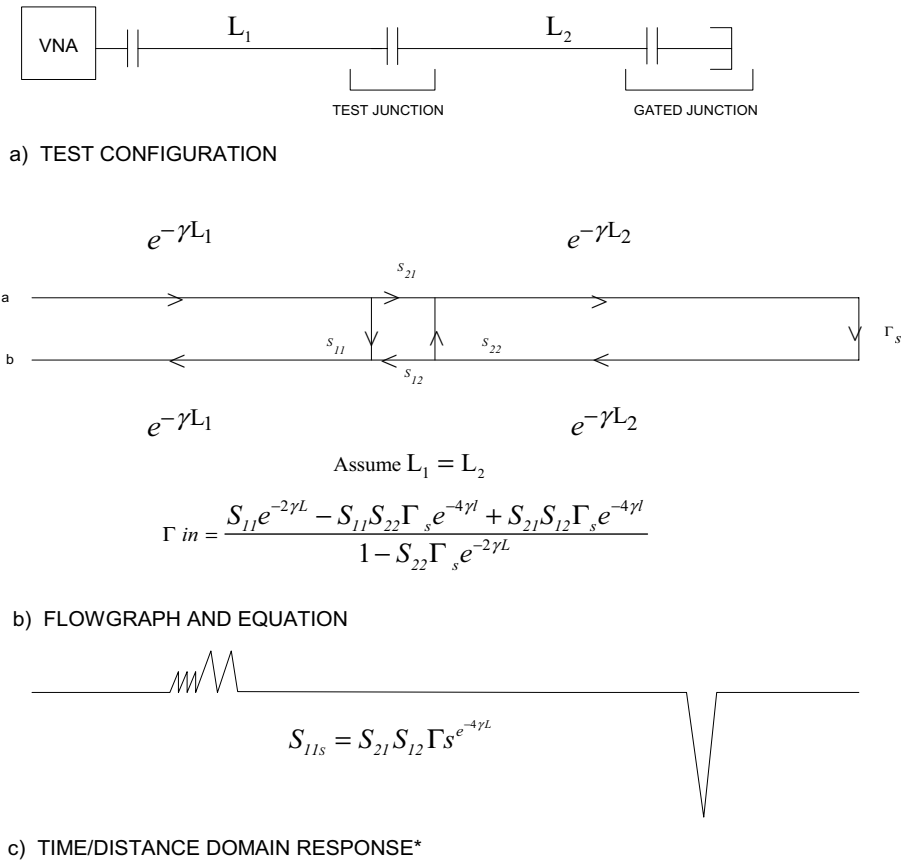


Figure 12—Comparison test line

Figure 13 depicts the measurement process.



*NOTE—This equation is derived by making S_{11} and S_{22} equal to 0. This assumption is only valid if one uses the gating feature to “zero” out the connector under test reflections in the time domain.

Figure 13— S_{21} test configuration and diagrams for insertion loss and phase measurements

To measure the insertion loss and phase of a connector pair, the comparison test piece is first measured in the frequency domain to confirm normality. The termination is replaced with a short circuit. Transform to the time domain and apply a time gate around the short circuit. Transformation back to the frequency domain produces the two-way loss and phase. The comparison piece is now replaced by the two lines joined at the test connectors, and the process is repeated. Subtraction of the results provides the incremental difference caused by the inclusion of the connector pair.

3.4.4 Insertion loss and phase repeatability

Either of the reflection methods can be used to perform loss and phase repeatability measurements. The transmission method can be used for repeatability without rotation but becomes awkward when rotation is included.

To perform the test, an initial measurement is made as in the insertion loss and phase test. This trace is then used as a reference.

Subsequent measurements are then made and compared with the initial measurement. If the data are in S -parameter form, the magnitudes of S_{11} are subtracted from the initial reading to obtain the values of ΔS_{21} *mag*. Likewise the values for phase are subtracted from the initial reading to obtain ΔS_{21} *arg*. Both results are to be divided by 2 to obtain the true readings. This accounts for the two-way path.

Data for a series of the magnitude and phase repeatability tests are shown in Figure 14. Again, the data spread should be divided by 2.

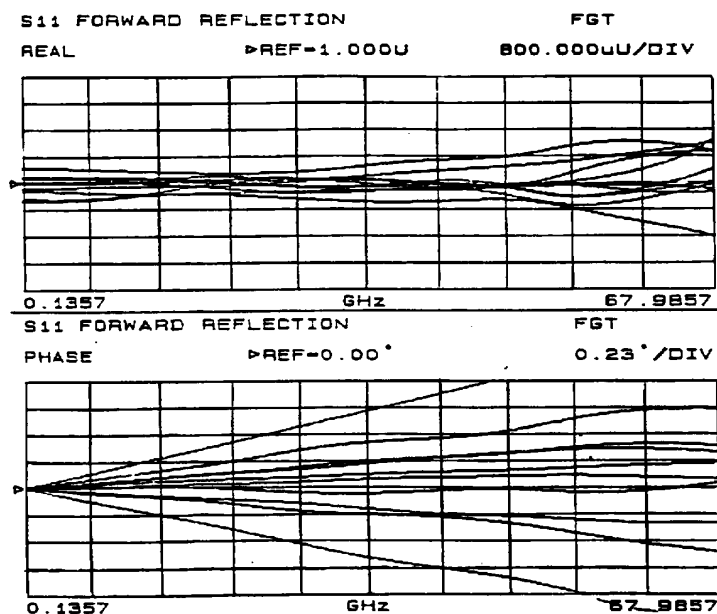


Figure 14—Repeatability S_{21} of magnitude (above) and phase (below) for a 1.85 mm GPC/GPC pair

Alternatively, a slotted line equipped with one of the test connectors of a pair can be used, with an open and a short as the other connector of the test pair. The SWR is then measured by twice the minimum method. These results are used to compute the connector pair attenuation (see Harris [B8]).

3.5 Shielding effectiveness

Three methods are presented for the shielding effectiveness (SE) measurement of a coaxial connector. They are (1) the traditional triaxial test fixture, (2) the mode-stirred method, and (3) the broadband terminated fixture.

3.5.1 Triaxial method

Figure 15 is a diagram of a test fixture that is used in the triaxial technique (see Dimitrios [B4] and Zorzy and Muehlberger [B37]). The test fixture is a segment of a coaxial transmission line surrounded by an outer tubular conductor, which forms externally a second coaxial system that is normally configured for a characteristic impedance of $50\ \Omega$. This implies for each connector and cable size measured that a new test fixture has to be designed and configured to maintain a constant $50\ \Omega$ characteristic impedance throughout the test fixture and reduce internal reflections that are a source of errors in the measured SE. The excitation of the outer coaxial line is believed to be principally transverse electromagnetic, although it is possible for higher order modes to exist, depending on frequency. The wavelength at the operating frequency shall be

greater than the mean circumference of the coaxial system to prevent propagation of higher order modes that can add uncertainty to the measurement.

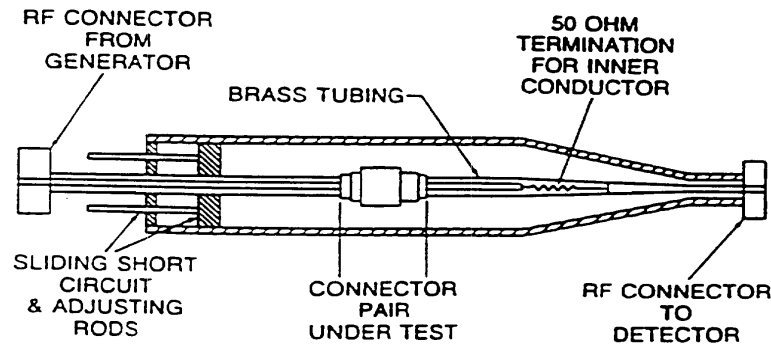


Figure 15—Triaxial test fixture

The second external coaxial system in Figure 15 is terminated at one end in a sliding short circuit and at the other tapered transition in a matched detector. The sliding short circuit is positioned to produce a maximum indication at the detector for each test frequency measured. Positioning of the sliding short circuit shall exceed a half-wavelength between the short circuit and the connector pair under test. On a connector assembly that is properly mounted on semi-rigid cables or air lines, there are three possible leakage areas: the region around the mating face and locking mechanism of the connector, plus the two regions where the connector is attached to the cable or air line.

The SE of the connector pair under test is determined by establishing as a reference and measuring the total applied power P_1 that is fed through the inner coaxial line. Next the power P_2 leakage through the connector pair into the outer coaxial structure is maximized at the detector by the sliding short circuit and measured. The SE of the connector pair in decibels is determined using the following equation (see also Zorzy and Muehlberger [B37]).

$$SE = 10 \log_{10} \frac{P_1}{P_2} \quad (3)$$

3.5.2 Mode-stirred method

Figure 16 is a diagram of a mode-stirred test system as specified in accordance with Method 3008 of MIL-STD-1344A [B18]. The test chamber is essentially a low-loss shielded enclosure that includes an input antenna, a reference antenna, and a mode stirrer. Testing is conducted inside the test chamber whose smallest dimension is at least three wavelengths at the lowest test frequency to ensure an ample mode density, which is a necessary condition of the validity of the mode-stirred technique (see Crawford and Koepke [B3], Jesch [B14], and Staeger and Bolinger [B29]). In addition, the minimum distance between the DUT and the chamber walls is at least one wavelength at the lowest test frequency to maintain a uniform electric field throughout the chamber. The chamber is excited by an input antenna provided by a line wire mounted parallel to the chamber walls. To reduce reflections, impedance matching tapers are used at both ends of the antenna. One end of the antenna is terminated in $50 \, \Omega$, whereas the other end is connected to the signal source. A reference antenna of the same length as the input antenna is mounted on the opposite wall with one end connected to a receiver and the other terminated into $50 \, \Omega$ through impedance matching tapers.

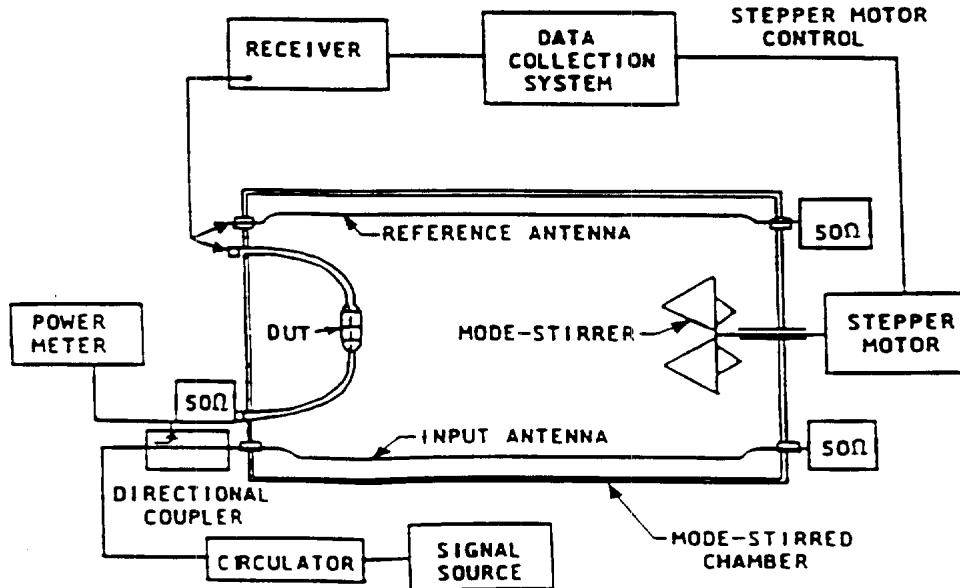


Figure 16—Diagram of mode-stirred test systems from MIL-STD-1344A [B18]

The mode-stirrer, typically a paddle wheel tuner, serves to randomize the multimode electromagnetic fields existing inside the test chamber when rotated by significantly altering the complex standing wave patterns. Rotation of the mode-stirrer changes the relative amplitude of the modes, and it is intended to ensure that the field at any point is uniform on a time-averaged basis.

The mode-stirred chamber as specified in MIL-STD-1344A [B18] was intended for use to 10 GHz. Substituting horn antennas for the wire style extends the frequency range.

To measure the SE of the connector pair under test (DUT), the power P_1 is fed through the input antenna and received by the reference antenna to establish a reference level. Next the power P_2 leaking into the DUT is measured. The SE of the DUT is determined by taking the $10 \log_{10}$ ratio of the averages (P_1 and P_2) over one rotation of the mode-stirrer.

3.5.3 Broadband terminated fixture

This broadband fixture is triaxial with both the outer and the inner coaxial line terminated on both ends (see Crawford and Koepke [B3], IEC Publication 1169-1-3 [B12], and Staeger and Bolinger [B29]). With this test setup as shown in Figure 17, cable and connector shielding effectiveness measurements over more than seven frequency decades can be performed. The setup permits measurement of directive effects, which occur on both cables and connectors due to several discrete leakage points. Wide dynamic range (up to 150 dB) is achieved by using a combination of synthesized signal generator, synthesized spectrum analyzer, or receiver and low noise preamplifier.

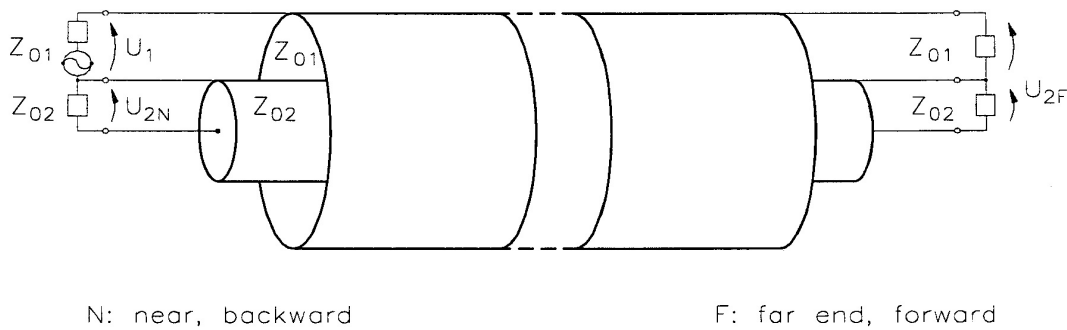


Figure 17—Basic configuration for a broadband terminated fixture

The test connector pair is in the center of the inner connector for that coaxial system. The coupling to the inner coaxial system is measured.

The test configuration is shown in Figure 18 (see Kubota et al. [B15]). This covers the frequency ranges of 1 kHz to 10 MHz and 10 MHz to 10 GHz.

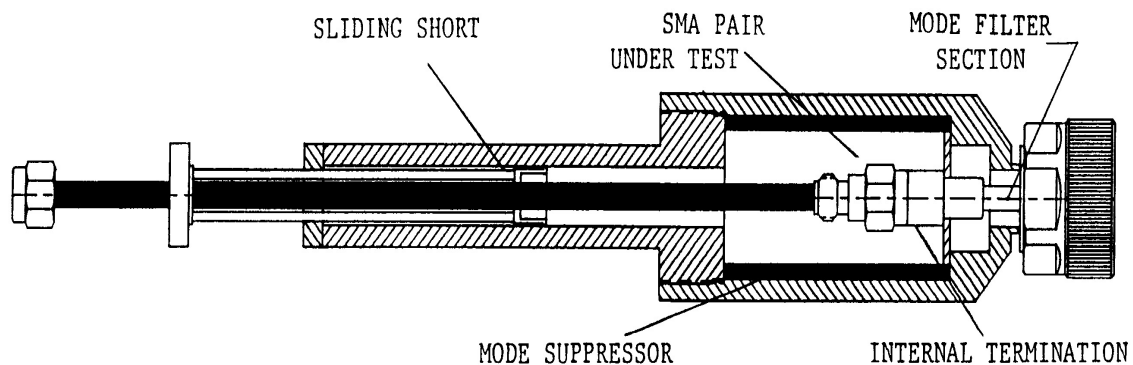


Figure 18—Test configuration for a triaxial broadband fixture

The test source and leakage receiver should be chosen to measure attenuation up to 160 dB.

3.6 Direct-current contact resistance

Diagrams describing a measurement technique for low-level, direct-current contact resistance are shown in Figure 19 and Figure 20. The contact-resistance values to be reported are those of the inner-conductor and outer-conductor joints, irrespective of the resistance of the conductor materials. Contacts should not be cleaned or conditioned prior to testing. For the outer conductor, the resistance of each connector body (AB and CD) is first determined as indicated in Figure 20(a). The standard conductive coupling mechanism is replaced with a nonconductive coupling with the connectors mated and tightened to the recommended torque. The overall resistance from end to end (A to D) is measured. Care shall be taken to make the probe connections in the same location and manner as Figure 19(a). The outer conductor contact resistance is the difference between these measurements [see Figure 19(b)].

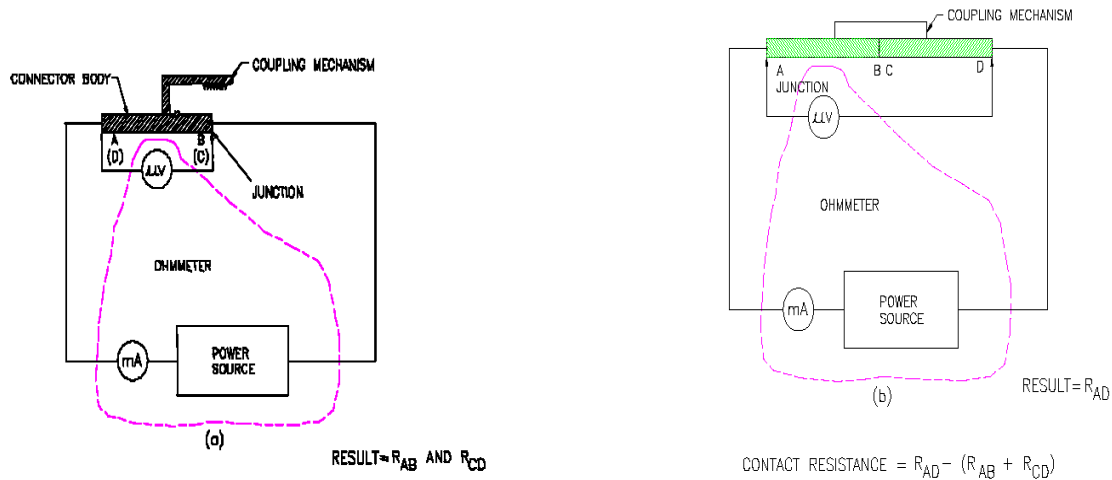


Figure 19—Outer conductor contact-resistance measurement method: (a) Initial measurement (single connector) and (b) final measurement (mated connector pair)

For the inner conductor, the contact resistance specified includes the resistance due to all moving contact parts. The initial measurements of the inner conductor resistance shall not include the resistance inherent in the moving parts. In the initial measurement, one probe is placed at the end of the contact that attaches to the precision line, whereas the other probe is placed at a point just behind the moving contacting parts. The final measurement is made from end to end of a mated pair of inner contacts assembled in the connector housings. The contact resistance is the difference between these measurements; see Figure 19(a) and (b).

If points B and C are accessible in the mated connector, a single measurement for contact resistance is permitted.

The measurements can be made directly using a four-terminal ohmmeter (Kelvin Double Bridge) with thermal EMF compensation. A separate voltmeter and current source can also be used. In this case, each voltage is measured with equal magnitude positive and negative currents, and each result is

$$R_{xx} = \frac{|V_{\text{positive}}| + |V_{\text{negative}}|}{2I} \quad (4)$$

With either method, the source should not exceed 100 mA and 20 mV open circuit (dry circuit).

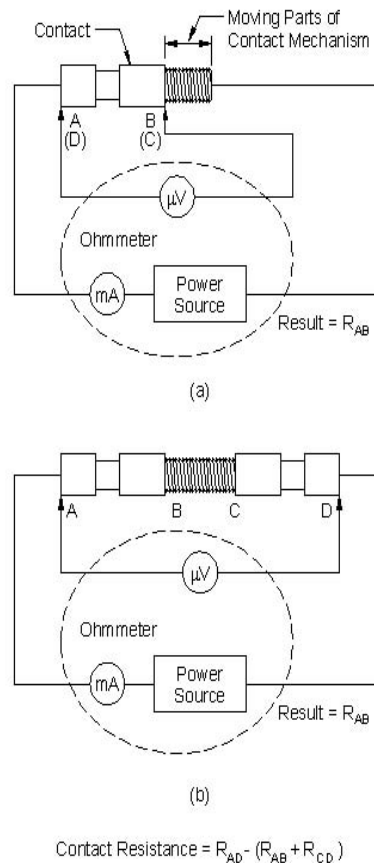


Figure 20—Inner conductor contact-resistance measurement method: (a) Initial measurement and (b) final measurement (mated contacts)

4. Recommended mechanical test procedures for GPC and LPC

4.1 Mechanical requirements specified

4.1.1 Dimensional measurements

Measurement of dimensions that influence the impedance of an air line:

- Outer conductor internal diameter
- Inner conductor external diameter
- Inner conductor to outer conductor eccentricity

4.1.2 Inner conductor axial force

Measurement of the range of axial force applied to the inner conductor of the hermaphroditic GPC to bring the inner contact into a coplanar condition relative to the outer conductor.

4.1.3 Inner conductor protrusion

Measurement of the range of protrusion of the inner contact (collet) of a hermaphroditic GPC beyond the reference plane before mating.

4.1.4 Inner conductor axial displacement

Measurement of the maximum axial displacement of the inner conductor of a hermaphroditic GPC resulting from the application of a specified force for a given duration.

4.1.5 Maximum insertion and withdrawal forces

Measurement of the maximum insertion and withdrawal force of a socket inner conductor of a pin and socket connector when a standard test pin is inserted and withdrawn at the specified rate to the specified depth.

4.1.6 Displacement due to insertion and withdrawal force

Measurement of the maximum temporary, as well as resulting permanent, displacement of the socket inner conductor as a result of the maximum insertion and withdrawal forces as measured in 4.1.5.

4.1.7 Minimum insertion and withdrawal force

Measurement of the minimum axial withdrawal force of a polarized socket inner conductor when mated with a standard test pin as specified in the detail specifications.

4.1.8 Angular deflection

Measurement of the angular deflection of both hermaphroditic and polarized GPC inner conductors when a specified torque is applied. This torque is to be referred to the center of the dielectric support, and it shall be applied to the rear of the dielectric support.

Measurement uncertainties: Regardless of the measurement method chosen, the uncertainty of the method should be low enough so as to provide satisfactory results. Good measurement practices dictate that the ratio of tolerance to measurement uncertainty be at least 4 to 1. For example, if one were measuring a diameter with a tolerance of ± 0.01 mm, the uncertainty of the measurement tool should be no more than ± 0.0025 mm.

4.1.9 Connect/disconnect life

Measurement of the connect/disconnect life of a connector pair is specified in the detail specifications.

4.2 Recommended mechanical test procedures

4.2.1 Measurement of dimensions that influence the impedance of an air line

Three main dimensions affect the impedance of an air line; the inside diameter of the outer conductor, the outside diameter of the inner conductor, and the eccentricity of the two relative to each other.

4.2.1.1 Measurement of outer conductor internal diameter

Many methods can be used to measure the diameter of an internal bore. These methods fall into two categories: contact and noncontact measurements. An example of a contact measurement would be a plug

gage. An example of a noncontact measurement would be an air gage. For tolerances shown in the detail specifications, the use of a contact measurement is not recommended. A properly implemented air gage measurement is considered the best functional inspection of bore diameters for microwave purposes.

Figure 21 shows a cross-sectional drawing of an outer conductor being measured with the probe of an air gage.

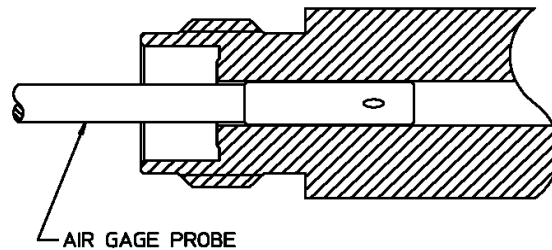


Figure 21—Cross section of an air line outer conductor being measured with an air gage

Air gages, when calibrated with the highest grade of standards, can achieve measurement uncertainties on the order of $0.5\ \mu\text{m}$. The calibration standards chosen should be of the highest quality affordable and should be directly traceable to the National Institute of Standards and Technology (NIST) (see Sherwood [B25]) or other national standards laboratories as appropriate (see Sherwood [B26]). The gage should be calibrated frequently, and proper techniques, as dictated by the gage manufacturer, should be followed.

To achieve the lowest possible uncertainty, multiple measurements along the bore should be made. Proper fixturing of the test piece is a must. Temperature effects should also be considered. It is recommended that the test piece “soak” in the same temperature environment as the gage to allow its temperature to match that of the environment.

Air gaging has some limitations, the largest of which is that the air gage cannot measure the diameter of the part right up to the end of the bore. Since the gage works on a back pressure principle, the gage requires a minimum length of bore to achieve accurate results. If the air gage is used to measure up to the end of a bore, air will begin to leak out of the bore and an error in the measurement will be introduced. Other methods shall be used to determine that the end of the bore meets its dimensional requirements. One method that is commonly used is a coordinate measurement machine (CMM).

4.2.1.2 Measurement of inner conductor outside diameter

The recommended method for measuring the outer diameter of an inner conductor is to use a laser micrometer; one such gage is shown in Figure 22. The laser micrometer is a noncontact measurement. Unlike a standard micrometer, nothing other than the beam of light touches the part. A laser micrometer has a beam that is on the order of $0.1\ \text{mm}$ wide. The beam is swept in a vertical direction by a system of spinning mirrors. When a part is placed in the beam to be measured, it blocks the beam. The gage has the capability of converting the time the beam is blocked into a dimensional reading of the diameter of the part.

Another method that is commonly used to measure inner conductor diameters is an air gage for external diameters. Instead of a probe, the tip is an annular ring that fits over the outside of the inner conductor.

Measurement uncertainties on the order of $0.5\ \mu\text{m}$ can be achieved with either method. The part should be rotated as the diameter is being measured. As in the case of the air gage, multiple measurements along the length of the part should be taken.

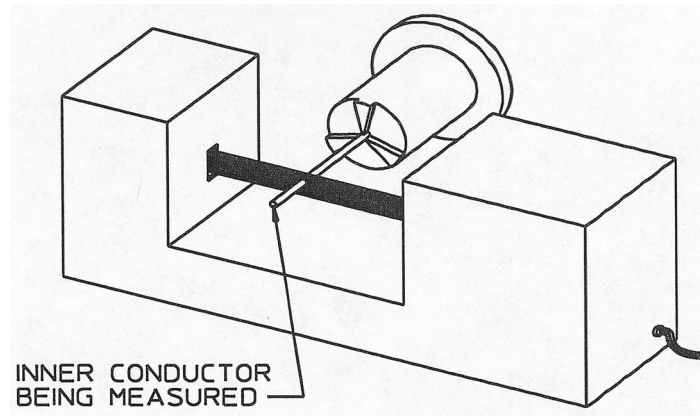


Figure 22—Laser micrometer measuring the diameter of a test part

The best results will be achieved with the highest level of calibration standards. These standards should be directly traceable to the NIST (see Sherwood [B25]) or other national standards laboratories as appropriate, and should be of the highest quality affordable (see Sherwood [B26] and Wong [B34]). The gage should be calibrated frequently and proper techniques, as dictated by the gage manufacturer, should be followed.

Neither the air gage nor the laser micrometer can measure the form of the parts. The form should be measured on a good roundness spindle.

4.2.1.3 Measurement of inner to outer conductor eccentricity

Two methods measure the eccentricity of the inner to outer conductor. Which method is used depends on the desired result. Eccentricity can have both a mechanical and an electrical effect on the performance of the connector. Mechanically, if the inner and outer conductors are out of eccentricity specification, damage may occur when connectors are mated to one another. On the other hand, electrically, the eccentricity can cause an error in the impedance of the connector leading to an unwanted reflection.

The eccentricity at the reference plane can be inspected using an optical method: either a tool maker's microscope or an optical comparator. This measurement would help to prevent mechanical damage to the connector pairs since it checks eccentricity at the reference plane only, not down inside the connector. It is helpful if the measurement equipment used is coupled with a controller so that the operator can be assisted in making the measurement.

4.2.1.4 Determining characteristic impedance

In air-spaced coax lines where the skin depth is insignificant compared with the dimensional uncertainties, the characteristic impedance can be calculated by

$$Z_0 = \frac{2c \times 10^{-7}}{\sqrt{\epsilon_r}} \ln \frac{D}{d} \quad (5)$$

$$= \frac{59.9585}{\sqrt{\epsilon_r}} \ln \frac{D}{d} \quad \equiv$$

where

c is the velocity of light in vacuum, in meters/second

$\epsilon_r \cong$ is the 1.000649 for 50% RH, 104 kPa, and 23 °C
 D is the inner diameter of the outer conductor in meters
 d is the outer diameter of the inner conductor in meters

and

$$\frac{\Delta Z_0}{Z_0} \cong \frac{240 \epsilon^2}{Z_0 - (D^2 - d^2)} \quad (6)$$

where ϵ is the displacement from the centerline of the inner conductor in meters.

4.2.2 Inner conductor axial force

Measurement of the range of axial force applied to the inner conductor of a hermaphroditic GPC to bring the contact coplanar with the outer conductor reference plane.

Fixture design: Figure 23 shows one possible solution to this measurement problem. There are three main components to this fixture: the connector retainer, the force gage, and the parts that hold the connector together. The connector retainer should be designed so that different connectors may be tested with the fixture. The force gage is mounted in a horizontal manner on a slide mechanism.

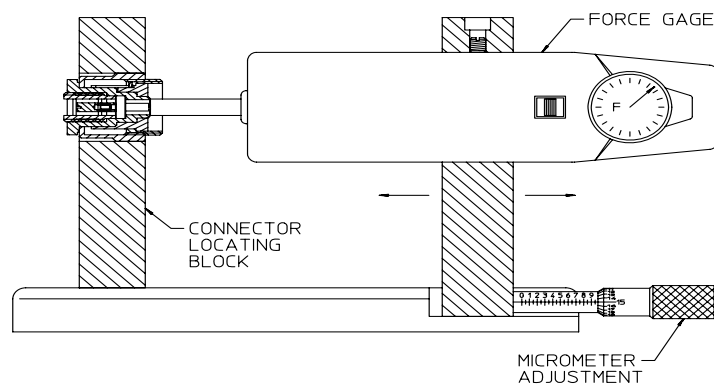


Figure 23—Fixture for measuring the force to compress collet on GPC connector

Provisions are made for a linear micrometer; this would be used to both move the force gage horizontally and allow the measurement of its axial position. The tip of the force gage is designed so that it abutts the outer conductor reference plane when the collet is fully compressed.

Fixture use: After the connector is clamped into the holding fixture, slowly bring the force gage forward toward the connector using the micrometer adjustment. Once the tip of the force gage contacts the collet, stop and make note of the reading on the micrometer, as well as any force showing up on the gage. Using the micrometer, continue moving the force gage toward the connector and, thereby, compress the collet.

Using small increments on the micrometer, such as 0.005 mm, take note of the force versus distance as the collet is compressed. Continue to compress the collet until the tip of the force gage hits the outer conductor reference plane of the connector. A simple electrical continuity setup can be attached to the fixture to tell when the tip of the force gage hits the connector outer conductor reference plane. Plot the data in a graph of force versus distance. This graph will show the force required to compress the collet to the point where it is coplanar with the outer conductor reference plane.

4.2.3 Range of protrusion of contact on hermaphroditic connector

One way this measurement could be made is with an optical method such as a shadow-graph or optical comparator. The connector could be held in place, with its outer coupling mechanism removed, and measured in side view. This method has been used; however, care shall be taken to properly align the connector before measurement. Any nonperpendicularity of the connector relative to the lense will cause an error in the measurement. With an optical method, it is sometimes difficult to properly focus on the surface from which the measurements shall be taken.

A mechanical method may also be used to make this same measurement.

Fixture design: Figure 24 shows one possible configuration for a fixture to make this measurement. The fixture would have an interchangeable method for holding the connector to be tested. This interchangeable holding method would allow different connectors to be tested in the same fixture. A linear height gage would be mounted horizontally on a sliding mechanism. The sliding mechanism would be used to take up any large excesses in position of the end of the gage relative to the connector collet being measured. The gage would have an electrical continuity system that would allow the user to know exactly when contact has been made to the connector.

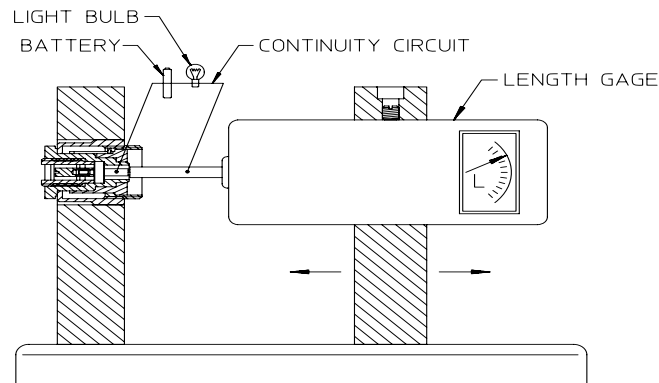


Figure 24—Fixture for measuring the protrusion of a hermaphroditic connector's collet

Fixture use: Install the assembled connector into the holding fixture. Bring the linear gage up into contact with the outer conductor reference plane and zero the gage. Slide the gage back, and align the tip up with the collet. Slowly let the gage tip move toward the collet until the continuity occurs. Record the length measurement at the exact point where electrical continuity is achieved between the collet and the tip of the gage.

4.2.4 Inner conductor axial displacement

Fixture design: Figure 25 shows one possible solution to this measurement problem. The fixture has a method of holding the connector that is identical to the fixture shown in Figure 23. The fixture also has means for holding both a force and a length gage horizontally on either end of the connector assembly. The connector holding block is movable horizontally so that the connector may be brought into contact with the length gage. The force gage can also move horizontally so that the axial force applied to the inner conductor can be varied for each connector to be tested. The force and length gages also have interchangeable end tips that can be used depending on which connector is being tested. The length gage may be a horizontally mounted height gage. The length gage shall have a very small spring force; it should be small enough so that it does not affect the results of this test. The fixture itself can be used to measure the distance gage's axial force.

Fixture use: Once the connector is assembled, it is clamped into the fixture. The length gage is brought into contact with the back of the connector's inner conductor. Again, this gage shall have a very small spring force so that it will not affect the force setting. The gage is zeroed once it makes contact with the inner conductor. Next, the force gage is brought into contact with the front of the inner conductor. Slowly the force gage is advanced toward the connector until it is applying the specified amount of axial force to the inner conductor. The fixture is left in this condition for the specified amount of time. At the end of this time, the length is noted. Next, the force is removed by backing off the force gage. When the force is completely removed, the length is noted again.

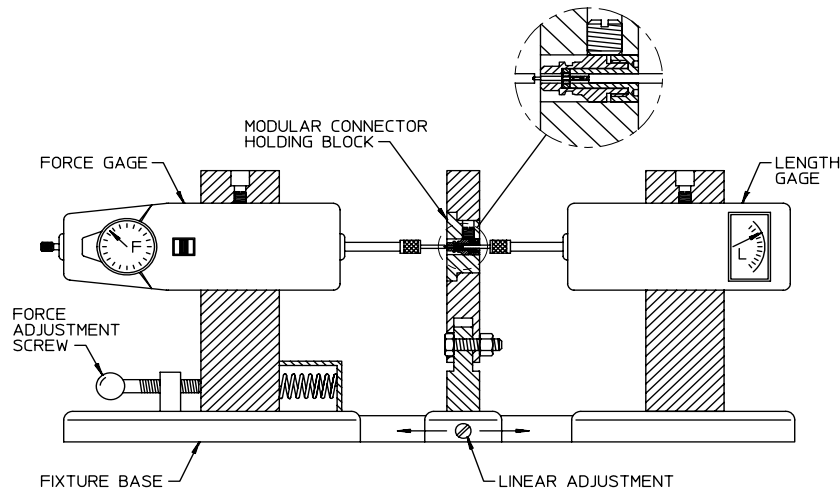


Figure 25—Fixture to measure inner conductor deflection under a specified load

4.2.5 Maximum insertion and withdrawal forces

Measurement of the maximum insertion and withdrawal force of a socket inner conductor of a polarized connector when a standard test pin is inserted and withdrawn at the specified rate to the specified depth.

Fixture design: This test requires a fixture that can insert a standard test pin into a socket inner conductor contact at a specified rate.

Figure 26 shows one possible design for a fixture to perform this test. The fixture consists of two main parts: the force gage with drive mechanism and the inner conductor holding collet. The force gage is mounted in a horizontal direction on a slide that can be driven at different linear rates. The slide mechanism needs to have an adjustable rate so that the fixture can be used to test different connectors. The holding collet should be designed so that it will hold any inner conductor size that needs to be tested. An adjustable stop should be provided so that different depths of penetration can be set on the test pin.

Fixture use: Start by loading the proper size collet into the inner conductor holding mechanism. Load the inner conductor to be tested into the collet and tighten to secure it. Load the proper test pin for the test being conducted into the force gage. Slide the gage with test pin up to the inner conductor, and adjust the alignment of the two halves of the fixture. Set the adjustable insertion rate at the specified rate for the connector inner conductor being tested. Adjust the stop mechanism to the proper depth of penetration, as dictated in the detail specifications. Start the test pin moving toward the inner conductor, and record the insertion force while the pin is going into the socket inner conductor. Note the force as the pin is being withdrawn as well.

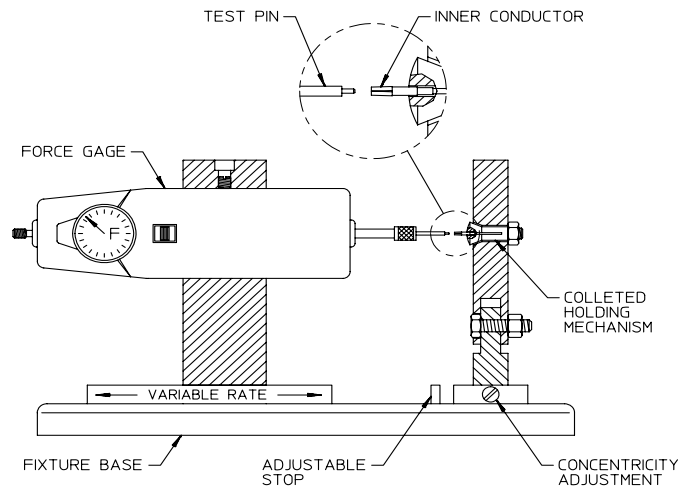


Figure 26—Insertion/withdrawal force measurement fixture

4.2.6 Displacement due to insertion and withdrawal force

Measurement of the maximum temporary, as well as resulting permanent, displacement of the socket inner conductor as a result of the maximum insertion and withdrawal forces as measured in 4.2.4.

Refer to 4.2.4 for the design and use of the fixture shown in Figure 25. The same fixture will work for this test.

4.2.7 Minimum insertion and withdrawal force

Measurement of the minimum axial withdrawal force of a socket inner conductor when mated with a standard test pin as specified in the detail specifications.

Refer to 4.2.5 for the design and use of the fixture shown in Figure 26. The same fixture will work for this test. The main difference in this test will be that the dimensions of the test pin used will change; these dimensions will be specified in the detail specifications for the connector being tested.

4.2.8 Angular deflection

Measurement of the angular deflection of both hermaphroditic and polarized GPC inner conductors when a specified torque is applied. This torque is to be referred to the center of the dielectric support, and it shall be applied to the rear of the dielectric support.

Fixture design: This fixture shall be capable of applying a variable torque to the inner conductor of a connector while, at the same time, measuring the resulting angular deflection of the inner conductor.

Figure 27 suggests a design that may be used to perform this test. A holding mechanism, which is the same as in the fixtures described above, can be used on this fixture. This mechanism should be capable of holding any of the connectors that shall be tested. A force gage is mounted with a method of moving it perpendicular to the inner conductor. By moving the force gage toward the inner conductor, the torque that is applied to the connector can be increased. If a known length is used for the component that is connected to the back of the inner conductor, the torque can be easily calculated using the following formula:

$$\text{Torque} = \text{Force} \times \text{Length}$$

The outer conductor of the connector shall be modified to allow for the measurement of the deflection of the inner conductor. Since an optical method will be used to measure the deflection, the outer conductor shall be sectioned to allow sighting down into the connector to the inner conductor. A section of 45° should be sufficient to allow seeing down inside the connector. The remaining portion of the outer conductor will be strong enough to hold the bead ring assembly.

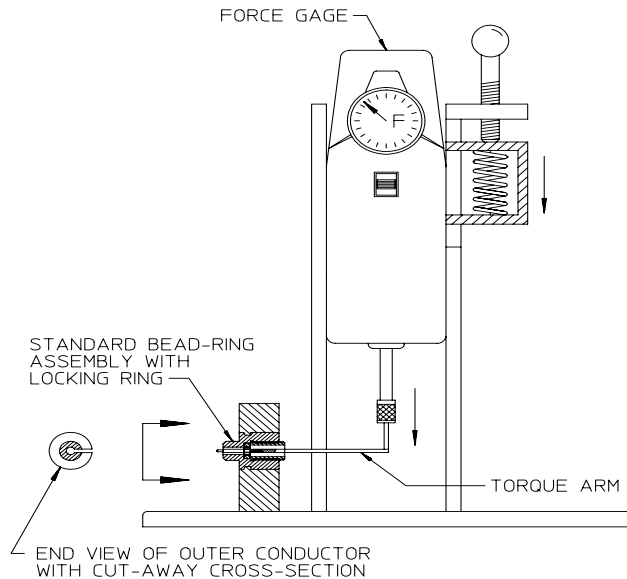


Figure 27—Fixture to measure angular deflection as a result of a specified torque

Fixture use: First, assemble the connector to be tested, attach the torque rod to the back of the inner conductor, and tighten around the bead. Place the inner conductor assembly into the connector body, and tighten it using the locking piece. Mount the entire connector assembly into the holding fixture. Place the entire fixture on the bed of an optical comparator. Align the axis of the comparator with the centerline of the inner conductor. Bring the force gage up into contact with the torque arm. Apply the correct amount of force to establish the specified torque at the center of the bead. Using the comparator, measure the angular deflection of the inner conductor under the specified torque value.

4.2.9 Connect/disconnect life

Determination of connect/disconnect life as specified in the detail specifications.

This test is most easily performed by mounting a mateable pair of connectors (e.g., pin and socket) on air lines. Begin by measuring

$$|S_{11}|, S_{21}, \arg S_{21}, \text{ repeatability } \Delta |S_{11}|, \text{ repeatability } \Delta |S_{21}|, \text{ and repeatability } \Delta \arg S_{21}$$

Mount one air line in a fixture or otherwise clamp so that it is held rigidly. For pin/socket combinations, the socket half of the pair preferably is held rigid. Connect the second air line to the first air line such that the connectors to be exposed are connected together by hand. With a torque wrench, tighten the coupling mechanism to the specified torque. With the torque wrench, untorque the coupling mechanism such that the disconnect can be performed by hand. Completely disconnect the connectors. This constitutes one cycle. A