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EIA STANDARD

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Attenuation Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnection Systems

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Electronic Components, Assemblies & Materials Association

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(From Standards Proposal Number 4153-A, formulated under the cognizance of the CE-2.0 National Connector Standards Committee.)

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TEST PROCEDURE No. 101

ATTENUATION TEST PROCEDURE FOR ELECTRICAL CONNECTORS, SOCKETS, CABLE ASSEMBLIES OR INTERCONNECTION SYSTEMS

(From EIA Standards Proposal No. 4153-A, formulated under the cognizance EIA CE-2.0 Committee on National Connector Standards.)

1 Introduction

1.1 Scope

This standard is applicable to electrical connectors, sockets, cable assemblies or interconnection systems.

1.2 Object

This standard describes one time and two frequency domain methods to measure attenuation as a function of frequency.

1.3 Definitions

1.3.1 Attenuation

The reduction of average power during the transmission from the input to the output of the specimen, usually measured in decibels (dB)

1.3.2 Specimen environment impedance

The impedance presented to the signal conductors by the fixture. This impedance is a result of transmission lines, termination resistors, attached receivers or signal sources, and fixture parasitics.

2 Test resources

2.1 Equipment

2.1.1 Frequency domain

A network analyzer is preferred. When greater dynamic range is required, a signal generator and spectrum analyzer may be used. For differential measurements, an 8 port network analyzer or baluns may be used. For the Open/Short method, an impedance or vector network analyzer may be used.

2.1.2 Time domain

A time domain reflectometer (TDR), triggered impulse generator, and appropriate fast fourier transform (FFT) software shall be used.

2.2 Fixture

Unless otherwise specified in the referencing document the specimen environment impedance shall match the impedance of the test equipment. Typically this will be 50 ohms for single-ended measurements and 100 ohms for differential.

2.2.1 Specimen conductor assignments

2.2.1.1 For each measurement, the line to be measured shall be fixtured as indicated in the referencing document. The far end (destination) and the near end (driven) of the line shall be terminated in the specimen environment impedance specified using one of the methods in figures A.2 or A.3.

NOTE — For the Open/Short method, the far end of the specimen is not terminated, but means must be available to connect both an open and a short circuit to the far end of the specimen.

2.2.1.2 In the special case where the drive signal is differential and not balanced, the common mode energy shall be terminated. Adjacent signal lines to these should likewise be terminated if possible. Note, electrically long adjacent signal lines may resonate, adding error to the results. Unless otherwise specified a 1:1 signal to ground ratio (2:1 if differential measurements are performed) shall be used with each end having all grounds commoned. (For an example, see figure A.4.).

2.2.2 Specimen fixture and signal line terminations for specimen environment impedance

Care should be taken to minimize the reactances of the resistive terminations over the range of test frequencies.

NOTE — The fixture geometry and materials may impact the measurements due to the fixture parasitics. Usually the product's intended use dictates the most meaningful way to fixture it.

2.2.3 Insertion technique

The fixture shall be designed to allow measurement of attenuation with and without the specimen; see figure A.1.a. If baluns are used for a measurement, or minimum loss pads used for impedance matching, these are included in the fixture. Figures A.2 and A.3. show typical configurations with minimum loss pads.

2.2.4 Reference fixture technique

In this technique a separate fixture that combines both near end and far end is used for the fixture attenuation measurement; see figure A.1.b. This fixture shall be a duplicate of the specimen fixture, only without the specimen. Traces, if used, shall include fixture connectors, vias, bends, and corners. If baluns are used for a differential measurement, or minimum loss pads used for impedance matching, these are included in the fixturing. Figures A.2 and A.3. show typical configurations with minimum loss pads.

3 Test Specimen

3.1 Description

For this test procedure the test specimen shall be as follows:

> NOTE — As the specimen length approaches ¼ wavelength, careful interpretation of the results is required due to possible resonance effects. It is recommended that the specimen electrical length be < 1/8 the wavelength of the maximum test frequency.

3.1.1 Separable connectors

A mated pair with identified signals and grounds.

3.1.2 Cable assembly

Assembled connectors and cable, and mating connector(s) with identified signal and ground contacts and wires.

3.1.3 Sockets

A socket and test device or a socket and pluggable header adapter with identified signal and grounds.

4 Test procedure

Unless otherwise specified all measurement results shall contain a minimum of 200 frequency points. Each fixture measurement and its associated specimen attenuation measurement shall be taken at the same frequencies. Generate a magnitude versus frequency plot; 1 dB per division vertical scale and log frequency sweep are recommended. When applicable, single frequency results shall be tabulated, as specified in the referencing document. Place the specimen a minimum of 5 cm from any objects that would affect measured results.

NOTE — The test professional should be aware of limitations of any math operation performed by an instrument, (e.g. normalization or software filtering).

4.1 Fixture attenuation

Fixture attenuation shall be measured separately so that it can be removed from and compared to the specimen measurement. If the referencing document precisely specifies the fixture so that its attenuation contribution is fixed, then the fixture attenuation measurement is optional.

NOTES — Results may be inaccurate when:

1 The fixture attenuation is greater than the specimen attenuation.

2 The fixture electrical length is greater than 1/8 wavelength at the highest test frequency, unless special precautions are taken to ensure good impedance matching throughout the measurement path. This can be confirmed by sweeping across a wide frequency range and observing if there are nulls due to moding, fixture or balun resonances, etc.

4.2 Method A, frequency domain

4.2.1 Network or spectrum analyzer (direct technique)

4.2.1.1 Calibration

4.2.1.1.1 When using a network analyzer, at a minimum, a "through" calibration at the reference plane (include analyzer cables but not specimen fixture) shall be performed. Where possible a 12 term calibration is recommended.

4.2.1.1.2 When using a spectrum analyzer and signal generator, take a reference measurement similarly. The generator output shall be kept the same for both fixture and specimen-with-fixture attenuation measurements made later.

4.2.1.2 Insertion technique

4.2.1.2.1 Assemble the fixture so that the near end is connected to the far end without the specimen in between; see figure A.1.a. Connect the network analyzer ports, or the signal generator and spectrum analyzer, to the appropriate locations of the driven line fixture.

4.2.1.2.2 When using a network analyzer measure the fixture attenuation (S_{21}).

4.2.1.2.3 When using a spectrum analyzer, measure the power from the generator through the fixture. Then divide the magnitude of this signal by that of the reference measurement performed in 4.2.1.1.2 at each frequency (subtract dB). This is the fixture attenuation.

4.2.1.3 Reference fixture technique

4.2.1.3.1 Construct a reference fixture that duplicates the specimen fixture but without the specimen. Include both near and far ends; see figure A.1.b. Connect the network analyzer ports, or the signal generator and spectrum analyzer to the appropriate locations of the driven line fixture.

4.2.1.3.2 When using a network analyzer, measure the fixture attenuation (S_{21}).

4.2.1.3.3 When using a spectrum analyzer, measure the power from the generator through the fixture. Then divide the magnitude of this signal by that of the reference measurement performed in 4.2.1.2.3 at each frequency (subtract dB). This is the fixture attenuation.

4.2.1.4 Specimen attenuation measurement

4.2.1.4.1 Add specimen to fixture.

4.2.1.4.2 When using a network analyzer, connect the analyzer drive port to the near end of the fixture and the receiver port of the analyzer to the far end of the fixture. Measure the specimen-with-fixture attenuation in dB.

4.2.1.4.3 When using a spectrum analyzer, connect the generator output port to the near end of the fixture and the analyzer input to the far end of the fixture. Measure the signal power (typically in dBm). Divide the magnitude of this signal by that of the reference measurement, see 4.2.1.1.2, at each frequency (subtract dBm). Record specimen-with-fixture results in dB.

4.2.1.5 Divide the specimen-with-fixture attenuation by the fixture attenuation (subtract dB) and plot. This is the specimen attenuation. Record single frequency results and tabulate, if requested.

4.2.2 Impedance analyzer (open/short method)

4.2.2.1 Calibrate the instrument according to the manufacturer's instructions. This is typically done using short and open circuit standards connected one at a time at the specimen measurement location of the fixture.

4.2.2.2 Connect the specimen to the fixture with the far end of the specimen open-circuited, and measure the magnitude and phase of the specimen plus fixture impedance.

4.2.2.3 Short-circuit the far end of the specimen, and measure the magnitude and phase of the specimen plus fixture impedance.

4.2.2.4 Calculate the attenuation of the specimen plus fixture using the following equations: [1)]

$$P = (|Z_{OP}|\,|Z_{ST}|)^{1/2} \quad \text{and} \quad \phi = (\theta_{ST} - \theta_{OP}) / 2,$$

where:

Z_{OP} and θ_{OP} are the open-circuit impedance and phase, respectively, and Z_{ST} and θ_{ST} are the short-circuit impedance and phase, respectively. The attenuation constant,

$$\alpha = 8.6859\ (1/2l)\ \ln\ [((1+x)^2 + y^2) / ((1-x)^2 + y^2)]^{1/2} \ \text{dB/m},$$

where:

l = specimen physical length (meters)
$x = P \cos \phi$
$y = P \sin \phi$

4.2.2.5 Divide the specimen-with-fixture attenuation by the fixture attenuation (subtract dB) and plot. This is the specimen attenuation. Record single frequency results and tabulate, if requested.

4.2.3 Additional measurements

Repeat this entire procedure for each measurement requested.

1) Procedure and equations from "*Measuring Cable Parameters*," Hewlett-Packard Appliaction Note 380-2, p.15.

4.3 Method B, time domain

This method requires that the network analyzer procedure be followed, but with the following changes. A TDR in time domain transmission (TDT) mode with a triggered short impulse generator to measure the response of the specimen to an impulse stimulus shall be used. Fast fourier transform (FFT) software is used to compute the attenuation of the specimen in the frequency domain.

4.3.1 Connect the TDR output to the input of an impulse generator.

4.3.2 Connect the output of the impulse generator to the near end of the test fixture, and connect the far end of the test fixture to the input of a TDR sampling head.

4.3.3 For each measurement, measure the TDT response to the impulse stimulus.

4.3.4 Compute the FFT of the time domain response, the result being the attenuation in the frequency domain. From these data the complex propagation constants alpha (attenuation versus frequency) and beta (phase versus frequency) may be calculated over a very wide frequency range. If combined with low frequency capacitance measurements, the specimen may be completely characterized, including attenuation as well as complex impedance as functions of frequency.

5 Details to be specified

The following details shall be specified in the referencing document:

5.1 Method to be used, time or frequency domain

5.2 Specimen signal and ground assignments for each measurement. As a minimum, the driven conductor or conductor pair, the nearest signal conductors in each direction, and the associated (adjacent) grounds of all these, shall be identified.

> NOTE — A sufficient number of lines to be measured based on a consideration of geometry, should be specified so that the best and worst case performance will be determined. It is recommended that the following be considered: conductor spacing, conductor orientation, conductor length, etc.

5.3 The type of drive signal, single-ended or differential. Refer to 2.2.1 in the special case of differential and not balanced signals.

5.4 Specimen environment impedance if other than 50 ohms for single-ended or 100 ohms for differential.

5.5 Points between which the attenuation shall be measured

5.6 Measurement frequency range

5.7 Tabulated single frequency results, if desired

5.8 Plot magnitude format, if other than dB and log frequency

5.9 Any special requirements with respect to fixture and termination construction and electrical properties.

5.10 Any special calibration technique

6 Test documentation

Documentation shall contain the details specified in clause 5, with any exceptions, and the following:

6.1 Title of test

6.2 Test equipment used, and date of last and next calibration

6.3 Measured fixture, measured specimen-with-fixture, and calculated specimen attenuation plots and tabulated single frequency results.

6.4 Balun specifications, if used

6.5 Test method used, time domain or frequency domain, (direct or open/short)

6.6 Observations

6.7 Name of operator and date of test

Annex

A Normative

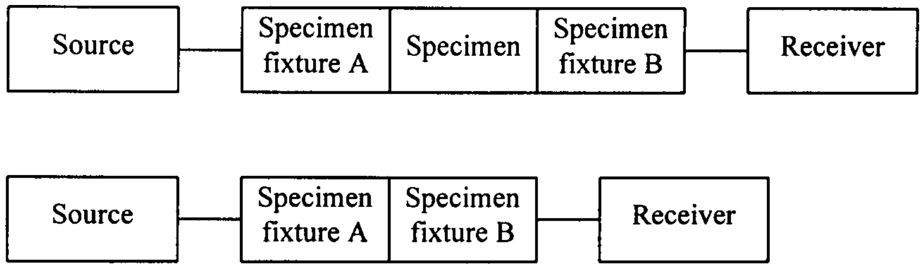


Figure A.1.a - Insertion technique

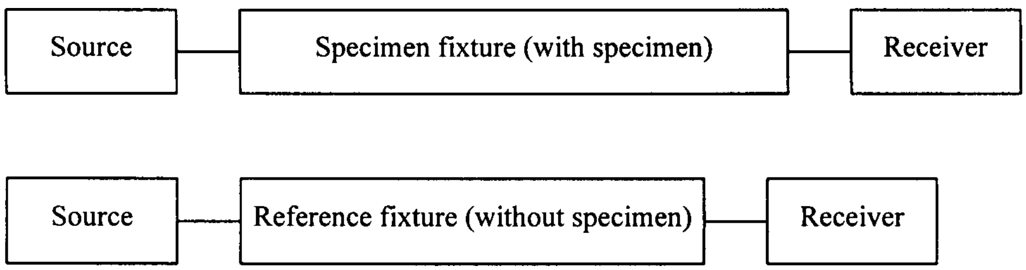
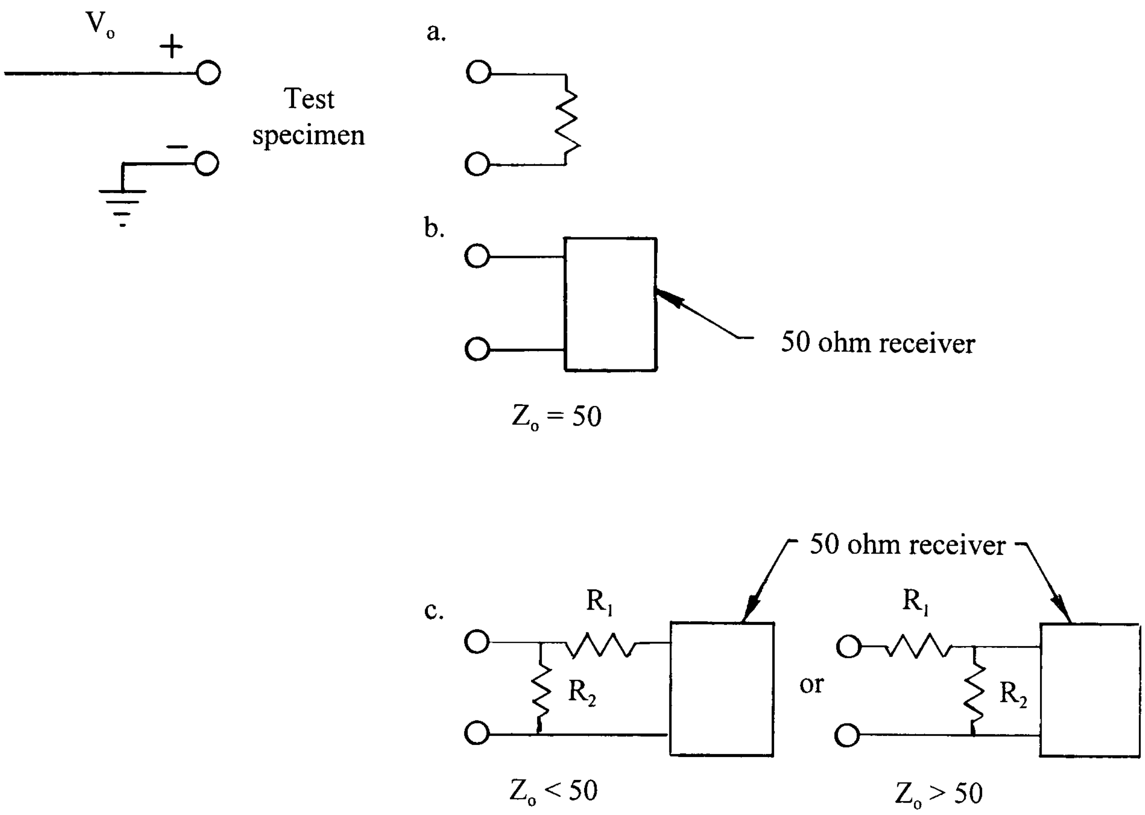


Figure A.1.b - Reference fixture technique

Figure A.1 - Technique diagrams

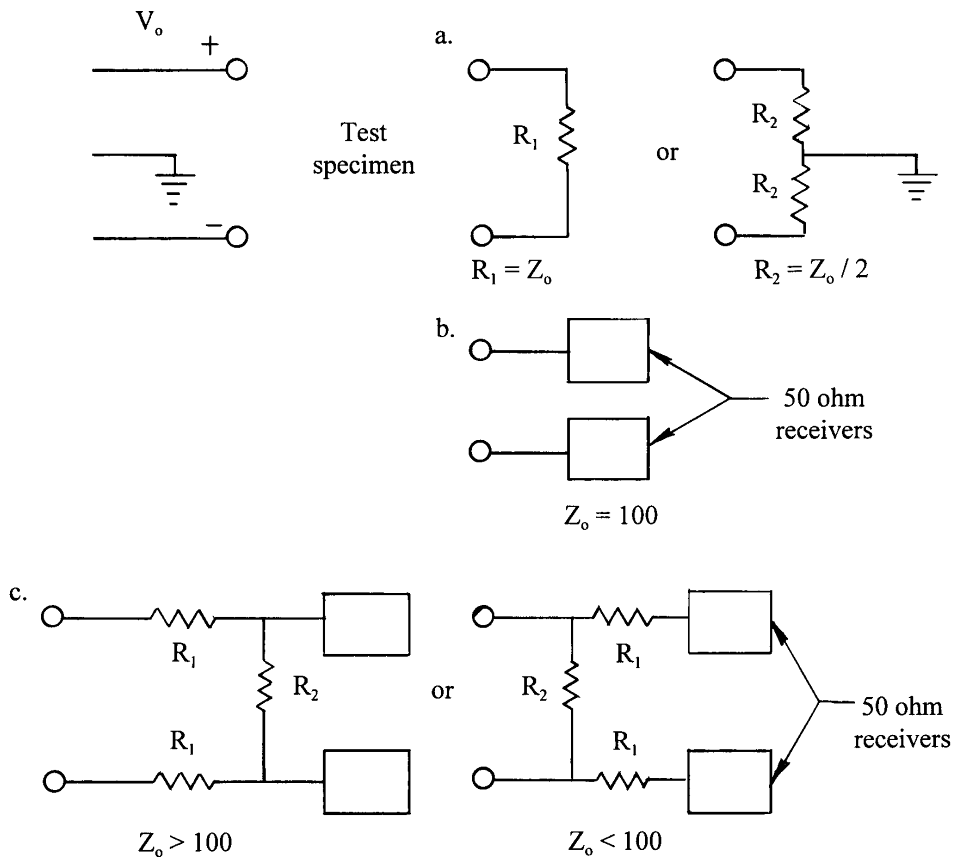


Minimum loss pad equations:

$R_1 = 50\,[\,1 - (Z_o / 50)\,]^{0.5}$ $R_1 = Z_o\,[\,1 - (50 / Z_o)\,]^{0.5}$

$R_2 = Z_o / [1 - (Z_o / 50)\,]^{0.5}$ $R_2 = 50 / [1 - (50 / Z_o)\,]^{0.5}$

Figure A.2 – Single-ended terminations



Minimum loss pad equations:

$R_1 = Z_o [1 - (100 / Z_o)]^{0.5} / 2$ $\quad$ $R_1 = 100 [1 - (Z_o / 100)]^{0.5} / 2$

$R_2 = 100 / [1 - (100 / Z_o)]^{0.5}$ $\quad$ $R_2 = Z_o / [1 - (Z_o / 100)]^{0.5}$

Figure A.3 - Differential (balanced) terminations

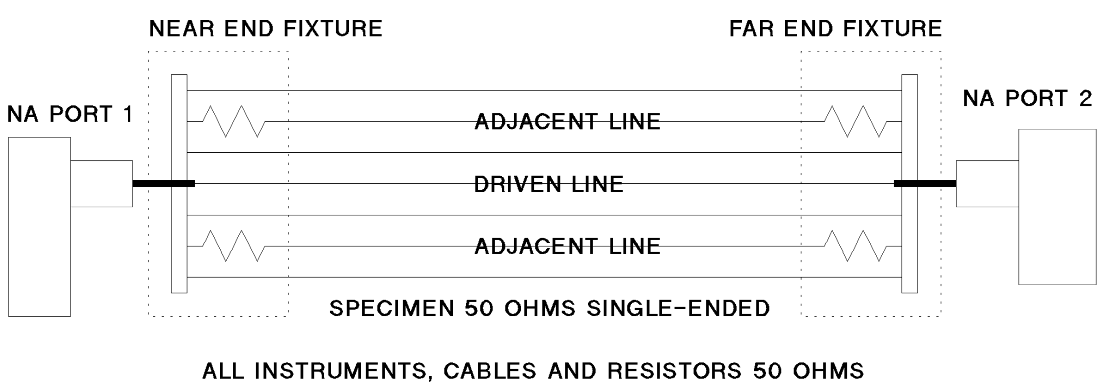


Figure A.4 - Example of specimen in fixture for attenuation

B Informative

B.1 Practical guidance

Near perfect resistive terminations of the signal lines may not be possible at high frequencies due to parasitic reactances in both signal and ground conductors. These reactances will have an impact on measured results. In this case it is desirable that the test fixture duplicate the exact geometry (parasitics) of the actual application. This may involve the use of transmission lines in addition to the components of figures A.1 and A.2. Most instruments used for these measurements are internally terminated in 50 ohms at both source and detector ports.

EIA Document Improvement Proposal

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