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Test Method for Transfer Impedance

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1. Introduction

1.1. Executive Summary

Transfer impedance is a measure of shielding effectiveness. This procedure provides instructions for performing the measurement on flexible coaxial drop cables.

1.2. Scope

This procedure is for the measurement of transfer impedance of coaxial drop cables from 5 MHz to the maximum specified frequency using a terminated tri-axial test fixture.

1.3. Benefits

Using this procedure, the transfer impedance of a cable can be characterized and used to determine its shielding effectiveness. Lower transfer impedance means better shielding and less signal ingress or egress.

1.4. Intended Audience

This is a laboratory measurement used primarily by development engineers for the improvement of coaxial drop cable shields.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- No normative references are applicable.

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

- No informative references are applicable.

3.2. Standards from Other Organizations

- No informative references are applicable.

3.3. Published Materials

- No informative references are applicable.

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5. Abbreviations

dB	decibel
RF	radio frequency
MHz	Megahertz (1 x 10 ⁶ Hz)
SCTE	Society of Cable Telecommunications Engineers

6. Equipment

- Terminated Tri-axial Test Fixture (See Figure 6.)
- Signal Source (Swept Frequency Oscillator)
- Detector, Display
- (Note: A spectrum analyzer with a tracking generator may be used or a network analyzer with a signal source may be used for the signal source, detector and display.)
- Termination loads
- Attenuators
- Optional Power Attenuators (used in conjunction with the optional RF Amplifier)
- Optional RF Power Amplifier
- Coaxial “T” (For velocity of propagation measurements)

7. Calibration

The frequency of the signal source and loss of the attenuators shall conform to appropriate laboratory standards including traceability to recognized measurement standards.

8. Specimen Preparation & Installation

Measure the cable so that it will be long enough to fit through the chamber and toroids and connect to the fittings at the end of the test fixture.

Carefully remove two small “windows” of jacket from the specimen. Each window should be approximately 0.5 to 1 cm (3/16 to 3/8 inch) long and approximately 0.5 cm (3/16 inch) wide. The windows should be placed 1.00 meter (39.37 inches) apart and each 0.5 meter (19.69 inches) from the center of the sample so that the chamber probes, which are spaced 1 meter apart, can make electrical contact with the outer conductor of the specimen. Care must be taken not to damage the outer conductor when cutting through the jacket especially if the outer most layer of the outer conductor is a thin aluminum tape. See Figure 1.

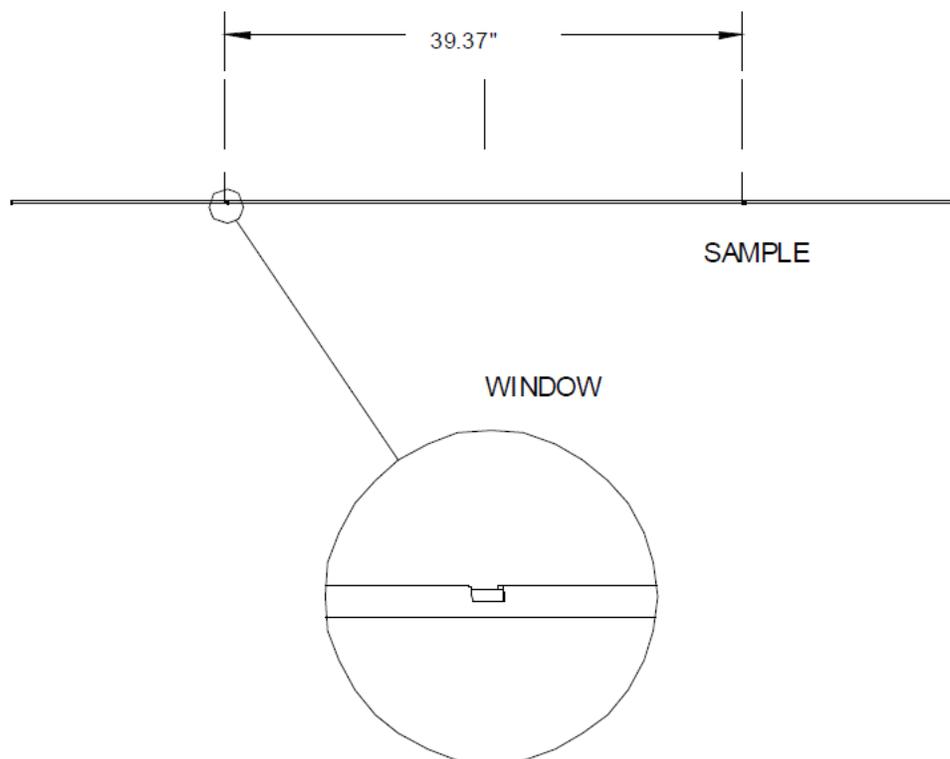


Figure 1 - Specimen and Window

Install the specimen through the terminated tri-axial test fixture. See Figure 6. Install the appropriate connectors at the ends of the specimen. Insert the probes into the chamber to make electrical contact with the outer conductor of the specimen. Care should be taken not to damage the shield of the specimen especially if the outer conductor is a thin aluminum tape. An electrical continuity test can be performed to assure that the probes are making contact with the outer conductor of the specimen.

9. Velocity Of Propagation Measurement

Measure and record the length of the specimen, L_x . The length of the specimen is the distance from the center of the coaxial “T” to the open circuit at the end of the specimen. Connect the equipment as shown in Figure 2. Measure the frequency of two adjacent null points. Calculate the velocity of propagation for the specimen, V_{gx} , from:

$$V_{gx} = \frac{2\Delta f L_x}{11.8 \times 10^9}$$

Where:

V_{gx} = Velocity of Propagation (decimal)

$\Delta f = F_2 - F_1$ = Difference between two adjacent nulls (Hz)

L_x = Length of the specimen or chamber (inches)

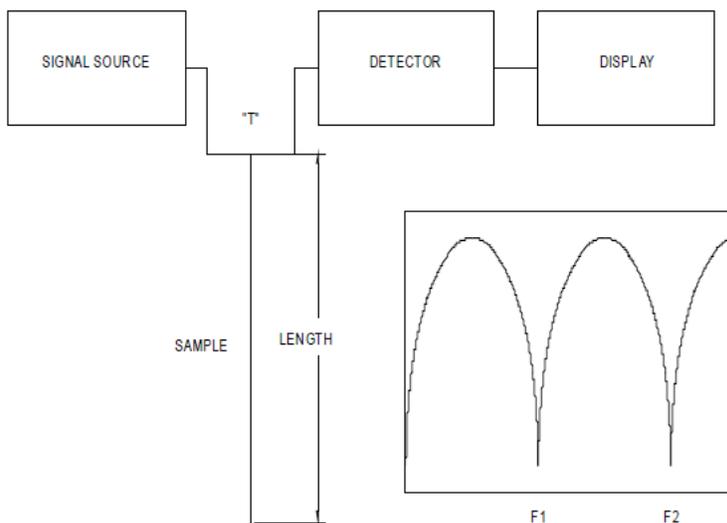


Figure 2 - V_g Equipment Arrangement And Display

(Example: The specimen length, L_x is 72 inches; the “T” is 1 inch; the total length is 73 inches. The first null, F1, occurred at 33MHz and second, F2, null at 99MHz. The difference between two adjacent nulls, Δf , is 66×10^6 Hz. The velocity of propagation of the sample is, therefore: $[2 \times (66 \times 10^6\text{Hz}) \times 73 \text{ inches}] / [11.8 \times 10^9 \text{ inches/sec}] = 0.82$.)

Measure and record the length of the chamber, L_c . The length of the chamber is the distance from the center of the “T” to the open circuit, which includes the length of the probe (see Fig. 6), the length of the chamber (39.37 inches) plus the length of the second probe. Connect the “T” to one of either of the probes on the chamber. Measure the frequency of two adjacent null points, as before and calculate the velocity of propagation for the chamber, V_{gc} .

10. Optimum Measurement Frequencies

The reverse response, dB_{REV} , which is measured in section 14, is a function of the sum of the specimen and chamber phase constants and has a characteristic peak and null. Although the reverse response can be measured at any frequency, the greatest accuracy is achieved when the reverse response exhibits a peak. This occurs when:

$$f = \frac{n299.79 \times 10^6}{2} \left(\frac{1}{\frac{1}{V_{gs}} + \frac{1}{V_{gc}}} \right)$$

For $n = 3, 5, 7, \dots$

Where:

V_{gs} = Specimen Velocity of Propagation (decimal)

V_{gc} = Chamber Velocity of Propagation (decimal)

(Example: If the chamber velocity of propagation is 0.81 and the specimen velocity of propagation is 0.82, then the optimum frequencies for measuring the reverse response would be, 183 MHz, 305 MHz, 428 MHz, ...)

11. System Frequency Response

Connect the output of the signal source to the detector and measure and record the frequency response of the system. This level will serve as the reference level from which all other measurements will be made. (If the measurement system has the capability, the frequency response of the system may be stored and automatically subtracted from all of the following measurements.) If a power amplifier and power attenuators are used to increase the dynamic range of the system, it is necessary to measure and record their frequency response also.

12. Chamber Insertion Loss Measurement (α_c)

Connect the equipment as shown in Figure 3 and measure and record the chamber attenuation (α_c) with respect to the reference level measured in section 11 over the frequency band of interest. Measure the attenuation of the specimen if it is suspected to be more than 1dB in the frequency band and add it to the chamber loss.

Example: If the reference level is -2dB and the chamber measurement was -5dB then the chamber attenuation is 3dB.

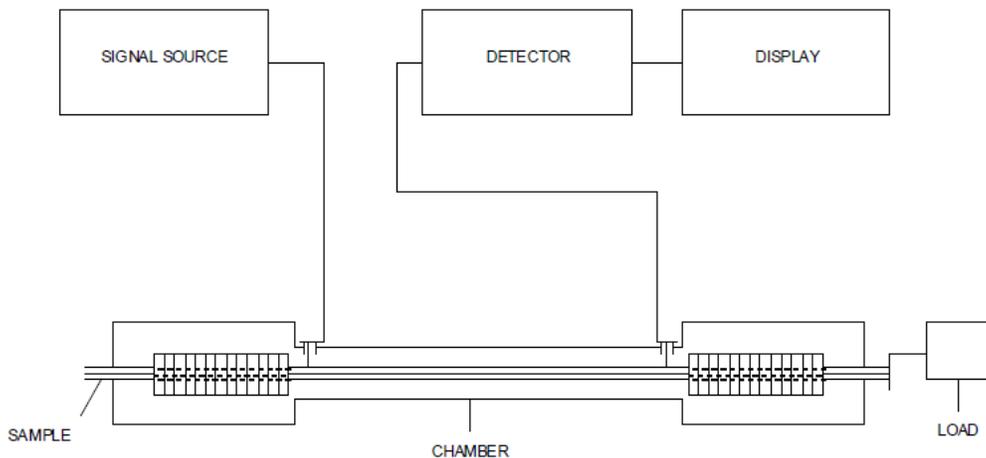


Figure 3 - Chamber Insertion Loss Measurement

13. Forward Measurement (dB_{FWD})

Connect the equipment as shown in Figure 4 and measure and record the forward response (dB_{FWD}) with respect to the reference level of the sample over the frequency band of interest.

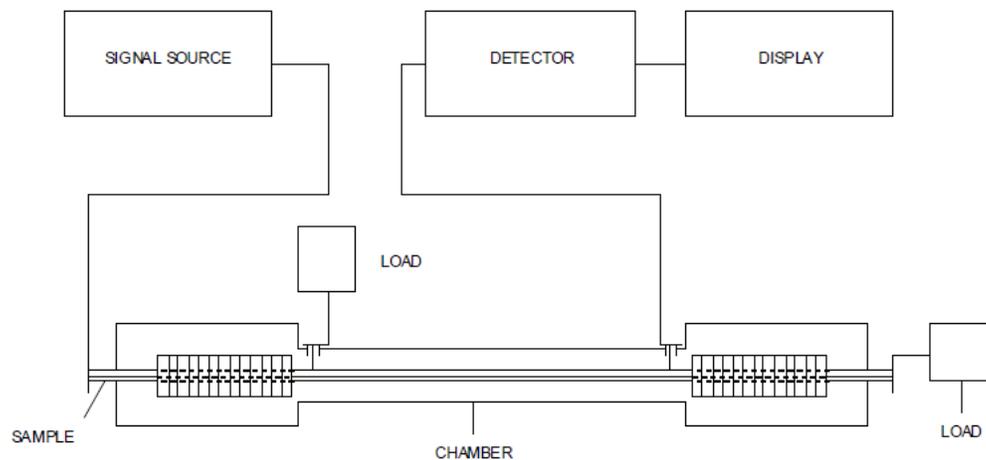


Figure 4 - Forward Response Measurement

14. Reverse Measurement (dB_{REV})

Connect the equipment as shown in Figure 5 and measure and record the reverse response (dB_{REV}) with respect to the reference level of the sample at the optimum frequencies described in section 10

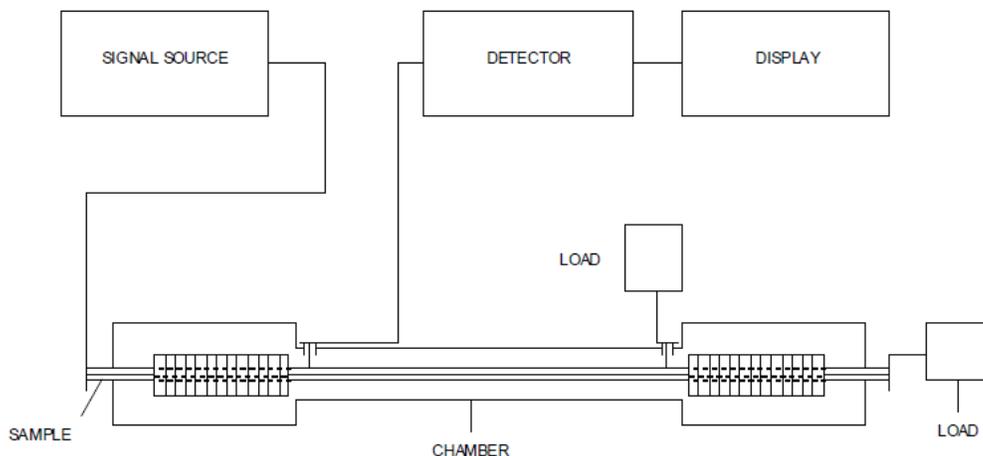


Figure 5 - Reverse Response Measurement

15. Capacitive Coupling Impedance Calculation

Since capacitive coupling impedance, Z_f , varies directly with frequency, the corresponding capacitance, C , which is independent of frequency, may be calculated at the optimum frequencies described in section 10 and an average capacitance value obtained. The average may be used in the calculation of transfer impedance in section 16.

$$Z_f = \sqrt{Z_s Z_c} \left(\frac{M}{e^x} - \frac{N}{e^y} \right)$$

Where:

Z_f = Capacitive Coupling Impedance (Ohms/meter)

Z_s = Specimen Characteristic Impedance (Ohms)

Z_c = Chamber Characteristic Impedance (Ohms)

$$x = \left(\frac{dB_{REV} - \alpha_c / 2}{8.686} \right), y = \left(\frac{dB_{FWD} - \alpha_c / 2}{8.686} \right)$$

Where:

dB_{REV} = Reverse Response (Probe closest to source) (dB)

dB_{FWD} = Forward Response (Probe furthest from source) (dB)

α_c = Chamber (plus sample) attenuation (dB)

$$M = \left| \frac{P}{\sin P} \right|, \text{ where } P = \left(\frac{\pi f}{299.79 \times 10^6} \right) \left(\frac{1}{V_{gs}} + \frac{1}{V_{gc}} \right)$$

$$N = \left| \frac{Q}{\sin Q} \right|, \text{ where } Q = \left(\frac{\pi f}{299.79 \times 10^6} \right) \left(\frac{1}{V_{gs}} - \frac{1}{V_{gc}} \right)$$

Example: For $Z_s = 75$ Ohms, $Z_c = 75$ Ohms, $V_{gs} = 0.82$, $V_{gc} = 0.81$, $f = 183$ MHz, $\text{dB}_{\text{REV}} = 80\text{dB}$, $\text{dB}_{\text{FWD}} = 80\text{dB}$ and $\alpha_c = 1.0\text{dB}$, then $P = 4.706$ radians, $Q = -0.02887$ radians, $M = 4.706$ and $N = 1.000$. (Note: if $V_{gs} = V_{gc}$, Q is not defined. However, it can be shown that when $V_{gs} = V_{gc}$, $N = 1$.) Also, $x = 9.153$, $y = 9.153$ and $Z_f = 0.02945$ Ohms/meter.

The capacitive coupling impedance, Z_f , should be obtained at 3 to 5 of the optimum frequencies described in section 10. Calculate the coupling capacitance, C , at each frequency from:

$$C = \frac{Z_f}{2\pi f}$$

Example: For $Z_f = 0.02945$ Ohms/meter and $f = 183$ MHz, $C = 25.6 \times 10^{-12}$ F/m.

The average capacitance, C_{AVG} , is calculated and used in the calculation of transfer impedance and capacitive coupling impedance at any frequency.

$$C_{\text{AVG}} = \frac{C_1 + C_2 + C_3 + \dots + C_n}{n}$$

16. Transfer Impedance Calculation

The transfer impedance can be calculated at any frequency from the following equation:

$$Z_t = 2\sqrt{Z_s Z_c} e^{-y} + 2\pi f C_{\text{AVG}}$$

Where:

$$Z_t = \text{Transfer Impedance (Ohms/meter)}$$

Example: For $C_{\text{AVG}} = 20 \times 10^{-12}$ F/m, $f = 183$ MHz, $y = 9.153$, $Z_s = 75$ Ohms, $Z_c = 75$ Ohms, then $Z_t = 0.0389$ Ohms/m.

17. Terminated Triaxial Test Fixture

Figure 6 shows the key components of the terminated tri-axial test fixture. The size of the chamber should be selected so that the phase constant and impedance match the phase constant and impedance of the sample as close as possible. The chamber may be fabricated from copper water pipe. The sample may be concentrically supported by a polyethylene tube which is in turn supported by Teflon discs. By selecting the appropriate chamber size and polyethylene support tube, the impedance and phase constant can be matched to the cable sample. The baluns can be made from metallic boxes that can be electrically sealed from ingress signals and leakage from the test leads. The size of the box should be physically large so that it offers a high impedance at the end of the chamber. Thus the load at the probe provides good impedance matching with the chamber. The test leads should be as short as possible and well shielded. The ferrite toroids can be purchased with the appropriate inside diameter to fit over the cable sample's jacket. Nickel zinc toroids with an initial permeability of 125 are adequate. The number of toroids affects the frequency response of the fixture. The response of the fixture can be characterized by measuring the return loss and attenuation of the chamber with a specimen installed. Typically, 30 toroids, each ¼ inch wide, provide good system response down to about 5 MHz. The low frequency response can be extended by adding more toroids. The high frequency response can be extended by improving the impedance matching through the chamber (e.g., by improving the concentricity of the specimen inside the chamber and locating the ferrite toroids as close to the probes as possible). The probes can be made from BNC type female bulkhead receptacles. A solid pin can be soldered on the end of the center pin contact of the receptacle, but a preferred design is to use a spring-loaded contact to prevent damage of the cable sample.

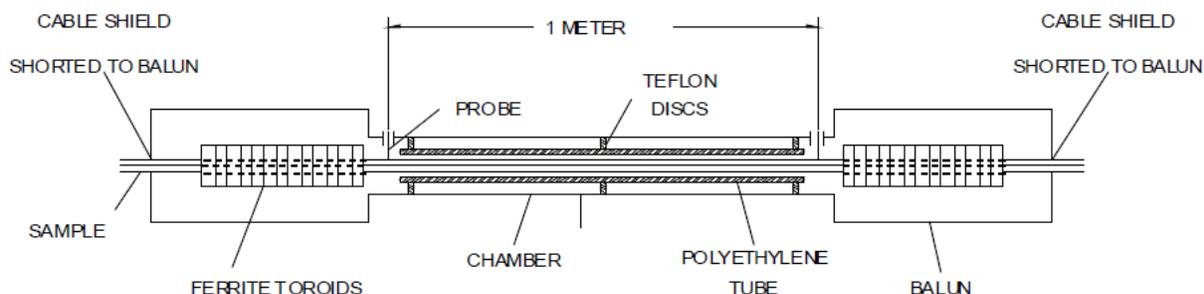


Figure 6 - Terminated Triaxial Test Fixture

18. Test Report**Transfer Impedance Measurement and Calculation Report**

Tested By	
Date	
Cable type	

Section	Measurement or Calculation	Value
9	Length of Specimen, L_x (inches)	
	First null frequency, F_1 (hertz)	
	Second null frequency, F_2 (hertz)	
	Difference between nulls, $F_2 - F_1$ (hertz)	
	Calculated specimen velocity of propagation, V_{gx} (%)	
9	Length of chamber, L_c (inches)	
	First null frequency, F_1 (hertz)	
	Second null frequency, F_2 (hertz)	
	Difference between nulls, $F_2 - F_1$ (hertz)	
	Calculated chamber velocity of propagation, V_{gc} (%)	
10	Calculated optimum measurement frequencies	
11	Optimum frequency response	
12	Chamber attenuation, α_c (dB)	
13	Forward response measurement, dB_{FWD} (dB)	
14	Reverse response measurement, dB_{REV} (dB)	
15	Capacitive coupling impedance calculation, Z_f (ohms/meter)	
16	Transfer impedance calculation, Z_t (ohms/meter)	

Attach Plot Below: