



IEEE Standard for Precision Coaxial Connectors at RF, Microwave, and Millimeter-Wave Frequencies— Part 1: General Requirements, Definitions, and Detailed Specifications

IEEE Instrumentation and Measurement Society

IEEE Microwave Theory and Techniques Society

Developed by the
High Frequency Measurement and Connector Committee
and the
Standards Coordinating Committee

IEEE Std 287.1™-2021

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Approved 8 December 2021

IEEE SA Standards Board

Abstract: The IEEE 287 series of documents presents the combined efforts of IEEE P287 Working Group that reflect the knowledge and experience of leading specialists in the development and measurement of precision coaxial connectors for RF, microwave, and millimeter-wave frequencies. It presents minimum performance requirements to standardize both hermaphroditic and pin-and socket-type connectors (IEEE Std 287.1™-2021, this document). It provides recommended electrical and mechanical test procedures for Instrument Grade and Metrology Grade precision connectors (IEEE Std 287.2™-2021). Recommended reference procedures including connector effects, connector care and cleaning, connector repeatability and reproducibility test procedures, and a color code for connectors are detailed in the third part of the series (IEEE Std 287.3™-2021). A bibliography provides a list of pertinent references for measurement techniques used in determining electrical, mechanical, and dimensional parameters for coaxial connectors.

Keywords: IEEE 287.1™, instrument grade connector (IGC), metrology grade connector (MGC), minimum performance requirement, pin and socket connector, precision coaxial connector

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Introduction

This introduction is not part of IEEE Std 287.1-2021, IEEE Standard for Precision Coaxial Connectors at RF, Microwave, and Millimeter-Wave Frequencies—Part 1: General Requirements, Definitions, and Detailed Specifications.

This standard is a minimum performance requirements standard for precision coaxial connectors developed by the IEEE Subcommittee P287. It builds on the previous version of this standard. The main purpose of this rewrite is to modernize the standard with regard to drawings, mechanical, and electrical tests; it also includes several new connector sizes that were not available when the standard was rewritten in 2007. This standard has been broken into three parts. The first part, IEEE Std 287.1-2021 contains the specifications for all of the included coaxial connector types. IEEE Std 287.2-2021 is a recommended practice guide for all of the mechanical and electrical tests that are needed to verify the specifications of the connectors. The third part, IEEE Std 287.3-2021, is a recommended practice that contains a set of guidelines, practices, and information that should be useful to users of coaxial connectors.

Contents

1. Overview	15
1.1 Scope	15
1.2 Purpose	15
1.3 Word usage	15
2. Normative references	16
3. General requirements and definitions	16
3.1 Mechanical	16
3.2 Electrical	20
3.3 Environmental	22
4. Connector summary table	22
4.1 Introduction	22
4.2 How to use this summary table	23
4.3 Definitions	23
Annex A (normative) Detail specifications for precision 7–16 connectors	28
Annex B (normative) Detail specifications for precision 14 mm connectors	36
Annex C (normative) Detail specifications for precision 4.3–10 connectors	42
Annex D (normative) Detail specifications for precision 7 mm connectors	52
Annex E (normative) Detail specifications for precision Type-N (50 Ω) connectors	60
Annex F (normative) Detail specifications for precision Type-N (75 Ω) connectors	69
Annex G (normative) Detail specifications for precision coaxial 3.5 mm connectors	76
Annex H (normative) Detail specifications for precision coaxial 2.92 mm connectors	84
Annex I (normative) Detail specifications for precision coaxial 2.4 mm connectors	92
Annex J (normative) Detail specifications for precision 1.85 mm connectors	100
Annex K (normative) Detail specifications for precision 1.35 mm connectors	108
Annex L (normative) Detail specifications for precision 1 mm connectors	116
Annex M (normative) Detailed specifications for precision 0.8 mm connectors	124
Annex N (informative) Bibliography	131

List of Figures

Figure A.1—7–16 instrument grade socket connector	31
Figure A.2—7–16 instrument grade pin connector.....	33
Figure A.3—7–16 metrology grade socket connector	33
Figure A.4—7–16 metrology grade pin connector	35
Figure A.5—7–16 minimum withdrawal force test pin	35
Figure A.6—7–16 maximum insertion and withdrawal force test pin	35
Figure B.1—14 mm metrology grade connector, inner contact details.....	39
Figure B.2—14 mm metrology grade connector, outer contact details.....	40
Figure B.3—Attachment dimensions for mounting a 14 mm metrology grade connector to airline.....	40
Figure B.4—14 mm metrology grade connector with suggested coupling and inner conductor support mechanism	41
Figure C.1—4.3–10 instrument grade socket connector	45
Figure C.2—4.3–10 instrument grade pin connector (screw type).....	46
Figure C.3—4.3–10 metrology grade socket connector	47
Figure C.4—4.3–10 metrology grade pin connector (screw type).....	48
Figure C.5—4.3–10 minimum withdrawal force test pin	49
Figure C.6—4.3–10 maximum insertion and withdrawal force test pin	49
Figure C.7—4.3–10 minimum insertion and withdrawal force test ring	50
Figure C.8—4.3–10 maximum withdrawal force test ring	51
Figure D.1—Precision 7 mm instrument grade interface	55
Figure D.2—Precision 7 mm metrology grade interface	56
Figure D.3—7 mm instrument grade interface (polarized).....	57
Figure D.4—7 mm metrology grade interface (polarized)	57
Figure D.5—7 mm metrology grade airline with sleeve extended and center conductor engaged with collected center conductor.....	58
Figure D.6—7 mm engaged and disengaged center pin	59
Figure D.7—7 mm transmission line instrument grade connector: Attachment dimensions	59
Figure E.1—Precision Type-N (50 Ω) instrument grade socket connector.....	64
Figure E.2—Precision Type-N (50 Ω) instrument grade pin connector.....	65
Figure E.3—Precision Type-N (50 Ω) metrology grade socket connector	66

Figure E.4—Precision Type-N (50 Ω) metrology grade pin connector	67
Figure E.5—Precision Type-N (50 Ω) minimum withdrawal force test pin	68
Figure E.6—Precision Type-N (50 Ω) maximum insertion and withdrawal force test pin	68
Figure F.1—Type-N (75 Ω) instrument grade socket connector	72
Figure F.2—Type-N (75 Ω) instrument grade pin connector	73
Figure F.3—Type-N (75 Ω) metrology grade socket connector	74
Figure F.4—Type-N (75 Ω) metrology grade pin connector.....	75
Figure G.1—3.5 mm instrument grade socket connector	79
Figure G.2—3.5 mm instrument grade pin connector	80
Figure G.3—3.5 mm metrology grade socket connector.....	81
Figure G.4—3.5 mm metrology grade pin connector	82
Figure G.5—3.5 mm minimum withdrawal force test pin	83
Figure G.6—3.5 mm maximum withdrawal and insertion force test pin	83
Figure H.1—2.92 mm instrument grade socket connector	87
Figure H.2—2.92 mm instrument grade pin connector	88
Figure H.3—2.92 mm metrology grade socket connector.....	89
Figure H.4—2.92 mm metrology grade pin connector	90
Figure H.5—2.92 mm minimum withdrawal force test pin	91
Figure H.6—2.92 mm maximum withdrawal and insertion force test pin	91
Figure I.1—2.4 mm instrument grade socket connector.....	95
Figure I.2—2.4 mm instrument grade pin connector	97
Figure I.3—2.4 mm metrology grade socket connector	97
Figure I.4—2.4 mm metrology grade pin connector.....	99
Figure I.5—2.4 mm minimum withdrawal force test pin.....	99
Figure I.6—2.4 mm maximum withdrawal and insertion force test pin	99
Figure J.1—1.85 mm instrument grade socket connector.....	103
Figure J.2—1.85 mm instrument grade pin connector.....	104
Figure J.3—1.85 mm metrology grade socket connector	105
Figure J.4—1.85 mm metrology grade pin connector	106
Figure J.5—1.85 mm minimum withdrawal force test pin	107
Figure J.6—1.85 mm maximum withdrawal and insertion force test pin	107

Figure K.1—1.35 mm instrument grade socket connector	111
Figure K.2—1.35 mm instrument grade pin connector	112
Figure K.3—1.35 mm metrology grade socket connector	113
Figure K.4—1.35 mm metrology grade pin connector	114
Figure K.5—1.35 mm minimum withdrawal force test pin	115
Figure K.6—1.35 mm maximum insertion and withdrawal force test pin	115
Figure L.1—1 mm instrument grade socket connector	119
Figure L.2—1 mm instrument grade pin connector	120
Figure L.3—1 mm metrology grade socket connector	121
Figure L.4—1 mm metrology grade pin connector	122
Figure L.5—1 mm minimum withdrawal force test pin	123
Figure L.6—1 mm maximum withdrawal and insertion force test pin	123
Figure M.1—0.8 mm instrument grade socket connector	127
Figure M.2—0.8 mm instrument grade pin connector	128
Figure M.3—0.8 mm metrology grade socket connector	129
Figure M.4—0.8 mm metrology grade pin connector	130

List of Tables

Table 1—Coaxial line sizes and operating frequencies	16
Table 2—Connector summary table: Part 1	24
Table 3—Connector summary table: Part 2	26
Table A.1—High-frequency electrical specifications	28
Table A.2—DC electrical specifications	29
Table A.3—Mechanical specifications	29
Table A.4—Environmental specifications	30
Table B.1—High-frequency electrical specifications	36
Table B.2—DC electrical specifications	37
Table B.3—Mechanical specifications	38
Table B.4—Environmental specifications	38
Table C.1—High-frequency electrical specifications	42
Table C.2—DC electrical specifications	43
Table C.3—Mechanical specifications	44
Table C.4—Environmental specifications	44
Table D.1—High-frequency electrical specifications	53
Table D.2—DC electrical specifications	53
Table D.3—Mechanical specifications	54
Table D.4—Environmental specifications	54
Table E.1—High-frequency electrical specifications	61
Table E.2—DC electrical specifications	62
Table E.3—Mechanical specifications	62
Table E.4—Environmental specifications	63
Table F.1—High-frequency electrical specifications	69
Table F.2—DC electrical specifications	70
Table F.3—Mechanical specifications	70
Table F.4—Environmental specifications	71
Table G.1—High-frequency electrical specifications	76
Table G.2—DC electrical specifications	77

Table G.3—Mechanical specifications	77
Table G.4—Environmental specifications.....	78
Table H.1—High-frequency electrical specifications.....	84
Table H.2—DC electrical specifications	85
Table H.3—Mechanical specifications.....	85
Table H.4—Environmental specifications.....	86
Table I.1—High-frequency electrical specifications	92
Table I.2—DC electrical specifications	93
Table I.3—Mechanical specifications	93
Table I.4—Environmental specifications	94
Table J.1—High-frequency electrical specifications	100
Table J.2—DC electrical specifications.....	101
Table J.3—Mechanical specifications	101
Table J.4—Environmental specifications	102
Table K.1—High-frequency electrical specifications.....	108
Table K.2—DC electrical specifications	109
Table K.3—Mechanical specifications.....	109
Table K.4—Environmental specifications.....	110
Table L.1—High-frequency electrical specifications	116
Table L.2—DC electrical specifications.....	117
Table L.3—Mechanical specifications	117
Table L.4—Environmental specifications	118
Table M.1—High-frequency electrical specifications	124
Table M.2—DC electrical specifications.....	125
Table M.3—Mechanical specifications	125
Table M.4—Environmental specifications	126

IEEE Standard for Precision Coaxial Connectors at RF, Microwave, and Millimeter-Wave Frequencies— Part 1: General Requirements, Definitions, and Detailed Specifications

1. Overview

1.1 Scope

The scope of this standard is to specify coaxial connectors for precision electrical measurements for use at radio frequency (RF), microwave, and millimeter-wave frequencies. Current state-of-the-art coaxial connectors are covered by the standard.

1.2 Purpose

The purpose of this standard is to present minimum performance requirements for those precision connectors used at RF, microwave, and millimeter-wave frequencies. It introduces the performance requirements needed to standardize precision hermaphroditic and pin and socket type connectors and displays specification values from individual connector types in a connector summary table. This standard embodies the general requirements and definitions for all connector types covered by the standard, and for ease of use, separates the “detail specifications” information for each connector type for standardization into separate annexes. The previous version of this standard included 14 mm, 7 mm, Type-N (50 Ω), 3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm, and 1 mm connector sizes; the following connector sizes are being added to this version of the standard: 7–16, 4.3–10, Type-N (75 Ω), 1.35 mm, and 0.8 mm.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should equals is recommended that*).

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

There are no normative references in this standard.

3. General requirements and definitions

3.1 Mechanical

3.1.1 Coaxial line sizes

The coaxial line sizes associated with the connectors in this standard cover a large range of frequencies. [Table 1](#) shows a synopsis of the outer conductor diameter and upper frequencies covered.

Table 1—Coaxial line sizes and operating frequencies

Connector	Inside diameter of outer conductor in mm (nominal)	Recommended upper operating frequency in GHz	Cut-off frequency in GHz
7–16	16.060	7.5	8.5
14 mm	14.288	8.5	9.5
4.3–10	10.000	12.0	13.6
7 mm	7.000	18.0	19.4
Type-N, 50 Ω	7.000	18.0	19.4
Type-N, 75 Ω	7.000	18.0	21.8
3.5 mm	3.500	33.0	38.8
2.92 mm	2.920	40.0	46.5
2.4 mm	2.400	50.0	56.6
1.85 mm	1.850	67.0	73.4
1.35 mm	1.350	90.0	100.6
1 mm	1.000	110.0	135.9
0.8 mm	0.800	145.0	169.7

The cut-off frequencies in [Table 1](#) are defined as the frequency at which the first higher order mode (TE_{11}) can propagate in the airline proper [described by the Inside Conductor Outer Diameter (ICOD) and the Outer Conductor Inside Diameter (OCID)] ignoring material parameter effects. The values are from numerically solving the modal eigenvalue equation for the coaxial line (see [3.2.7](#)) and were computed using an air permittivity of 1.

3.1.2 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 7–16, Type-N (50 Ω) and Type-N (75 Ω); they are available as instrument grade connectors (IGCs) and metrology grade connectors (MGCs), which differ in dimensional

tolerances and in electrical performance. These differences are visible in the individual connector annexes. These connectors attach directly to the transmission lines of [Table 1](#).

In the IGC and MGC connectors, the dielectric support shall be sufficiently recessed from the reference plane such that the electrical specifications are met as follows:

- a) For the 7–16 and Type-N connectors, 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.

3.1.3 Characteristic impedance

For MGCs, the characteristic impedance is calculated at a point removed from the interface and cannot actually be measured. Thus, the reflection magnitude is based on a calculated value from diameters and tolerances and these calculated values are reported in the summary tables ([Table 2](#) and [Table 3](#)) and in [Annex A](#) through [Annex M](#) (some annexes also have example measured numbers to represent observable quantities for historical reasons). As MGCs will be used primarily for error reduction/calibration devices, knowing the characteristic impedance of the connector is what is important. The IGCs will be used for more general-purpose applications, and as such, the reflection magnitude that comes from a connector pair (i.e., a measurement) is more important.

3.1.4 Mateability and available combinations

[Subclauses 3.1.4.1](#) through [3.1.4.4](#) contain mechanical requirements for both hermaphroditic as well as pin and socket connectors.

3.1.4.1 Outer conductors

In all line sizes, for IGC and MGC connectors, hermaphroditic and polarized outer conductors are permitted as follows:

- a) IGC and MGC 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 7–16, 4.3–10, Type-N-50Ω, Type-N-75Ω, 3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm, 1.35 mm, 1.0 mm, and 0.8 mm (see NOTE in [3.1.4.4](#)).

3.1.4.2 Inner conductors

In all line sizes, for IGC and MGC connectors, hermaphroditic and polarized inner conductors are permitted. The following conditions must be met:

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

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

3.1.4.3 Hermaphroditic MGCs

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 a supported IGC or MGC to support the inner conductor of an unsupported IGC or MGC.

3.1.4.4 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 [B20]) without adapters.⁸ 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.⁹

3.1.5 Mating and reference planes

Three basic planes can be distinguished in a mated connector pair: outer conductor mating plane (OCMP), inner conductor mating plane (ICMP), and reference plane.

Most connectors presented in this standard are designed so that the OCMP is essentially the same as the ICMP. The only exceptions, where the OCMP and the ICMP are significantly different, are the 7–16 connector and the two Type-N connectors.

All but one of the connectors presented in this standard are designed such that the reference plane—i.e., the plane to which all electrical lengths refer—coincides with the OCMP. The only exception is the 4.3–10 connector, where, for reasons pointed out in C.1 of Annex C, the reference plane does not coincide with the OCMP. However, the 4.3–10 connector is designed so that the OCMP coincides with the ICMP. This leads to the need to distinguish between an electrical and a mechanical reference plane for this connector.

3.1.6 Components captive to the connector

All components of an unsupported IGC or MGC 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 (IGC and MGC) shall be detachable.

3.1.7 Protection and maintenance of butting electric surfaces

Provision shall be made to protect the unmated butting electric surfaces. It shall also be possible to re-polish, re-lap, or replace the butting electric surfaces of the MGC.

⁸The numbers in brackets correspond to those of the bibliography in Annex N.

⁹Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

3.1.8 Subjection to axial forces

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

3.1.9 Torque

The detail specifications specify the range of mating torque and of the maximum torque (i.e., safety torque) which will not cause damage. Torque specifications may be specific to the materials employed and/or specific to a construction method (e.g., snap ring versus ball bearings).

3.1.10 Attachment to the 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]).

3.1.11 Connector diameter tolerances

The detail specifications list dimensional tolerances for both MGC and IGC 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.

3.1.12 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.

3.1.13 Inner-conductor applied (mating) force limits

3.1.13.1 For hermaphroditic inner contacts

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

3.1.13.2 For pin and socket connectors

The inner-conductor force limits for pin and socket connector criteria are as follows:

- a) *Maximum 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) *Maximum insertion and withdrawal force, pin center conductor.* For same axial forces as in item a), specify maximum temporary and permanent displacement.
- c) *Minimum withdrawal force (retention force), socket inner contact.* Using test pin prescribed by drawing, specify minimum axial force for withdrawal.

3.1.14 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.

3.1.15 Dimensions

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

3.2 Electrical

Subclauses 3.2.1 through 3.2.8 contain electrical requirements for both hermaphroditic and pin and socket connectors.

3.2.1 Reflection coefficient magnitude and return loss in decibels

The reflection coefficient magnitude, $|S_{11}|$, 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.

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

As stated in 3.1.3, the values of $|S_{11}|$ for MGC connectors are derived from diameters and tolerances. The characteristic impedance is calculated from:

$$Z_0 = \frac{1}{2\pi} \sqrt{\frac{\mu}{\epsilon}} \ln \frac{D}{d} \quad (2)$$

where

- D is the outer conductor inner diameter
- d is the inner conductor outer diameter
- μ is the free-space permeability
- ϵ is the free-space permittivity

The reflection coefficient is evaluated from this impedance relative to the design goal of 50 Ω [75 Ω in the case of Type-N (75 Ω)].

3.2.2 Insertion loss

The insertion loss of a mated connector pair will vary over frequency. The insertion loss is defined as the loss of a connector pair when inserted into a 50 Ω measurement system. This measurement is no longer part of the specifications but its definition is included as a reference:

$$IL[\text{dB}] = -20 \log_{10} |S_{21}| \quad (3)$$

3.2.3 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.

3.2.4 Repeatability with and without rotation

Repeatability conditions are detailed in 3.2.4.1 and 3.2.4.2.

3.2.4.1 Repeatability without rotation

The repeatability of a specified parameter determined from a set of repeatability measurements is defined as the maximum difference relative to the mean of the measurement set.¹⁰ The repeatability shall not exceed the specified values for the following:

- a) Magnitude of vectorial difference of reflection coefficient $|\Delta S_{11}|$ in decibels
- b) DC resistance ΔR_{dc} in milliohms

Maximum specified values for these parameters are found in the summary tables (Table 2 and Table 3) and/or the individual connector annexes. The nonrotational repeatability shall be the maximum difference relative to the mean of the specified parameters during 100 complete connect/disconnect cycles of the connector for 14 mm and 7 mm lines. For all other sizes, substitute 20 connect/disconnect cycles. See Clause 5 of IEEE Std 287.3™-2021 [B21] for more information on calculating repeatability.

3.2.4.2 Repeatability with rotation

The repeatability with rotation of a specified parameter determined from a set of repeatability measurements is defined as the maximum difference relative to the mean of the measurement set.¹¹ Determine the repeatability measurement values for rotation by rotation of one connector's orientation to the other connector in a connector pair of 16 approximately 45° increments over two complete 360° cycles. Maximum specified values for these parameters are found in the summary tables and/or the individual connector annexes. See Clause 5 of IEEE Std 287.3-2021 [B21] for more information on calculating repeatability.

3.2.5 Shielding effectiveness

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

3.2.6 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.

3.2.7 Rated minimum upper operating frequency and theoretical upper limit

The upper frequency and cutoff frequency 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 61141 [B11]). Although it may be practical to operate connectors above this frequency, the requirements of this standard do not apply. The cutoff frequency of a transmission line (see Dimitrios [B4]) is determined by the cutoff frequency of the TE₁₁ mode and, in this document, the values are determined by numerically solving the modal eigenvalue equation. The rated upper operating frequency results from the presence of dielectric supports that have lower TE₁₁ mode cutoff frequencies (see Gilmore [B5]).

¹⁰Note this differs from the definition in previous versions of this standard which considered repeatability to be the difference between the extreme values of the measurements. The previous definition did not match the electrical test process that referenced all measurements to the first measurement. Referencing the measurements to the mean provides better consistency with measurement results.

¹¹See Footnote 10

3.2.8 Detail specification parameters

3.2.8.1 Reflection coefficient magnitude and return loss

The detail specifications specify the maximum reflection coefficient magnitude (return loss in decibels) versus frequency of both a mated connector pair (IGC–IGC) and a single connector (MGC–IGC) when inserted with center conductor gaps as determined from Clause 3 of IEEE Std 287.3-2021 [B21] in a $50\ \Omega$ ($\Gamma_g = \Gamma_1 = 0$) system above 100 MHz.

3.2.8.2 Insertion loss

The detail specifications formerly specified the maximum insertion loss versus frequency of both a mated connector pair and a single connector above 100 MHz, but this is no longer part of the standard.

3.2.8.3 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.

3.2.8.4 Electrical length

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

3.2.8.5 Direct-current contact resistance

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

3.3 Environmental

3.3.1 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.

3.3.2 Operating

The specified operating conditions are 23 °C $\pm$ 10 °C and 20% to 80% RH.

3.3.3 Nonoperating

The nonoperating temperature range that shall not cause damage to the connector is $-50\ ^\circ\text{C}$ to $+70\ ^\circ\text{C}$. The nonoperating pressure range is 101.3 kPa to 0.145 Pa. Damage is defined as noncompliance with any specification under operating environmental conditions.

4. Connector summary table

4.1 Introduction

The purpose for including the connector summary table (Table 2) is to provide the user with an overview of the various connector types that make up this standard. This allows for easy comparison of these connectors, which is otherwise difficult since there are details and specifications distributed across the individual detail specifications.

4.2 How to use this summary table

As a matter of practicality, not all parameters are included in [Table 2](#). Also, many values are given as a maximum value, particularly where variation is encountered, which is frequency dependent, such as $|S_{11}|$ dB (return loss).

4.3 Definitions

Amplification of the various parameters, where appropriate, can be found in the specific detail specifications.

Table 2—Connector summary table: Part 1

Name	Style ^d	Type	Detail specification annex	Rated minimum upper operating frequency (GHz)	Nominal dimensions (mm) (outer\inner)	Dimensional ΔZ_{90°	f_{cu} Airline (GHz)	Connect/disconnect life	Repeatability $ \Delta S_{11} $ (dB)	$ S_{11} $ (dB) (defined by diameters and tolerances for MGC)	ΔR_{oc} (Milliohms) inner/outer
7–16	P&S	IGC MGC	Annex A	7.5	16.06 6.974	0.2 0.1	8.5	5k 5k	52 60	–40 –62	0.08 0.02
14 mm	H	IGC MGC	Annex B	8.5	14.29 6.20	0.2 0.05	9.5	5k 5k	71 77	–39 –63	0.18 0.03
4.3–10	P&S	IGC MGC	Annex C	12.0	10.0 4.342	0.3 0.15	13.6	5k 5k	52 60	–32 –60	0.1 0.1
7 mm	H	IGC MGC	Annex D	18.0	7.00 3.04	0.2 0.1	19.4	5k 5k	65 78	–34 –63	0.18 0.03
Type-N 50 Ω	P&S	IGC MGC	Annex E	18.0	7.00 3.04	0.2 0.1	19.4	5k 5k	55 60	–34 –58	0.5 1.0
Type-N 75 Ω	P&S	IGC MGC	Annex F	18.0	7.00 2.01	0.6 0.25	21.8	5k 5k	55 60	–50 –53	0.5 1.0
3.5 mm (slotless)	P&S	IGC MGC	Annex G	33.0	3.50 1.52	0.4 0.2	38.8	3k 3k	55/60 Data to 26.5 GHz	–32 –55	0.15 0.02
2.92 mm (slotted)	P&S	IGC MGC	Annex H	40.0	2.92 1.27	0.8 0.3	46.5	5k 5k	41 41	–30 –54	0.15 0.02
2.4 mm (slotless)	P&S	IGC MGC	Annex I	50.0	2.40 1.042	0.8 0.4	56.6	5k 5k	55 60	–24 –28 ^a	1.2 ^b 0.03 ^c

Table continues

Table 2—Connector summary table: Part 1 (continued)

Name	Style ^d	Type	Detail specification annex	Rated minimum upper operating frequency (GHz)	Nominal dimensions (mm) (outer\ inner)	Dimensional $\Delta Z_{0\%}$	f_{c11} Airline (GHz)	Connect/disconnect life	Repeatability $ \Delta S_{11} $ (dB)	$ S_{11} $ (dB) (defined by diameters and tolerances for MGC)	ΔR_{pc} (Milliohms) inner/outer
1.85 mm (slotted)	P&S	IGC MGC	Annex J	67.0	1.85 0.804	1.0 0.5	73.4	5k 5k	45 50	-22 -52	0.8 0.03
1.35 mm	P&S	IGC MGC	Annex K	90.0	1.35 0.586	1.0 0.6	100.6	3k 3k	43 48	-20 -48	0.8 0.03
1 mm	P&S	IGC MGC	Annex L	110.0	1.00 0.434	1.2 0.6	135.9	3k 3k	40 45	-18 -43	0.15 0.02
0.8 mm	P&S	IGC MGC	Annex M	145.0	0.8 0.348	2.0 1.5	169.7	3k 3k	40 45	-18 -42	0.5 0.02
Definition subclause	3.1.4.3, 3.1.4.4	3.1.2, 3.1.4	N/A	3.2.7	Table 1, 3.1.1, 3.1.3, 3.1.11	3.1.3	3.1.1, 3.2.7	3.1.14	3.2.4	3.2.1, 3.2.8.1	3.2.4
Test method subclause NOTE— Subclauses are in IEEE Std 287.2- 2021	N/A	N/A	N/A	N/A	4.2.1.1, 4.2.1.2	4.2.1	N/A	4.2.10	3.3	3.2	3.5

^aSpecifications shown are for a pair of connectors: -24 dB for IGC to IGC at 50 GHz and -28 dB for IGC to MGC at 50 GHz. The specification for a single connector would be -30 dB for a single IGC and, using the definition of diameters and tolerances for a single MGC, the value would be -52 dB.

^bThe change in dc resistance number was measured over 5000 connections, the number 1.2 Mohms is 6-standard deviations + 20% safety margin.

^cThe change in outer conductor dc resistance was measured over 200 connect cycles. 0.03 = 6 standard deviations.

^dP&S: Pin and socket connectors (sexed connectors); H: hermaphroditic connectors (sexless connectors).

Table 3—Connector summary table: Part 2

Name	Style ⁱ	Type	Max insertion/max withdrawal, min withdrawal force(N)	Depth of penetration (mm) ^b Rate of insertion (mm/S)	Min/Max ^a contact force	Coupling torque (N·m) [in-lbs]	Safety torque (N·m) [in-lbs]	Max R _{DC} milliohms inner/outer	Shielding effectiveness (dB)	Coupling nut wrench flat size (mm)
7–16	P&S	IGC MGC	28/28 6	1.5 0.3	N/A	2.5	30	0.8 1.9	110	32
14 mm	H	IGC MGC	N/A	N/A	6 8.9	4.0 [3 ft-lbs]	5.4 [4 ft-lbs]	0.5 0.07	130	25.4
4.3–10	P&S	IGC MGC	35/35 ^e 35/20 ^f 4/1.5 ^{e,f}	2.0 0.3	N/A	2.5	7.0	1.5 1.5	110	20
7 mm	H	IGC MGC	N/A	N/A	8.9N	1.3–1.7 [12–15]	5.4	1.0 0.1	120	19
Type-N 50 Ω	P&S	IGC MGC	8.9/8.9 0.55	2.0 0.3	N/A	1.3–1.7 [12–15]	[17.8]	1.5 (initial) 1.5 (initial)	120	19
Type-N 75 Ω	P&S	IGC MGC	9.0/TBD ^g 0.56	2.0 0.3	N/A	1.5±0.2	[17.8]	1.0 0.25	120	19
3.5 mm	P&S	IGC MGC	5.6/4.6 0.55	1.5 0.3	N/A	0.9±0.1 [8±1]	1.7 [15]	0.75 0.13	100	8
2.92 mm	P&S	IGC MGC	4.5/3.3 0.4	1.5 0.3	N/A	0.8±0.2 [5–9]	1.8 [16]	0.75 0.13	100	8
2.4 mm	P&S	IGC MGC	1.4/1.1 0.44	1.25 0.3	N/A	0.9±0.1 [8±1]	1.6 [14]	3.0 ^b 0.15 ^d	100	8

Table continues

Table 3—Connector summary table: Part 2 (continued)

Name	Style ⁱ	Type	Max insertion/max withdrawal, min withdrawal force(N)	Depth of penetration (mm) ^b Rate of insertion (mm/S)	Min/Max ^a contact force	Coupling torque (N•m) [in-lbs]	Safety torque (N•m) [in-lbs]	Max R _{DC} milliohms inner/outer	Shielding effectiveness (dB)	Coupling nut wrench flat size (mm)
1.85 mm	P&S	IGC MGC	0.9/ 0.56 0.14	1.25 0.3	N/A	0.9 ± 0.1 [8 ± 1]	1.6 [14]	2.2 0.15	100	8
1.35 mm	P&S	IGC MGC	1.3/1.3 0.14	0.8 0.3	N/A	0.9 ± 0.1	1.65	4.0 1.0	90	8
1 mm	P&S	IGC MGC	0.56/ 0.28 0.14	0.75 0.3	N/A	0.45 ± 0.05 [4 ± 0.4] ^h	0.7 [6]	4.0 0.2	90	6
0.8 mm	P&S	IGC MGC	0.56/0.2 0.05	0.60 0.3	N/A	0.45 ± 0.05	0.7	6.0 0.2	90	6
Definition subclause	—	—	3.1.13.2	3.1.13.2	3.1.13.1	3.1.9	3.1.9	3.2.3, 3.2.8.5	3.2.5, 3.2.8.3	3.1.15
Test method subclause NOTE— Subclauses are in IEEE Std 287.2- 2021)	—	—	4.2.6	4.2.6	4.2.2	N/A	N/A	3.5	3.4	N/A

^aH styles only.

^bP and S styles only.

^cThe max dc resistance number is over 5000 connections, 3.0 Mohms is = mean + 3.5 standard deviations.

^dThe max dc resistance (outer conductor) is from 200 connections, 0.15 Mohms = mean + 5 standard deviations.

^eMaximum insertion and Maximum withdrawal force—for slotted outer conductor.

^fMaximum insertion and Maximum withdrawal force—for slotted inner conductor.

^gTBD = To be determined.

^hThe appropriate coupling torque for 1 mm connectors when connecting to test port connectors is 0.45 N•m (4 in-lb). Torques higher than 0.45 N•m (4 in-lb) may be needed in certain other applications.

ⁱP&S: Pin and socket connectors (sexed connectors); H: hermaphroditic connectors (sexless connectors).

Annex A

(normative)

Detail specifications for precision 7–16 connectors

A.1 Introduction

The 7–16 connector (also known as “7/16 DIN-Connector”) is a pin and socket design which uses an air dielectric interface and assures single-mode operation up to 7.5 GHz. The 7–16 connector provides a very sturdy connection and is mostly used in telecommunication applications. The coupling engagement ensures that the outer conductors are coupled before the inner conductors can connect, thus guaranteeing a damage-free connection.

A.2 Specifications

The specifications detail the electrical, mechanical, and environmental requirements. Interface dimensions and details of force test pins are also given.

A.2.1 Electrical

[Table A.1](#) and [Table A.2](#) show the electrical specifications.

Table A.1—High-frequency electrical specifications

Description	Symbol	Instrument grade specification	Metrology grade specification	Definition subclause	Test method subclause (Note—Subclauses are in IEEE Std 287.2-2021)
Characteristic impedance	Z_0	50 Ω	—	3.1.3	4.2.1
Characteristic impedance tolerance (see NOTE)	ΔZ_0	0.2%	0.1%	3.1.3	4.2.1
Recommended upper operating frequency	f_{op}	7.5 GHz	—	3.2.7	n/a
Cut-off frequency (unsupported airline)	f_{c11}	8.5 GHz	—	3.2.7	n/a
Reflection magnitude	$ \Gamma $	−40 dB	−62 dB Example Measured: −50 dB (see NOTE)	3.2.1, 3.2.8.1	3.2
Repeatability of reflection	$ \Delta\Gamma $	52 dB	60 dB	3.2.4	3.3
Electrical length tolerance	Δl_e	$\pm 75 \mu\text{m}$	—	3.2.6 3.2.8.4	3.2
Shielding effectiveness	a_s	110 dB @ 1 GHz	—	3.2.5 3.2.8.3	3.4
NOTE—The connector reflection magnitude and tolerance are theoretical values that are determined from the outer and inner conductor diameters and the dimensional tolerances (see 3.1.3). This is a simplistic, first order metric. This is meaningful for low GHz frequencies but can result in very large errors at higher frequencies and in the MHz range and below may not be applicable without considering imperfect metal conductivity corrections. For a more detailed discussion, see the Connector Effects subclause in IEEE Std 287.3-2021.					

Table A.2—DC electrical specifications

Description	Symbol	Center conductor	Outer conductor	Definition subclause	Test method subclause (Note—Subclauses are in IEEE Std 287.2-2021)
DC contact resistance	R_{dc}	0.8 m Ω	1.9 m Ω	3.2.3 3.2.8.5	3.5
Repeatability of dc contact resistance	ΔR_{dc}	0.08 m Ω	0.02 m Ω	3.2.4	3.5

A.2.2 Mechanical

Table A.3 shows the mechanical specifications.

Table A.3—Mechanical specifications

Description	Symbol	Instrument grade specification	Metrology grade specification	Definition subclause	Test method subclause (Note—subclauses are in IEEE Std 287.2-2021)
Outer conductor inside diameter	D	16.06 mm ±0.005 mm	16.06 mm ±0.0025 mm	3.1.11, 3.1.1, 3.1.3	4.2.1.1
Inner conductor outside diameter	d	6.974 mm ±0.0035 mm	6.974 mm ±0.002 mm	3.1.11, 3.1.1, 3.1.3	4.2.1.2
Connect/disconnect life	L	5000 cycles		3.1.14	4.2.10
Maximum insertion force	F_i	28 N		3.1.13.2	4.2.6
Rate of insertion	R_i	0.3 mm/s		3.1.13.2	4.2.6
Depth of insertion	D_i	1.5 mm		3.1.13.2	4.2.6
Maximum withdrawal force ^a	F_w	28 N		3.1.13.2	4.2.6
Minimum withdrawal force ^a	F_m	6 N		3.1.13.2	4.2.8
Coupling torque	T_c	2.5 N•m		3.1.9	n/a
Maximum safety torque	T_s	30 N•m		3.1.9	n/a
Coupling nut wrench size	w	32 mm		3.1.15	n/a

^aThe maximum and minimum withdrawal force test is performed at the same rate as the insertion force test.

A.2.3 Environmental

Table A.4 shows the environmental specifications.

Table A.4—Environmental specifications

Environmental conditions	Operating specifications	Nonoperating specifications
Temperature	13 °C to 33 °C	–55 °C to 70 °C
Relative humidity	20% to 80%	
Atmospheric pressure	78 kPa to 104 kPa	

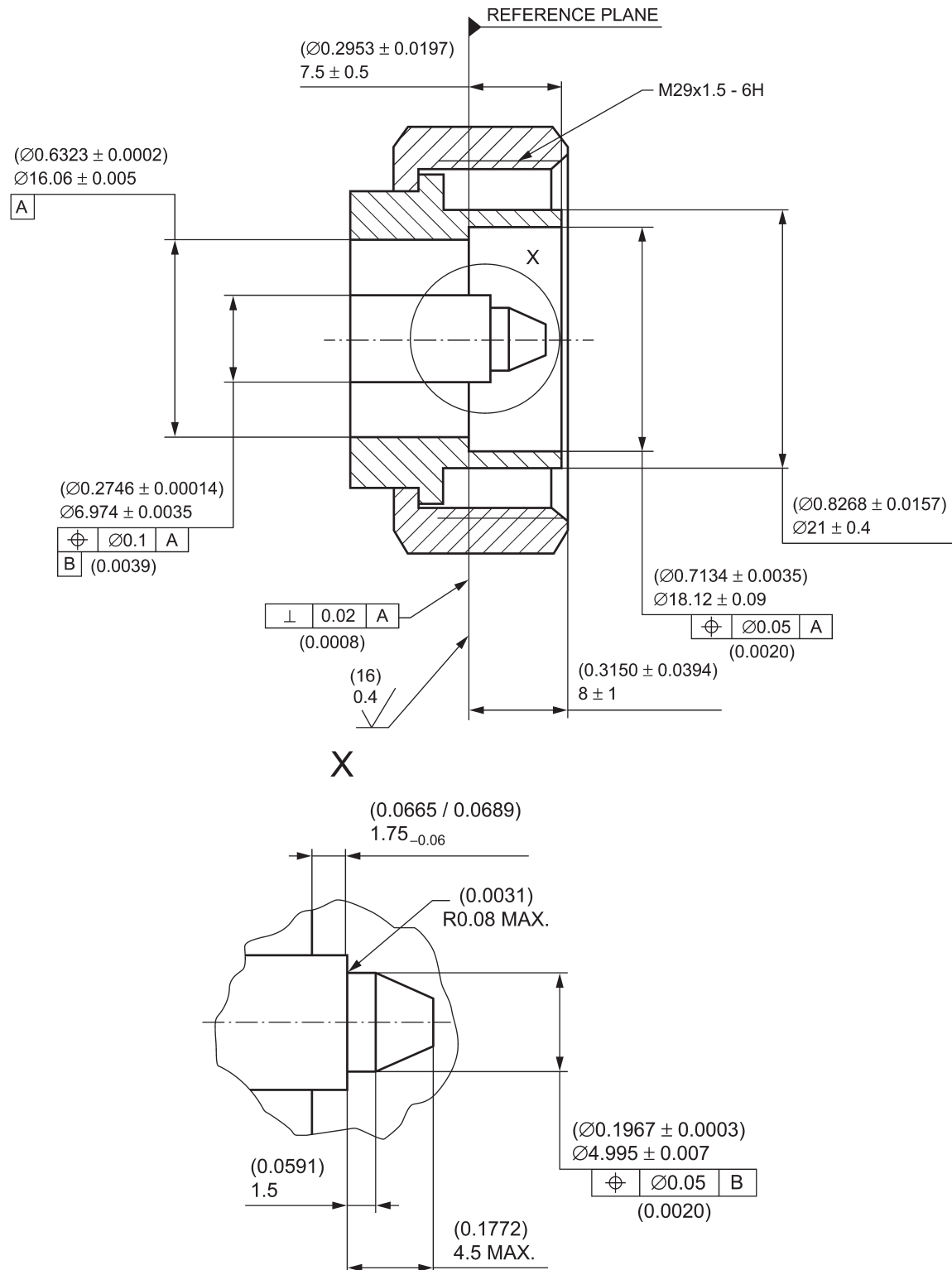
A.3 Drawings

Figure A.1 through Figure A.4 are drawings for the 7–16 connector. Figure A.5 and Figure A.6 show the corresponding test pins for determining the insertion and withdrawal forces.



NOTE 3—Design for slotting is optional, and should meet electrical and mechanical requirements, when mating with Ø 4.995 mm (Ø 0.1967 in) pin.

31



NOTE 1—Original design is in millimeters.

NOTE 2—All dimensions are shown in millimeters, under inches shown in brackets, and are the final or finished dimensions.

NOTE 3—The wrench flat size for the 7-16 pin connector is typically 32 mm.

Figure A.2—7-16 instrument grade pin connector



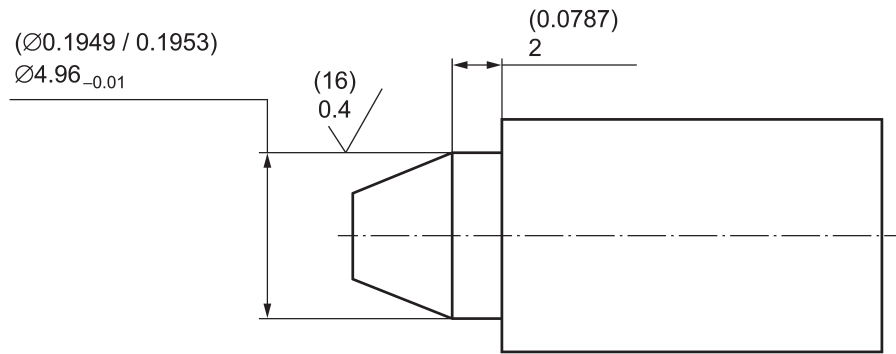
NOTE 3—Design for slotting is optional, and should meet electrical and mechanical requirements, when mating with Ø 4.995 mm (Ø 0.1967 in) pin.

33



NOTE 2—All dimensions are shown in millimeters, under inches shown in brackets, and are the final or finished dimensions.

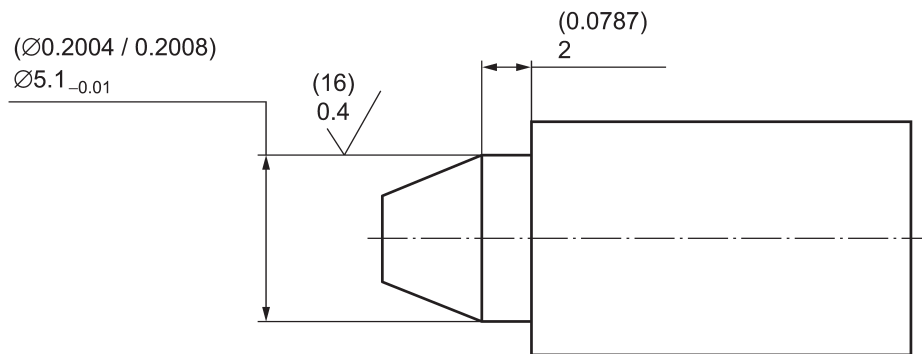
Figure A.4—7-16 metrology grade pin connector



NOTE 1—Original design is in millimeters.

NOTE 2—All dimensions are shown in millimeters, under inches shown in brackets, and are the final or finished dimensions.

Figure A.5—7-16 minimum withdrawal force test pin



NOTE 1—Original design is in millimeters.

NOTE 2—All dimensions are shown in millimeters, under inches shown in brackets, and are the final or finished dimensions.

Figure A.6—7-16 maximum insertion and withdrawal force test pin

Annex B

(normative)

Detail specifications for precision 14 mm connectors

B.1 Introduction

The 14 mm precision coaxial connector was designed in the early 1960s and was the first precision hermaphroditic coaxial connector introduced to the industry. Early on, this connector had a major impact on those national standards laboratories whose goals were to achieve the very highest accuracies of lumped parameter immittance (impedance and admittance) measurements at frequencies in the high kilohertz to the low megahertz region. The advent of the precision coaxial connector with its well-defined reference plane, high-level repeatability capabilities, and accuracy helped immeasurably with the development of coaxial air dielectric transmission lines as primary reference standards. These lines are nearly reflectionless and represent the ultimate in adherence to design principles in maintaining a constant characteristic impedance, Z_0 , throughout the precision airline sections. They are used to characterize and evaluate the system parameters of various measurement systems. The 14 mm connector with its upper frequency limit of 8.5 GHz also has a variety of applications in the RF and microwave region.

The 14 mm precision connector is used in both metrology and research applications and, as such, is widely used at low frequencies for the accurate measurement of lumped immittances. With its larger diameter size and dielectric support bead, this connector is used extensively for properties of materials research of both solid and liquid materials where dielectric and magnetic properties are to be measured. It is used on the 14 mm coaxial slotted line to obtain accurate values of impedances from measurements of magnitude and phase at frequencies from approximately 300 MHz to 8.5 GHz. The connector also has a high-power carrying capacity.

A popular commercial version of the 14 mm precision coaxial connector employs a unique gear-tooth alignment mechanism that allows 24 angular mating orientations, which is acceptable for most applications. An alternative version employs a rotatable gear with an angular span of one tooth for alignment at any orientation. This can result in some slight degradation in accuracy and repeatability.

B.2 Specifications

The specifications are provided to detail electrical, mechanical, and environmental requirements; interface dimensions; and airline mounting details for the 14 mm precision coaxial connector.

B.2.1 Electrical

[Table B.1](#) and [Table B.2](#) show the electrical specifications.

Table B.1—High-frequency electrical specifications

Description	Symbol	Instrument grade specification	Metrology grade specification	Definition subclause	Test method subclause (Note—Subclauses are in IEEE Std 287.2-2021)
Characteristic impedance	Z_0	50 Ω		3.1.3	4.2.1
Characteristic impedance tolerance (see NOTE)	ΔZ_0	0.20%	0.1%	3.1.3	4.2.1
Recommended upper operating frequency	f_{op}	8.5 GHz		3.2.7	n/a
Cut-off frequency (unsupported airline)	f_{c11}	9.5 GHz		3.2.7	n/a
Reflection magnitude	$ \Gamma $	−39 dB	−63 dB (see NOTE)	3.2.1, 3.2.8.1	3.2
Repeatability of reflection	$ \Delta\Gamma $	71 dB	77 dB	3.2.4	3.3
Electrical length tolerance	Δl_c	$\pm 50 \mu\text{m}$		3.2.6	3.2
				3.2.8.4	
Shielding	a_s	130 dB		3.2.5	3.4
Effectiveness				3.2.8.3	
NOTE—The connector reflection magnitude and tolerance are theoretical values that are determined from the outer and inner conductor diameters and the dimensional tolerances (see 3.1.3). This is a simplistic, first order metric. This is meaningful for low GHz frequencies but can result in very large errors at higher frequencies and in the MHz range and below may not be applicable without considering imperfect metal conductivity corrections. For a more detailed discussion, see the Connector Effects subclause in IEEE Std 287.3-2021.					

Table B.2—DC electrical specifications

Description	Symbol	Center conductor	Outer conductor	Definition subclause	Test method subclause (Note—Subclauses are in IEEE Std 287.2-2021)
DC contact resistance	R_{dc}	0.5 m Ω	0.07 m Ω	3.2.3 3.2.8.5	3.5
Repeatability of dc contact resistance	ΔR_{dc}	0.18 m Ω	0.03 m Ω	3.2.4	3.5

B.2.2 Mechanical

Table B.3 shows the mechanical specifications.

Table B.3—Mechanical specifications

Description	Symbol	Instrument ^a grade specification	Metrology ^a grade specification	Definition subclause	Test method subclause (Note— Subclauses are in IEEE Std 287.2- 2021)
Outer conductor inside diameter	D	14.2875 mm ±0.0051 mm		3.1.11, 3.1.1, 3.1.3	4.2.1.1
Inner conductor outside diameter	d	6.20395 mm ±0.00381 mm		3.1.11, 3.1.1, 3.1.3	4.2.1.2
Connect/disconnect life	L	5000 cycles		3.1.14	4.2.10
Maximum insertion force	F_i	n/a		3.1.13.2	n/a
Rate of insertion	R_i	n/a		3.1.13.2	n/a
Depth of insertion	D_i	n/a		3.1.13.2	n/a
Maximum withdrawal force ^a	F_w	n/a		3.1.13.2	n/a
Minimum withdrawal force ^b	F_m	n/a		3.1.13.2	n/a
Coupling torque	T_c	(4.0 ± 0.2) N•m		3.1.9	4.2.8
Maximum safety torque	T_s	5.4 N•m		3.1.9	n/a
Coupling nut wrench size	w	1.0 in		3.1.15	n/a

^aFor the 14 mm connector, specifications for the instrument grade and metrology grade connectors are the same.

^bThe maximum and minimum withdrawal force test is performed at the same rate as the insertion force test.

B.2.3 Environmental

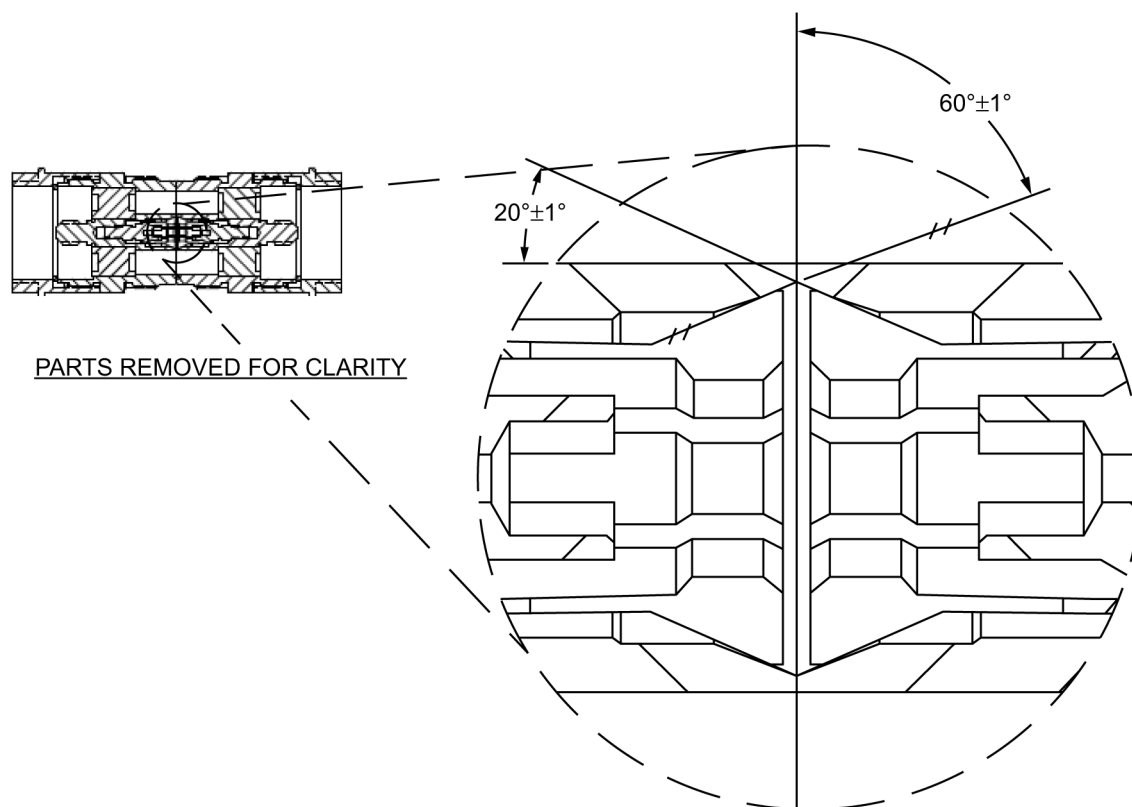
Table B.4 shows the environmental specifications.

Table B.4—Environmental specifications

Environmental conditions	Operating specifications	Nonoperating specifications
Temperature	13 °C to 33 °C	–55 °C to 70 °C
Relative humidity	20% to 80%	
Atmospheric pressure	78 kPa to 104 kPa	

B.3 Drawings

Figure B.1 through Figure B.4 are drawings for the 14 mm connector.



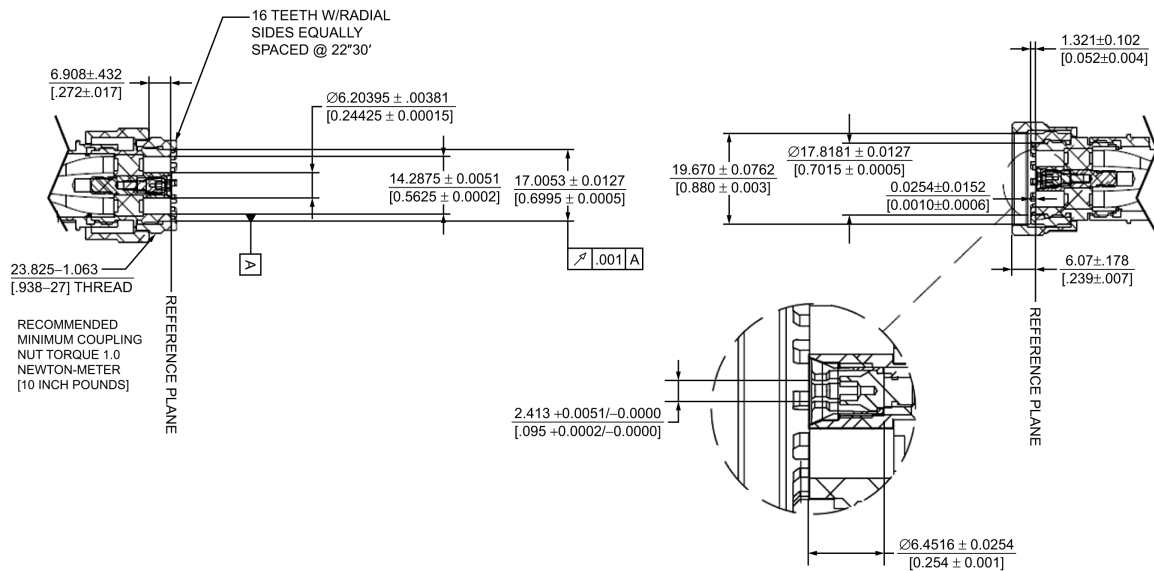
NOTE 1—Original design is in inches.

NOTE 2—All dimensions are shown in millimeters, under inches shown in brackets, and are the final or finished dimensions.

NOTE 3—With connectors unmated, faces of contacts should not extend beyond inner conductor by 0.127 mm (0.005 in) minimum.

NOTE 4—The coupling nut and bushing have been removed for clarity.

Figure B.1—14 mm metrology grade connector, inner contact details

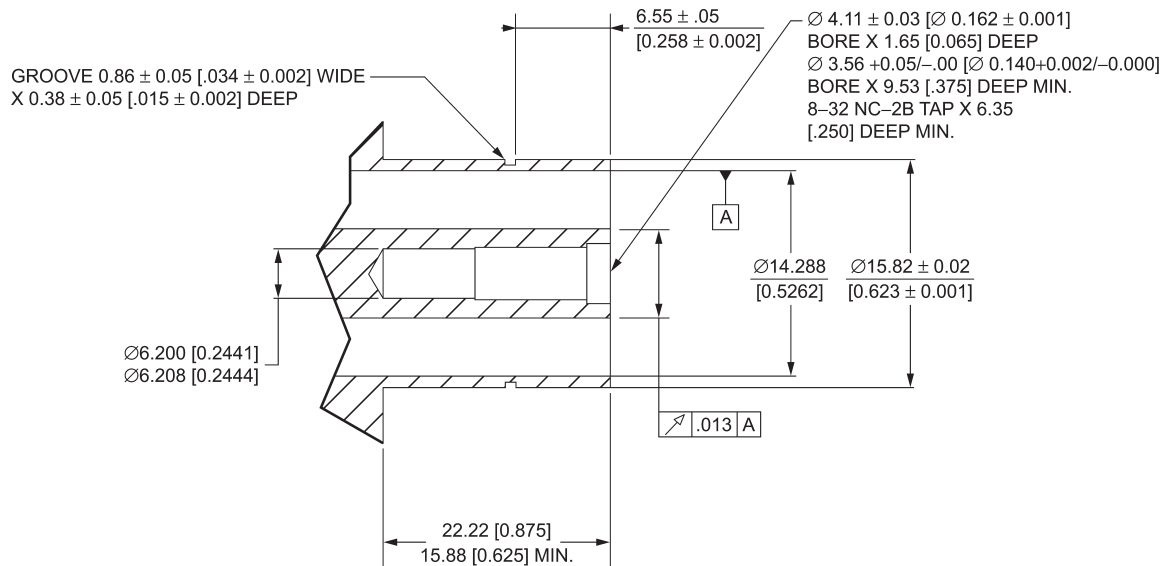


NOTE 1—Original design is in inches.

NOTE 2—All dimensions are shown in millimeters, under inches shown in brackets, and are the final or finished dimensions.

NOTE 3—Shape of coupling nut is optional; however, it needs to be compatible with a 1.0 in torque wrench.

Figure B.2—14 mm metrology grade connector, outer contact details



NOTE 1—Original design is in inches.

NOTE 2—All dimensions are shown in millimeters, under inches shown in brackets, and are the final or finished dimensions.

Figure B.3—Attachment dimensions for mounting a 14 mm metrology grade connector to airline