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Test Method For Coaxial Cable Impedance

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1.0 SCOPE AND DEFINITIONS

DEFINITIONS:

Return Loss – The ratio of reflected signal to incident signal, expressed in dB.

Bridge – A device for separating the incident and reflected signals in a return loss measurement.

Network Analyzer – An instrument used for measuring the swept frequency response of a cable.

SCOPE

1.1. The purpose of this procedure is to provide instructions for measuring cable impedance. Two test methods are presented. The accuracy, ease of use, and required test equipment differ for each test method. The two methods are as follows:

1.2. Variable bridge method: The return loss of a cable is measured, while varying the impedance of a reflection bridge. The value of impedance, which gives the minimum reflection, is the average cable impedance. This method requires simple, scalar (magnitude only) measurements. It is subject to errors from the cable connection and operator skill.

1.3. Fixed bridge method: The cable impedance as a function of frequency is calculated from a vector (magnitude and phase) return loss. The average of this impedance across the desired frequency range is the cable impedance. This may be automated, but requires a vector network analyzer, and may be subject to errors due to the cable connection.

2.0 TEST SAMPLES

2.1 Cable impedance is typically tested on whole reels of coaxial cable and two (2) tests are performed, one from each end of the cable. The cable to be tested must be terminated with a fixed, precision 75 ohm load for normal cable lengths. The effect of reflection from the end termination is reduced by twice the cable loss, such that for long lengths of cable, the precision of the end termination is not significant. For shorter lengths of cable, the end termination return loss plus twice the cable loss must be included in error analysis.

2.2 The input cable connector must be a good impedance match to the cable impedance or the measurement results will be affected. The cable must be prepared according to both the cable and connector manufacturer’s instructions.

Improper cable preparation can be a major source of error in impedance measurements.

3.0 EQUIPMENT – VARIABLE BRIDGE METHOD

3.1 Network analyzer (NA), such as Agilent 8753 or equivalent, with reference and test channels. Note: While the Agilent 8753 or equivalent vector network analyzer is referenced due to its wide use, it is entirely appropriate and acceptable to use a scalar network analyzer, such as the Agilent 8711 or equivalent, in this test.

3.2 "Two-resistor" power splitter, such as Agilent 11667A or equivalent.

3.3 Two (2) 50-75 ohm minimum loss pads, such as Agilent 11852B or equivalent.

3.4 Variable impedance bridge, such as Wideband Engineering A56UTD/S or equivalent.

3.5 Calibration kit, such as Agilent 85036B or equivalent.

3.6 Two (2) cable connectors to test port for the size of cable under test. For example, a Gilbert Model GTC-500-GHZ-N, or equivalent, is appropriate for a 500 Series cable.

3.7 Equipment set-up is shown in Figure 1 (Following page).

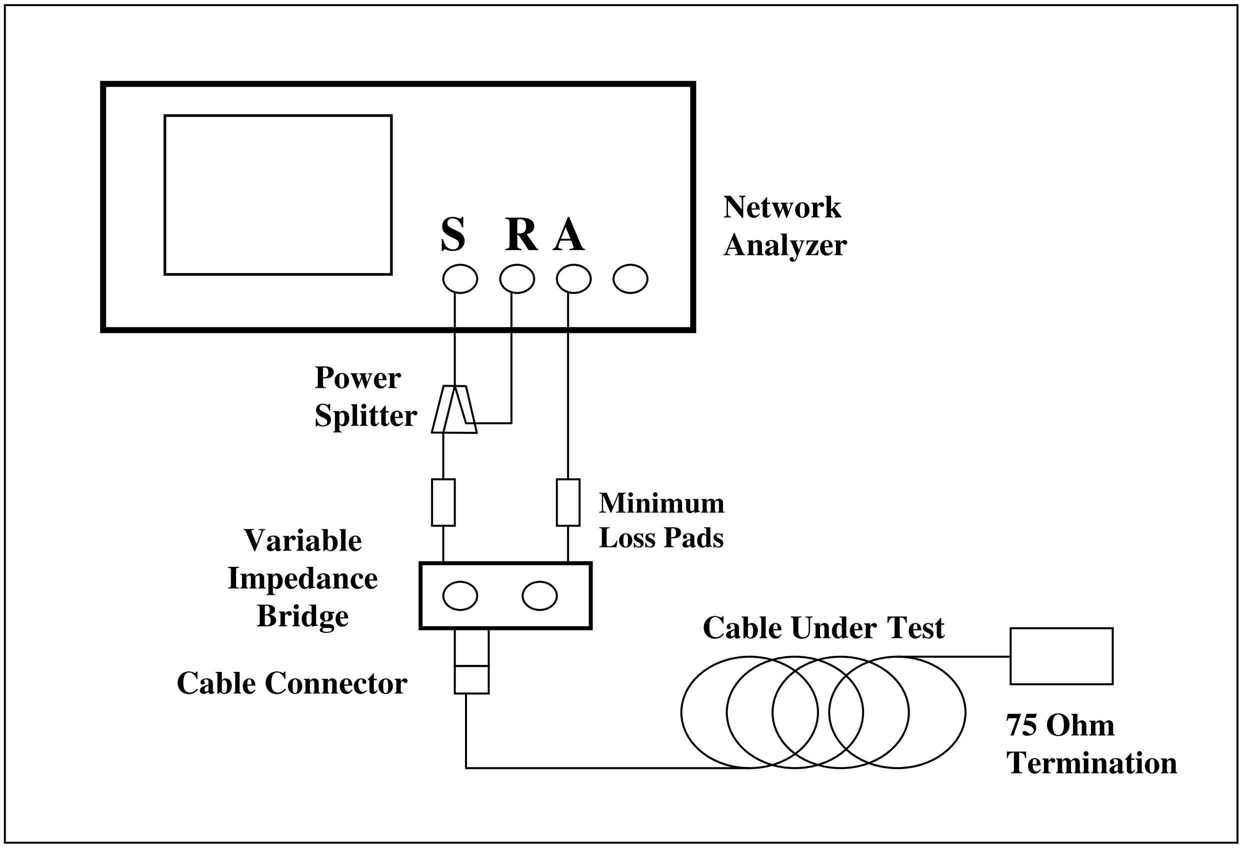

Figure 1: Equipment Set-Up for Variable Impedance Bridge Test Method

4.0 MEASUREMENT METHODOLOGY – VARIABLE BRIDGE

4.1 Set up the network analyzer as shown in Figure 1. Set the variable bridge impedance to 75 ohms and the capacitance to 0.0 pF.

4.2 Set up the network analyzer for a reflection measurement in accordance with the manufacturer's instructions. Set the start frequency to 5 MHz and set the stop frequency to 1002 MHz.

4.3 Perform a calibration (error correction) following the manufacturer's instructions. For a scalar network analyzer, this is an open response normalization. For a vector network analyzer this is a 1-port open/short/load calibration.

4.4 Connect the cable to be tested to the variable impedance bridge. Vary the impedance until the low frequency part of the trace is lowest (best return loss). Adjust the capacitance knob to "lay down" the high frequency part of the trace. This adjustment compensates for mismatch in the cable's input connector.

Continue adjusting the impedance (Z) and capacitance (C) knobs until the trace is as low and flat as possible. A typical trace is shown following; notice that the low end frequency response is adjusted to be as low as possible with the "Z" knob, then the trace is flattened with the "C" knob. Do not artificially raise the low end to improve reflection response in the mid- or high-end range. Figure 2 shows a typical display after proper adjustment of the impedance and capacitance knobs.

Measurements using the variable bridge method are more susceptible to errors which must be considered in measurement error analysis.

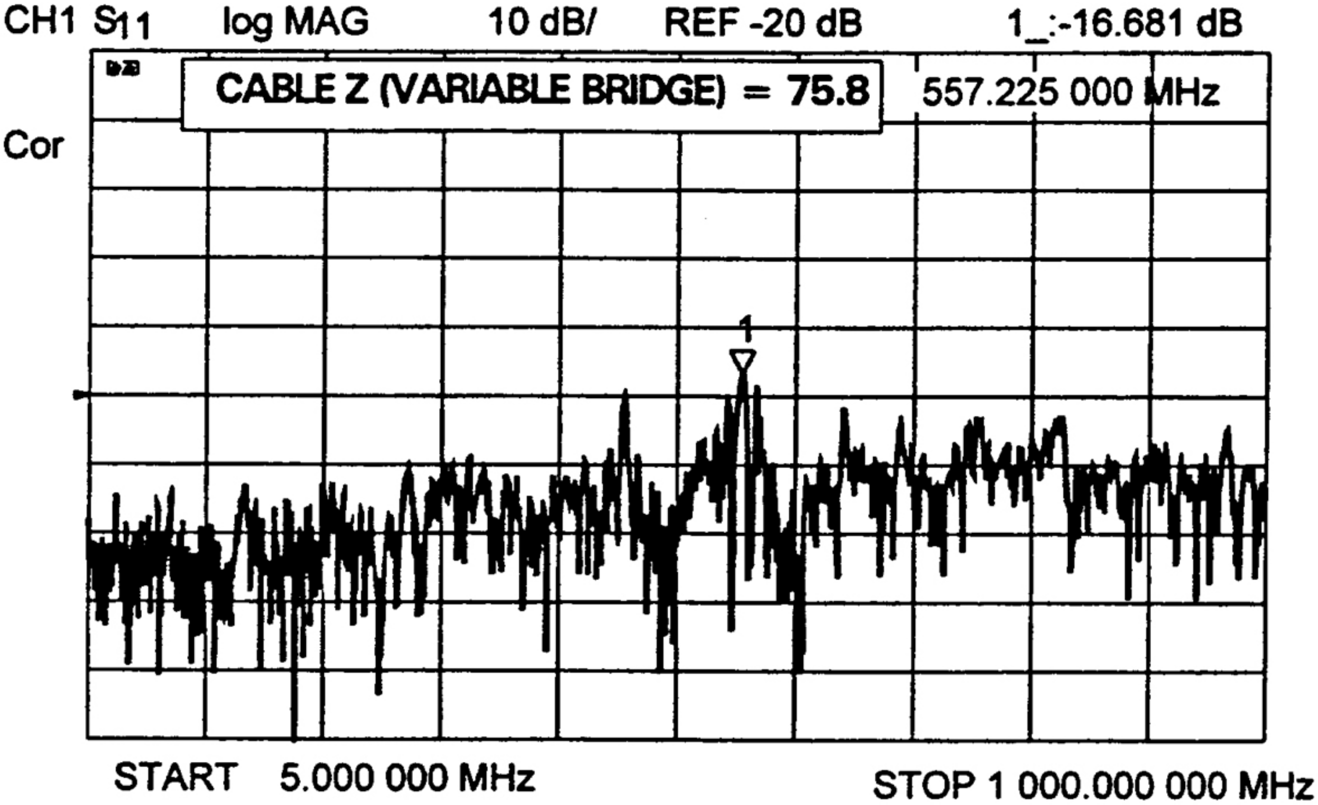

Figure 2: Typical return loss display after proper adjustment of Z and C knobs.

5.0 INSPECTION

After the lowest, flattest trace has been obtained, read the value of impedance from the impedance (Z) knob. Also record the value of the capacitance compensation, as this indicates the quality of the input connector.

6.0 REPORT

TESTER ______________________________ DATE ____________________

MANUFACTURER ____

CABLE TYPE/SIZE ____

LENGTH (FEET) ____

CABLE IMPEDANCE ____

CAPACITANCE READING ____

7.0 EQUIPMENT – FIXED BRIDGE METHOD

7.1 Network analyzer with impedance measuring capability, such as Agilent 8753, including fixed impedance (75 ohm) test bridge or equivalent.

7.2 Calibration kit, such as Agilent 85036B or equivalent.

7.3 Computer or built in analyzer functions to process fixed impedance data.

7.4 Termination (75 ohm load) for far end cable termination (the load in the calibration kit may be used).

7.5 Two (2) test port to cable precision adaptors for the size of cable under test. For example, a Gilbert Model GTC-625-GHZ-N, or equivalent, for a 625 size cable.

7.6 Equipment set-up is shown in Figure 3 (Following page).

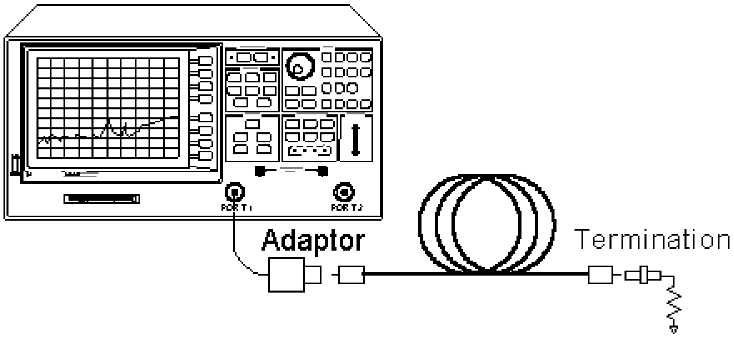

Figure 3: Test Set-Up for Fixed Bridge Measurement

8.0 MEASUREMENT METHODOLOGY – FIXED BRIDGE METHOD

8.1 Set up the network analyzer by setting the start frequency to 5 MHz. Set the stop frequency such that the input connector does not overwhelm the measurement. At high frequencies, the return loss of the input connector can distort the cable response. A recommended stop frequency of 210 MHz is to be used unless a higher frequency is required by specific customer applications. At higher test frequencies, connector compensation techniques may be required. Consult specific manufacturer's instructions for more details on connector compensation.

8.2 Perform a calibration (error correction) following the manufacturer's instructions. For a vector network analyzer, this is a 1-port open/short/load calibration.

8.3 Connect the cable under test to the network analyzer test port. Terminate the far end of the cable in fixed, 75 ohm precision termination. Measure the return loss over the frequency span.

8.4 Using a computer or built in analyzer function, calculate the average impedance over the frequency range. This is done by calculating the sum of the real parts (R) divided by the number of data points collected, and the sum of the imaginary parts (jX) divided by the number of data points collected. Then calculate the magnitude of the resulting average impedance (Z). Ideally, the imaginary part (jX) should be zero; if the imaginary part is not near zero, it indicates that the input connector may be affecting the result.

If a vector network analyzer is not used the impedance can be determined from a scalar analyzer using the following calculations:

Cable Impedance = Z = R +jX (rectangular coordinates)

or

Z= |Z| < θ (in polar coordinates)

If the network analyzer results are given in polar coordinates they must first be converted to rectangular coordinates using:

R=|Z|cos θ   and   X=|Z|sin θ

Assuming the network analyzer samples 201 data points (n=201) in the frequency range from 5 MHz to 210 MHz, the average impedance is calculated as follows:

$$R_{avg} = \sum_{i=1}^{n} \frac{R_i}{n} \qquad X_{avg} = \sum_{i=1}^{n} \frac{X_i}{n}$$

$$Z_{avg} = \sqrt{R_{avg}^2 + X_{avg}^2}$$

Table 1, Sample Average Impedance Calculations

Data in Polar Coordinates (5 points)	Polar Coordinates Converted to Rectangular Coordinates	
	R	jX
75<0.1	75.000	0.131
75<-0.1	75.000	-0.131
75<0.9	74.991	1.178
75<1.3	74.981	1.702
75<-1.0	74.989	-1.309
	$R_{avg} = \sum_{i=1}^{5} \frac{R_i}{5} = 74.974$	$X_{avg} = \sum_{i=1}^{5} \frac{X_i}{5} =0.314$

	$Z_{avg} = \sqrt{74.974^2 + 0.314^2} = 74.975$

9.0 INSPECTION

Figure 4 shows the result of a measurement of real part of impedance vs. frequency. The marker function calculates the average value of impedance between the two markers shown. The upper plot shows the impedance value for this trace calculated over the 5-210 MHz span, as recommended in this test procedure. Note that this correlates very well with the cable impedance measured with the variable bridge in Section 4. The lower plot shows the impedance value for the same trace calculated over the 5-1002 MHz. span; note that the impedance vs. frequency starts to vary at high frequency. Inspection of the imaginary part of the impedance reveals that it becomes large at these points, indicating errors due to connector response.

Record the value of the average impedance, as well as the stop frequency for the average calculation, if other than 210 MHz.

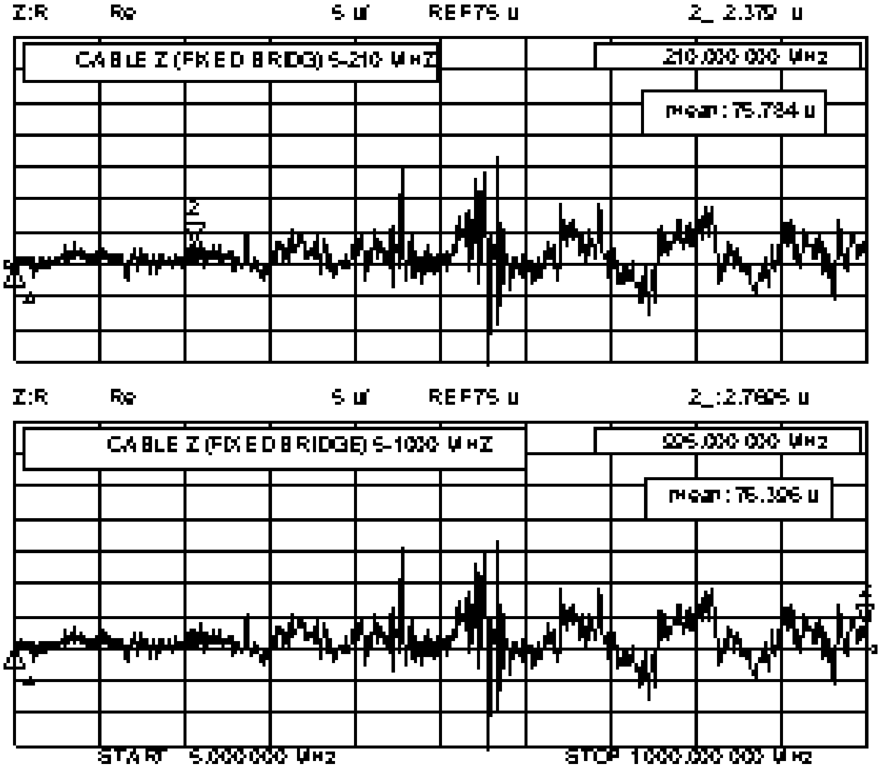

Figure 4: Average Impedance Comparison Between Markers (Fixed Bridge Method)

10.0 REPORT

TESTER ______________________________ DATE _________________________

MANUFACTURER ____

CABLE TYPE/SIZE ____

LENGTH (FEET) ____

CABLE IMPEDANCE ____

STOP FREQUENCY FOR AVERAGING _________________________________

11.0 ERROR ANALYSIS

11.1 The major source of error in this measurement is the directivity of the test system and the impedance mismatch of the test port adaptor. These two error terms combine to give a total error in the return loss measurement. An example of typical errors and their effect on the impedance measurement is shown below:

	Directivity (dB)	Directivity (linear)	Connector (dB)	Connector (linear)	Total Error (Dir + Conn)	Error Effect on Z
Variable Bridge	-45	0.0056	-52	0.0025	0.0085	1.2 ohms
Fixed Bridge	-49	0.0035	-52	0.0025	0.0060	0.9 ohms

11.2. First convert each return loss term (in dB) to linear terms and sum up the reflection error.

Reflection error:

$P_{er} = 10^{\text{(Directivity/20)}} + 10^{\text{(Connector Return Loss/20)}}$

Finally, calculate the error in impedance caused by the return loss error.

Impedance error:

$$Z_{er} = 75 \bullet \frac{1 + p_{er}}{1 - p_{er}} - 75$$

On short lengths of cable, the far end termination effect must be added to the reflection error. It is treated in the same way as the near end connector return loss, but the value of return loss may be reduced by twice the loss of the cable, before converting it to linear terms.

These are only example values. Consult with the equipment manufacturer to determine the actual error values, which may be much better over the 5-210 MHz range for this procedure.