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**Test Method for
Transfer Impedance**

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1.0 SCOPE

This procedure is for the measurement of transfer impedance of coaxial drop cables from 5 MHz to 1,002 MHz.

2.0 EQUIPMENT

2.1. Terminated Triaxial Test Fixture (See Figure 6.)

2.2. Signal Source (Swept Frequency Oscillator)

2.3. 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.)

2.4. Loads

2.5. Attenuators

2.6. Optional Power Attenuators (used in conjunction with the optional RF Amplifier)

2.7. Optional RF Power Amplifier

2.8. Coaxial "T" (For velocity of propagation measurements)

3.0 CALIBRATION

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

4.0 SPECIMEN PREPARATION & INSTALLATION

4.1. 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.

4.2. 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.

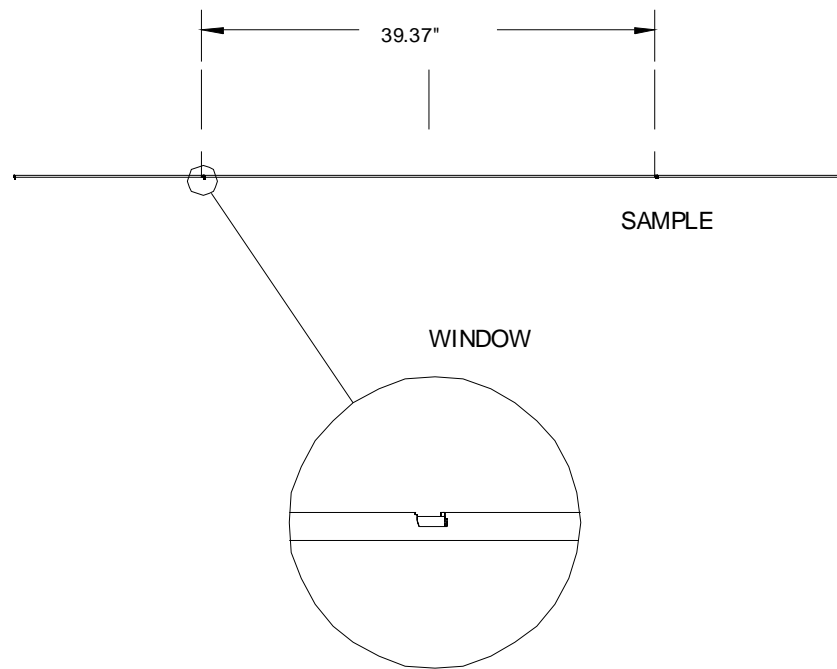


Figure 1 - SPECIMEN AND WINDOW

- 4.3. Install the specimen through the terminated triaxial 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.

5.0 VELOCITY OF PROPAGATION MEASUREMENT

- 5.1. Measure and record the length of the specimen, L_s . 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_{gs} , from:

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

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)

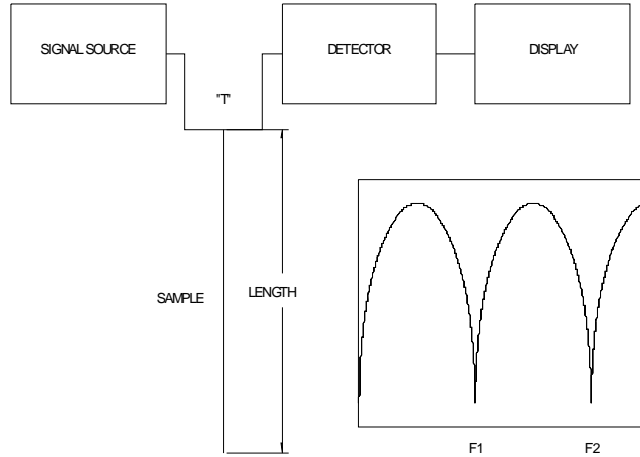


Figure 2 V_g EQUIPMENT ARRANGEMENT AND DISPLAY

(Example: The specimen length, L_s is 72 inches; the “T” is 1 inch; the total length is 73 inches. The first null, F_1 , occurred at 33MHz and second, F_2 , null at 99MHz. The difference between two adjacent nulls, Δf , is 66×10^6 Hz. The velocity of propagation of the sample is, therefore: $[2 \times (66 \times 10^6\text{Hz}) \times 73 \text{ inches}] / [11.8 \times 10^9 \text{ inches/sec}] = 0.82$.)

- 5.2 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} .

6.0 OPTIMUM MEASUREMENT FREQUENCIES

The reverse response, dB_{REV} , which is measured in paragraph 10.0, 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, ...)

7.0 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.

8.0 CHAMBER ATTENUATION 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 paragraph 7.0 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 the chamber loss.

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

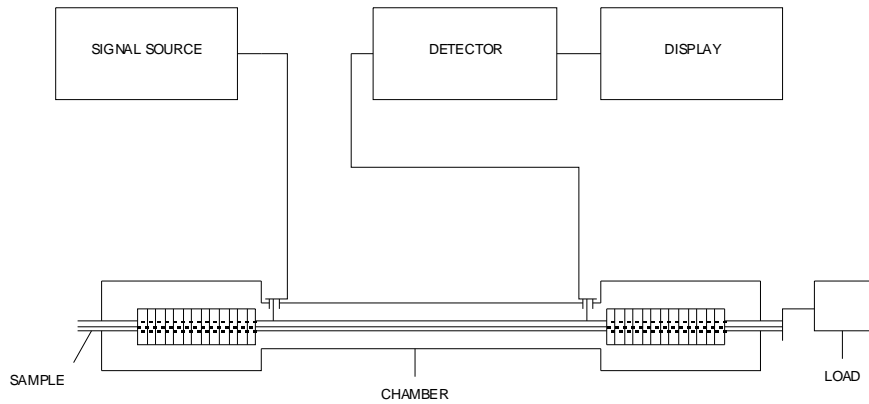


Figure 3 - CHAMBER INSERTION LOSS MEASUREMENT

9.0 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.

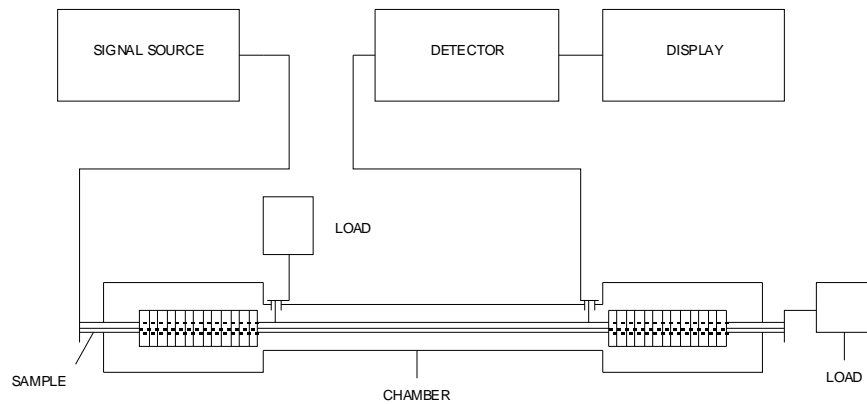


Figure 4 - FORWARD RESPONSE MEASUREMENT

10.0 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 paragraph 6.0.

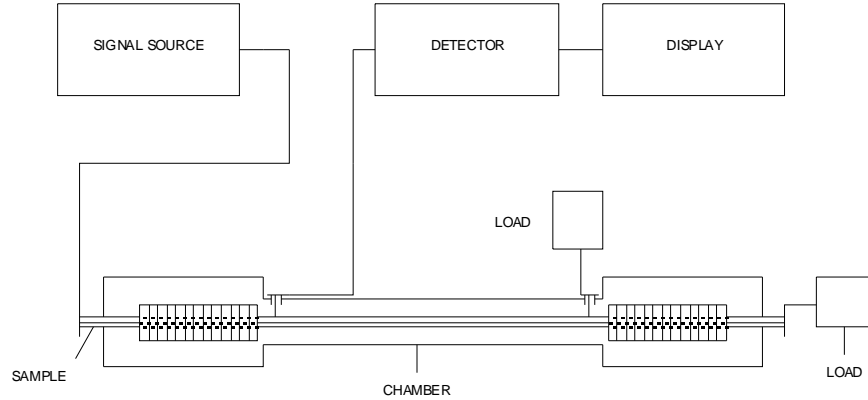


Figure 5 - REVERSE RESPONSE MEASUREMENT

11.0 CAPACITIVE COUPLING IMPEDANCE CALCULATION

- 11.1. 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 paragraph 6.0 and an average capacitance value obtained. The average may be used in the calculation of transfer impedance in paragraph 12.0.

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

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.

- 11.2. The capacitive coupling impedance, Z_f , should be obtained at 3 to 5 of the optimum frequencies described in paragraph 6.0. 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.

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

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

12.0 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.

13.0 TERMINATED TRIAXIAL TEST FIXTURE

Figure 6 shows the key components of the terminated triaxial 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 appropriated inside diameter to fit over the cable sample's jacket. Nickel zinc toroids with an initial permeability of 125 is adequate. The number of toroids effects 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.

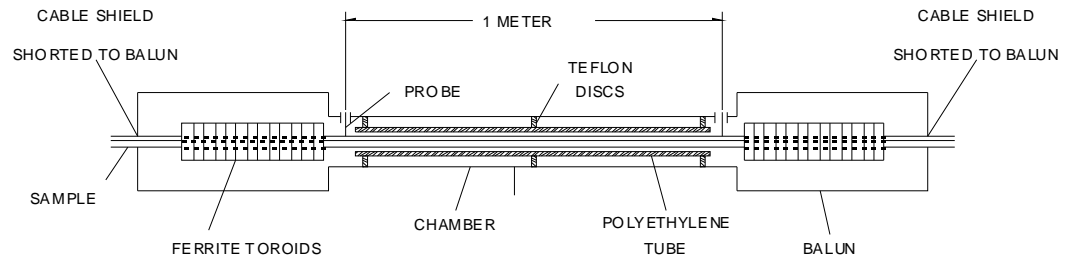


Figure 6 - TERMINATED TRIAXIAL TEST FIXTURE

14.0 TEST REPORT

Transfer Impedance Measurement and Calculation Report

Tested By	
Date	
Cable type	

Section	Measurement or Calculation	Value
5.1	Length of Specimen, L_s (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} (%)	
5.2	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} (%)	
6.0	Calculated optimum measurement frequencies	
7.0	Optimum frequency response	
8.0	Chamber attenuation, α_c (dB)	
9.0	Forward response measurement, dB_{FWD} (dB)	
10.0	Reverse response measurement, dB_{REV} (dB)	
11.0	Capacitive coupling impedance calculation, Z_f (ohms/meter)	
12.0	Transfer impedance calculation, Z_t (ohms/meter)	

Attach Plot Below: