SCTE · ISBE
STANDARDS

Interface Practices Subcommittee

AMERICAN NATIONAL STANDARD

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Test Method for Coaxial Cable Structural Return Loss

NOTICE

Table of Contents

List of Figures

List of Tables

1. Scope

The purpose of this procedure is to provide instructions to measure cable structural return loss (SRL).

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.

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

- ANSI/SCTE 66 2008, Test Method for Coaxial Cable Impedance

3.2. Standards from Other Organizations

- No informative references are applicable.

3.3. Published Materials

- No informative references are applicable.

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

Abbreviation	**Term**
SRL	Structural Return Loss

5.2. Definitions

Term	**Definition**
Structural Return Loss	The return loss of the cable relative to its own impedance.
Return Loss	The ratio of incident power (or voltage) to reflected power (or voltage), expressed in dB.
Network Analyzer	An instrument used to measure the swept frequency response of a cable.

6. Test Samples

6.1. SRL

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.

6.2. Input Cables

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.

6.3. Testing

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.

7. Equipment

1. Network Analyzer with impedance (or built-in SRL) measuring capability, Agilent ENA Series, or equivalent, including fixed impedance (75 ohm) test bridge, if required.
2. Calibration Kit, such as Agilent 85036B, or equivalent.
3. Computer or built in analyzer functions, to process fixed impedance data.
4. Termination (75 ohm load) for far end cable termination. Note: the load in the calibration kit *may* be used.
5. 1 GHz, Precision test connectors (2 Needed, Test port to cable adaptor) for the size of cable under test.
6. Equipment setup is shown in Figure 1.

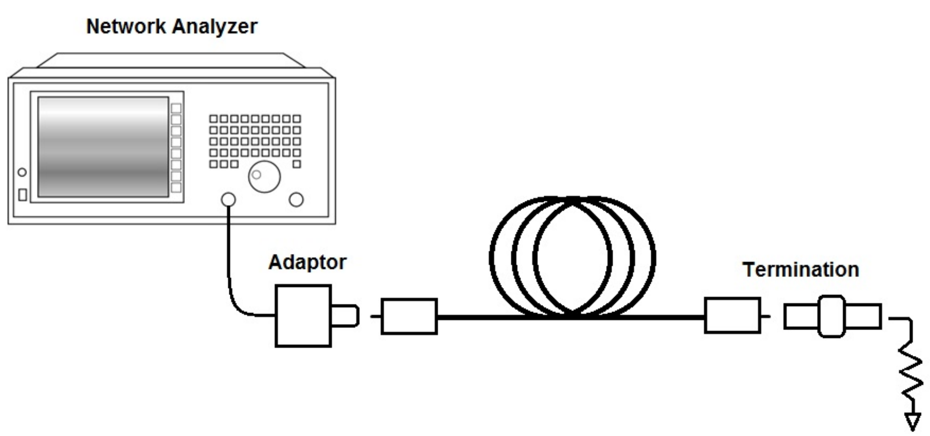

Figure 1 – Instrument Setup for Fixed Bridge Method

8. Measurement Methodology – Fixed Bridge

8.1. Set up Network Analyzer (NA)

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. Higher loss cables *may* not require the narrowest frequency resolution. The frequency resolution must be sufficient to capture any SRL peaks. 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* 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. For 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. Some newer network analyzers will be able to have a higher number of points (e.g., 6404) and can make the measurement in one sweep.

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.

8.2. Perform a Calibration

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.

8.3. Connect to Network Analyzer

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

8.4. Re-Normalize the Return Loss

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 2008.

8.5. Four Step Re-Normalization Process

The re-normalization *may* be done as shown in the next four steps.

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 $\rho(\omega)$

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 ANSI/SCTE 66 2016 cable impedance test procedure.

Step 3: Calculate the structural reflection coefficient, ρSRC(ω) using the following equation:

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

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

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

8.6. Sample Display

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 (capacitance adjustment) *may* be used to reduce connector effects. 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.

Notice that test equipment generally displays the decibel representation of the reflection coefficient, which is a negative number whenever the reflected power is less than the incident power ($P_{reflected} < P_{incident}$). Essentially, the test equipment is displaying the return "gain" rather than the return "loss." Thus, the results are often displayed as negative numbers, even though the "return loss" will always be positive when $P_{reflected} < P_{incident}$.

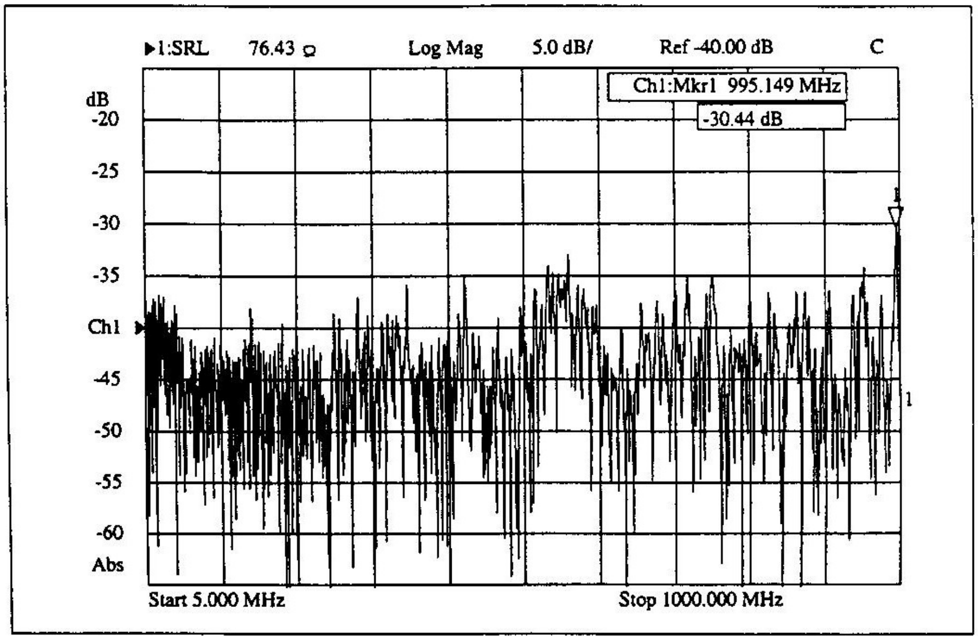

Figure 2 – Example Display of Structural Return Loss – Fixed Bridge Method

9. Inspection

Figure 2 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.

10. Sample Report

A typical report form might look like this:

TESTER ______________________________ **DATE** ________________________

CABLE SRL (TOP END) ________________ FREQUENCY ________________

CABLE SRL (BOTTOM END) __________ FREQUENCY _________________

11. Error Analysis

11.1. Major Source of Error

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 in Table 1.

Table 1 – Typical Errors on SRL Measurement

	Directivity (dB)	Connector Return Loss (dB)	SRL Level (dB)	Maximum Positive Error (dB)
Fixed Bridge	45	40	20	1.3
			30	3.5

11.2. Error Calculation

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:

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

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

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

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.

11.3. Add Cable

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.

