Society of Cable Telecommunications Engineers

ENGINEERING COMMITTEE
Interface Practices Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 03 2008

# Test Method for Coaxial Cable Structural Return Loss

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## 1.0 SCOPE AND DEFINITIONS

### 1.1 SCOPE

1.1.1 The purpose of this procedure is to provide instructions to measure cable structural return loss (SRL). There are two test methods presented, as the accuracy, ease-of-use, and required test equipment differs for each test method. The two methods, with their major advantages and deficiencies, are described below:

1.1.2 Variable Bridge Method: The return loss of a cable is measured, while varying the impedance of a reflection bridge, until the return loss is minimized. This method requires simple, magnitude only (scalar) measurements, but is subject to errors from the cable connection, and operator skill.

1.1.3 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 reference impedance." The structural return loss is calculated from the cable impedance as a function of frequency and the cable reference impedance. This may be automated, but requires a vector network analyzer, and may be subject to errors due to the cable connection

### 1.2 DEFINITIONS

1.2.1 Structural Return Loss (SRL): The return loss of the cable relative to its own impedance.

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

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

1.2.4 Network Analyzer: An instrument for measuring the swept frequency response of a cable.

## 2.0 TEST SAMPLES

2.1 SRL on cables is typically tested on whole reels. The tests are to be performed from each end of the cable. The cable to be tested must be terminated in a proper load. A fixed 75 ohm termination is sufficient for normal cable lengths. The effect of the end termination is reduced by twice the cable loss, such that for long lengths of cable, the end termination is not significant. For shorter lengths of cable, the end termination return loss plus twice the cable loss must be added to the error analysis.

2.2 The input cable connector must be high quality, or the measurement results will be affected. The cable must be prepared according to the connector manufacturer’s instructions. Improper cable preparation may be a major source of error in SRL measurements.

2.3 The cable to be tested should not have any damage, kinks, sharp bends, etc., or other faults which can cause discreet reflections. These cable faults will typically cause errors in the SRL test.

## 3.0 EQUIPMENT - VARIABLE BRIDGE METHOD

3.1 Network Analyzer (NA), such as Agilent 8753 or equivalent, with reference and test channels.

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 Test port to cable adaptor (2 needed) for the size of cable under test. For example, a Corning/Gilbert model GTC-700-GHZ-N, or precision test connector rated to 1 GHz or equivalent, for a 700 size cable.

3.7 Equipment Setup is shown in Figure 1 (following page).

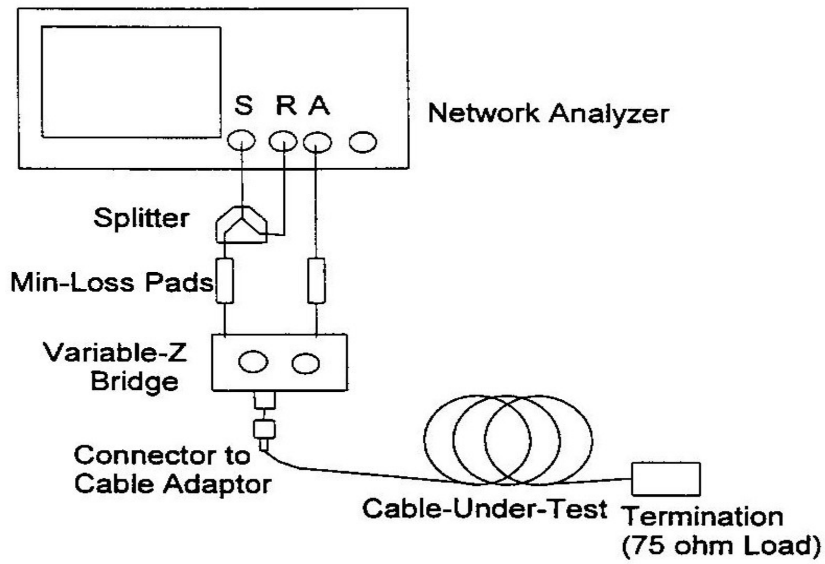


Figure 1: Equipment Setup, Variable Bridge Method

## 4.0 MEASUREMENT METHODOLOGY – VARIABLE BRIDGE

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

4.2 Set up the network analyzer (NA) for a reflection measurement, as per the manufacturer's instructions. Set the start frequency at 5 MHz; set the stop frequency at 1002 MHz, choose the maximum number of points (e.g., 1601). Structural return loss effects can be very narrow in frequency span, as they are caused by the cumulative effects of small reflections along the entire length of the cable. For this reason, the frequency spacing of the measurement points is related to the length of the cable.

For the worse case, reflection from the far end of the cable may combine with near end reflections at a frequency spacing that represents one-half wavelength of the cable. For very long cables, such as 800 meters (about 2600 feet), the frequency spacing may be as narrow as 150 kHz. The narrowest frequency spacing necessary may be calculated by the formula:

$f_{spacing} = (VOP*C)/(2*L)$

where:

VOP - Velocity of Propagation (percent of C/100),
C - speed of light, and
L - cable length.

Higher loss cables may not require the narrowest frequency resolution. The frequency resolution must be sufficient to capture any SRL peaks.

It may not be possible to take a single sweep of the network analyzer with sufficient resolution to see the SRL peaks. The resolution of the measurement can be increased by making several full band sweeps with slightly offset start frequencies, changing the start and stop frequency to obtain the required resolution each sweep, until the entire range is covered (in this example, 995 MHz divided by 1601 points yields about 600 kHz per point, thus four sweeps starting at 5.00 MHz, 5.15 MHz, 5.30 MHz and 5.45 MHz would be needed to ensure proper coverage). As an alternate method the band can be broken into 4 segments 5-250 MHz, 251-500 MHz, 501-750 MHz and 751-1002 MHz.

For some analyzers, it may be necessary to slow the sweep time to ensure good measurements, especially on long cables. Consult manufacturer's information for recommended sweep times.

4.3 Perform a calibration (error correction) following the manufacturer's instructions. For a scalar network analyzer, this is an open or open/short 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. Adjust the impedance knob 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 network analyzer display is shown in Figure 2. 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. The marker is set to the worst case (highest) return loss point. This value is recorded as the structural return loss.

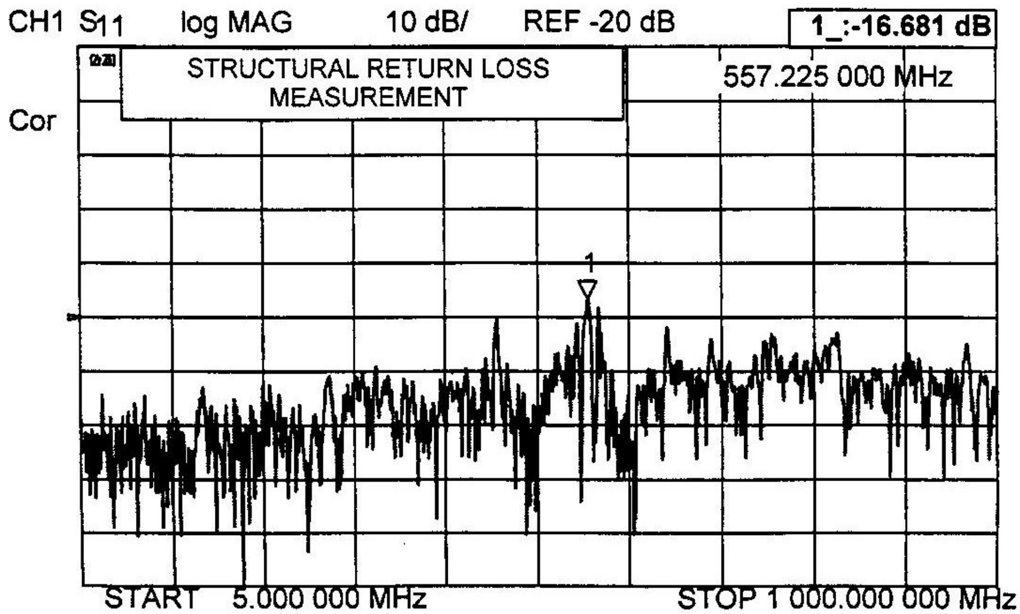


Figure 2: Typical display of a variable impedance bridge measurement with marker 1 placed at the worst case SRL peak.

## 5.0 INSPECTION

After the lowest, flattest trace has been obtained, read the worst case peak value and frequency. This is the structural return loss, other SRL peak values and frequencies may be recorded if desired.

## 6.0 EQUIPMENT – FIXED BRIDGE METHOD

6.1 Network Analyzer with impedance (or built-in SRL) measuring capability, Agilent 8753, or equivalent, including fixed impedance (75 ohm) test bridge, if required.

6.2 Calibration Kit, such as Agilent 85036B, or equivalent.

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

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

6.5 Test port to cable adaptor (2 needed) for the size of cable under test. For example, a Corning/Gilbert Model GTC-700-GHZ-N, or precision test connector rated to 1 GHz or equivalent, for a 700 size cable.

6.6 Equipment setup is shown in Figure 3.

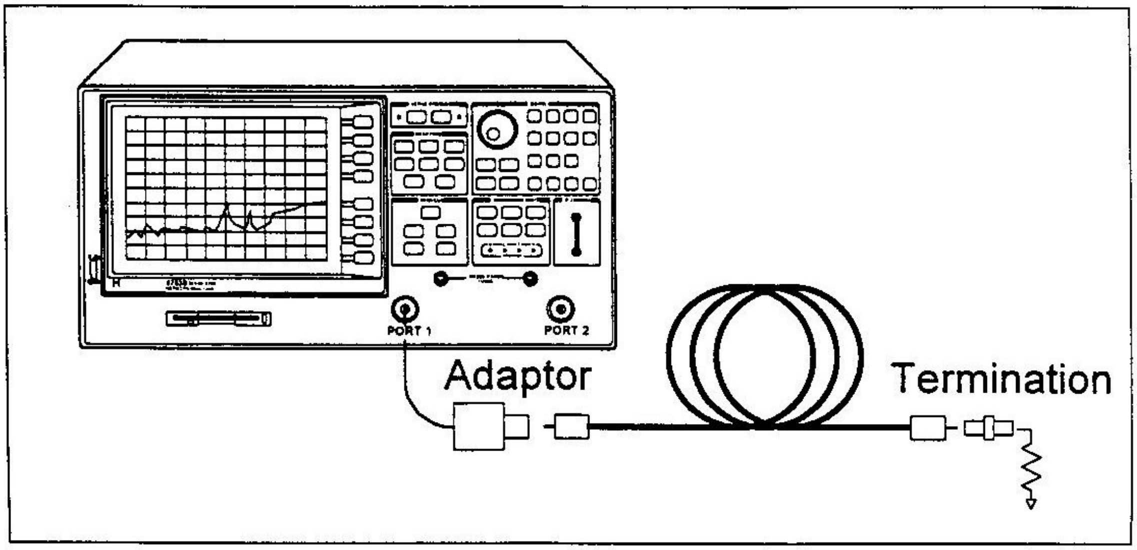


Figure 3: Instrument Setup for Fixed Bridge Method

## 7.0 MEASUREMENT METHODOLOGY – FIXED BRIDGE

7.1 Set up the network analyzer (NA) for a reflection measurement, as per the manufacturer's instructions. Set the start frequency at 5 MHz; set the stop frequency at 1002 MHz, choose the maximum number of points (e.g., 1601). Structural return loss effects can be very narrow in frequency span, as they are caused by the cumulative effects of small reflections along the entire length of the cable. For this reason, the frequency spacing of the measurement points is related to the length of the cable.

For the worse case, reflection from the far end of the cable may combine with near end reflections at a frequency spacing that represents one-half wavelength of the cable. For very long cables, such as 800 meters (about 2600 feet), the frequency spacing may be as narrow as 150 kHz. The narrowest frequency spacing necessary, $f_{spacing}$, is calculated by the formula in Section 4.2. Higher loss cables may not require the narrowest frequency resolution. The frequency resolution must be sufficient to capture any SRL peaks.

It may not be possible to take a single sweep of the network analyzer with sufficient resolution to see the SRL peaks. The resolution of the measurement can be increased by making several full band sweeps with slightly offset start frequencies, changing the start and stop frequency to obtain the required resolution each sweep, until the entire range is covered (in this example, 995 MHz divided by 1601 points yields about 600 kHz per point, thus four sweeps starting at 5.00 MHz, 5.15 MHz, 5.30 MHz and 5.45 MHz would be needed to ensure proper coverage). As an alternate method the band can be broken into 4 segments 5-250 MHz, 251-500 MHz, 501-750 MHz and 751-1002 MHz.

For some analyzers, it may be necessary to slow the sweep time to ensure good measurements, especially on long cables. Consult manufacturer's information for recommended sweep times.

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

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

7.4 Using a computer, or built in analyzer function, re-normalize the return loss to the average impedance value of the cable, as measured in ANSI/SCTE 66 2003. The re-normalization may be done as shown in the next four steps.

7.4.1 Step 1: Calculate the cable impedance, as a function of frequency using:

$$Z_{in}(\omega) = Z_0 * \frac{1+\rho(\omega)}{1-\rho(\omega)}$$

where:

$\rho(\omega)$ = complex reflection coefficient from the analyzer measured at each frequency,
$Z_0$ = 75Ω
$Z_{in}(\omega)$= Impedance of the cable resulting from $\rho(\omega)$

7.4.2 Step 2: Calculate the average impedance, $Z_{cable}$, of the cable over the frequency range using:

$$Z_{cable} = \left| \frac{\sum Z_{in}(\omega)}{N} \right|$$

where:

N – Number of data points ($\rho(\omega)$) measured

The cable impedance is the average of the measured impedance over a frequency range, typically 5 MHz - 210 MHz. For more information, see SCTE 66 2003 cable impedance test procedure.

7.4.3 Step 3: Calculate the structural reflection coefficient, $\rho_{SRC}(\omega)$ using the following equation:

$$\rho_{SRC}(\omega) = \frac{Z_{in}(\omega) - Z_{cable}}{Z_{in}(\omega) + Z_{cable}}$$

7.4.4 Step 4: Calculate the SRL (in dB) of the cable using:

$$SRL = 20 * \log[\rho_{SRC}(\omega)]$$

7.5 A sample display is shown in Figure 4. Notice that the trace may rise at higher frequencies. This is often caused by connections used to make the transition from the Network Analyzer to the cable. The best possible connection is necessary for good results. Connector compensation techniques may be used to reduce connector effects. These require adjustment similar to the capacitance adjustment in the variable bridge method. Time domain gating (such as found on many performance Vector Network Analyzers) can also remove connector effects, but care must be taken not to exceed the many constraints of the time domain transforms; consult with manufacturers' instructions.

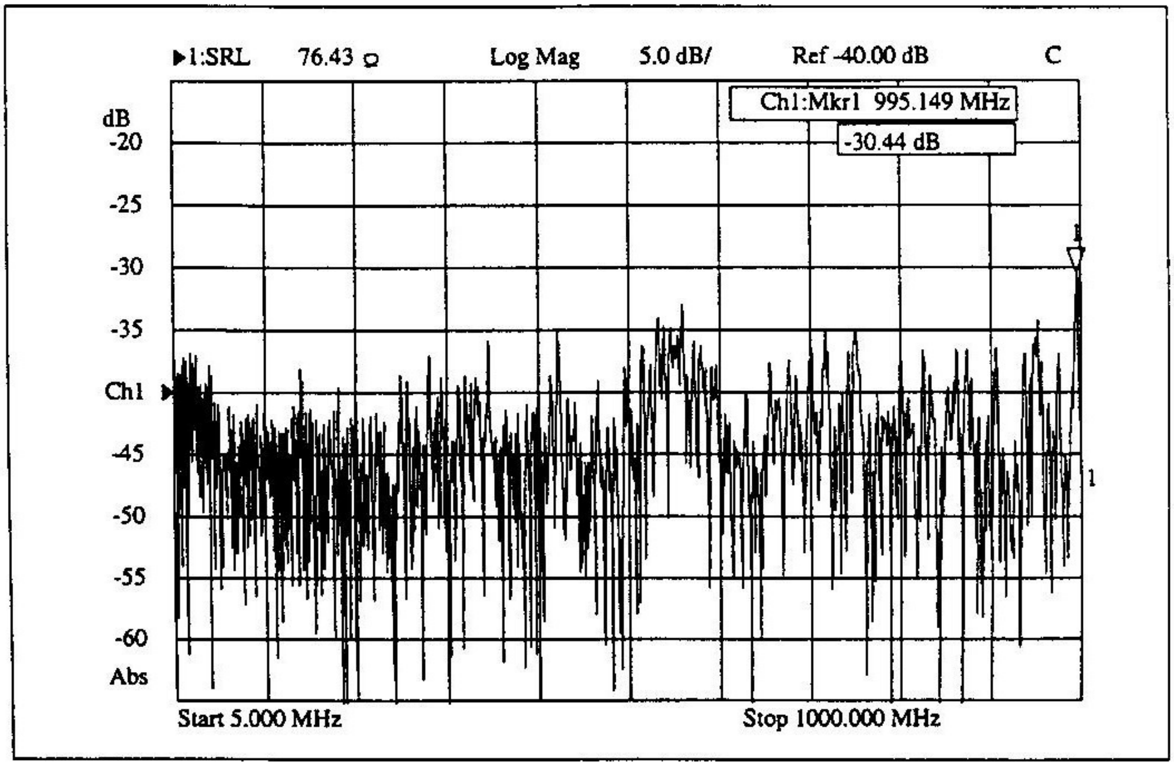


Figure 4: Typical Display of Structural Return Loss, Fixed Bridge Method

## 8.0 INSPECTION

Figure 4 shows the result of a measurement of SRL. This measurement must be repeated for each end of the cable. Record the maximum value for SRL for the top and bottom end of the cable.

## 9.0 REPORT

A typical report form might look like this:

TESTER______________________________ DATE________________________

CABLE SRL (TOP END)_______________FREQUENCY_______________

CABLE SRL (BOTTOM END)__________ FREQUENCY________________

## 10.0 ERROR ANALYSIS

10.1 A major source of error in SRL 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 SRL measurement is shown below:

| | Directivity (dB) | Connector Return Loss (dB) | SRL Level (dB) | Maximum Positive Error (dB) |
|---|---|---|---|---|
| Variable Bridge | -45 | -40 | -20 | 1.1 |
| | | | -30 | 3.1 |
| Fixed Bridge | -45 | -40 | -20 | 1.1 |
| | | | -30 | 3.1 |

10.2 This error is calculated by converting the directivity, connector reflection, and SRL measurements to linear terms. These are added together, and the sum is converted back to dB to get the resulting worst case maximum value:

$$Error = 20 * \log(\rho_{SRL} + D + C) - SRL$$

where:

$D = 10^{(Directivity/20)}$

$C = 10^{(Connector\ Return\ Loss/20)}$

$\rho_{SRL} = 10^{(SRL/20)}$

The difference between this maximum value and the measured SRL level is the maximum positive error. These are only example values; consult with the equipment manufacturer to determine the actual error values.

10.3 For short lengths of cable, an additional term must be added to the above error equation. The value of this term is the return loss of the far end termination (in dB) plus twice the loss of the cable at the frequency of interest. This term is treated in the same way as the directivity and connector terms. This term is typically negligible for whole cable reels.