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IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz

**Including Trial-Use Sections on
Insertion-Loss Repeatability and
Characteristic Insertion Loss of a Noninsertable Two-Port**

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IEEE Standard
Specifications and Test Methods for
Fixed and Variable Attenuators, DC to 40 GHz

Including Trial-Use Sections on
Insertion-Loss Repeatability and
Characteristic Insertion Loss of a Noninsertable Two-Port

Sponsor
Attenuation Subcommittee
of the
High-Frequency Instrumentation and Measurements Committee
of the
IEEE Instrumentation and Measurements Group

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Foreword

(This Foreword is not part of IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz.)

This document was written for the user of attenuators. It lists 26 parameters which characterize the performance of attenuators. In order to illustrate typical usage of these parameters, attenuators were divided into four functional groups:

- Fixed attenuators
- Continuously variable attenuators, manual
- Step attenuators, manual
- Programmable attenuators

This standard does not cover electronically variable attenuators.

These groups were divided into four classes of performance based upon usage:

- Class I Standard
- Class II Precision
- Class III General purpose
- Class IV Utility

Practical performance limits are furnished for most parameters and classes. Preferred test methods are furnished to verify accuracy of attenuation.

The use of these classes is not mandatory. Also, the limits are typically minimum performance limits. The specific application may require a tighter limit or permit a looser one. Not all parameters listed in Table 2 have to be specified. The user should only use those which he needs in his application.

The following matters were not covered in this document. The committee plans to consider them in a future revision.

(1) Specify performance not only in terms of scalars such as decibels and standing-wave ratios, but use S parameters; include measurement methods for phase in test section.

(2) Define voltage divider and include measurement method.

(3) State limits for repeatability of two-ports as a function of insertion/removal cycles. Parameters are misalignment, coupling torque, transfer forces (including moment).

(4) State typical values of phase distortion in Table 1 and show test methods.

(5) Furnish information on peak power rating versus pulse duration including single pulses.

(6) Include electronic attenuators. Cover power derating at low frequency, distortion, and intermodulation versus level, spurious output, and noise figure, response time.

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IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz

Including Trial-Use Sections on
Insertion-Loss Repeatability and
Characteristic Insertion Loss of a Noninsertable Two-Port

1. Purpose and Scope

This performance standard covers absorptive and reflective attenuators, both fixed as well as continuously variable or variable in fixed steps, both manual and programmable types. It does not cover electronic or solid-state-type attenuators.

This standard permits the user to select for a specification those minimum performance parameters which characterize an attenuator. A list of preferred test methods is included permitting verification of the attenuation characteristics.

Practical minimum performance limits are furnished for various applications. These are for guidance only and will improve with time.

2. Definition of Characteristic Insertion Loss

2.1 Interpretation of Characteristic Insertion Loss. An attenuator is ideally a linear network which may be in the form of a transmission line or waveguide component designed to reduce the input power by a predetermined ratio. The ratio of input to output power is commonly expressed in logarithmic terms such as decibels. The power output ratio as commonly used in the "characteristic insertion loss" relation is shown in Fig 1. The ratio specified is equal to the characteristic insertion loss since source and load are reflectionless. The term "attenuation" is used rather loosely and means "characteristic insertion loss" as defined in Fig 1. Attenuators include

absorptive and reflective devices, having at least two ports.

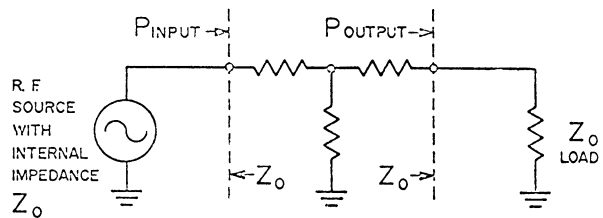


Fig 1

Definition of Characteristic Insertion Loss

P_{INPUT} = Incident power from Z_0 source

P_{OUTPUT} = Net power into Z_0 load

$$\text{Characteristic insertion loss} = 10 \log_{10} \frac{P_{INPUT}}{P_{OUTPUT}} \text{ (dB)}$$

There are fixed attenuators, continuously variable, and step attenuators. Only Z_0 matched, two-port attenuators, designed for use in a Z_0 system, are treated in this standard.¹ They are reversible except when specially noted as, for example, for a high-power attenuator. All attenuators in this standard are passive, linear, resistive or reactive, nominally symmetrical in impedance.¹ Voltage-variable attenuators, including vacuum tube or solid-state types, are not covered in this standard.

To specify a variable attenuator, one must know its end use. If the device is used to extend the range of a power meter, one requires to know its terminal-to-terminal or total loss. This is described by the characteristic insertion loss. However, in most applications the variation above the minimum loss is of major interest. One specifies then the

¹Section 8, published for trial use, includes attenuators having different input and output impedance.

residual characteristic insertion loss and the incremental characteristic insertion loss. Ideally, the terminal-to-terminal loss is the sum of both.

2.2 Power Rating. All attenuators have maximum average and peak pulse input power limits which usually decrease at elevated ambient temperature. If exceeded, failure of the attenuator results or its specified attenuation or calibration may permanently change. The specification of an attenuator must state the

maximum ambient temperature and conditions at which the full power can be applied without permanently changing the specified properties of interest.

NOTE: High-power attenuators may be constructed more economically if they are unilateral in power. In that case, the high-power input port shall be specified. This applies mainly to fixed attenuators.

2.3 Temporary Change of Attenuation with Temperature and Power. Attenuators usually have temperature coefficients of attenuation and power coefficients of attenuation. An

Table 1
Performance of Classes

	Characteristic	Class I	Class II	Class III	Class IV
(1)	Maximum standing-wave ratio Waveguide to 18 GHz Waveguide 18–40 GHz Coaxial, F in GHz	1.05 1.15 1.03+ $0.005F$	1.15 1.30 1.10+ $0.015F$	1.35 1.50 1.30+ $0.02F$	1.50 1.75 1.50+ $0.03F$
(2)	Amount of maximum deviation of attenuation A from that specified at reference frequency, in decibels 10 dB and less Over 10 dB	0.02 $0.002 \times A$	0.1 $0.01 \times A$	0.2 $0.02 \times A$	0.5 $0.05 \times A$
(3)	Amount of maximum permanent change in attenuation after temperature cycling, with rated radio-frequency power, in decibels 10 dB and less Over 10 dB	0.001 0.001	0.01 $0.001 \times A$	0.05 $0.005 \times A$	0.5 $0.05 \times A$
(4)	Amount of maximum frequency sensitivity, in decibels	$0.005 \times A \times B$	$0.02 \times A \times B$	$0.1 \times A \times B$	NA
(5)	Amount of maximum power sensitivity for rated input power, in decibels	0.001	$0.001 \times A \times P$	$0.005 \times A \times P$	NA
(6)	Amount of maximum temperature sensitivity of attenuation, in decibels	$10^{-6} \times A \times T$	$10^{-4} \times A \times T$	NA	NA
	Concentricity of coaxial connectors	2 percent of inner diameter of outer conductor or 3 mils whichever is greater		4 percent or 5 mils	NA
	insertion/removal life, cycles	2500	10 000	1000	NA
	cycling life, continuously variable attenuator, cycles	20 000	10 000	NA	NA
	cycling life, step attenuators, cycles	10 000	1 000 000	NA	NA

NOTES: A = Nominal attenuation, in decibels; P = Maximum rated average power, in watts; B = Bandwidth, in gigahertz; T = Change in temperature from nominal, in degrees Celsius; NA = Not applicable.

EXAMPLE: $A = 20$ dB, $P = 2$ watts, $B = 18$ GHz, $T = \pm 40^\circ\text{C}$, Class II

- (2) Δ dB = ± 0.2 dB
- (3) Δ dB = ± 0.02 dB
- (4) Δ dB (peak to peak) = 7.2 dB
- (5) Δ dB = ± 0.04 dB
- (6) Δ dB = ± 0.08 dB