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Interface Practices Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 03 2022

Test Method for Coaxial Cable Structural Return Loss

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Document Types and Tags

Document Type: Specification

Document Tags:

☒ Test or Measurement	☐ Checklist	☐ Facility
☐ Architecture or Framework	☐ Metric	☐ Access Network
☐ Procedure, Process or Method	☐ Cloud	☐ Customer Premises

Document Release History

Release	Date
SCTE 03 2003	*10/24/2003*
SCTE 03 2008	*2/29/2008*
SCTE 03 2016	*10/17/2016*

Note: Standards that are released multiple times in the same year use: a, b, c, etc. to indicate normative balloted updates and/or r1, r2, r3, etc. to indicate editorial changes to a released document after the year.

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1. Introduction

1.1. Executive Summary

The purpose of this document is to provide instructions to measure the structural return loss characteristics of a coaxial cable from 5 MHz to 3000 MHz.

1.2. Scope

The purpose of this procedure is to provide instructions to measure coaxial 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.

1.3. Benefits

Passive devices which have a poor structural return loss and/or voltage standing wave ration (VSWR) result in loss of signal power or degradation of signal information Return loss is a way to characterize impedance mismatches. There are two major causes of return loss degradation in a network: discontinuities and impedance mismatches. Discontinuities occur at connections where cable is terminated to plugs or jacks and within the plug/jack connection itself. A discontinuity can also occur if a cable is bent too much, kinked or otherwise damaged. Components need to have acceptable return loss in order to assure proper network operation.

1.4. Intended Audience

The intended audience for this document is for development/design engineers, lab technicians, technical operations, and installers.

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

[SCTE 15] ANSI/SCTE 15 2022 Specification for Trunk, Feeder and Distribution Cables

[SCTE 74] ANSI/SCTE 74 2011 Specification for Braided 75ΩFlexible RF Coaxial Drop Cable

[SCTE 177] ANSI/SCTE 177 2018 Specification for Braided 75Ω, Mini Series Quad Shield Coaxial Cable for CMTS and SDI cables

[SCTE 71] ANSI/SCTE 71 2018 Specification for Series 15, Braided, 75 Ω, Coaxial, Multi-Purpose Cable

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

[SCTE 66] ANSI/SCTE 66 2022, Test Method for Coaxial Cable Impedance

3.2. Standards from Other Organizations

No informative references are applicable.

3.3. Published Materials

[Return Loss] Return Loss https://broadbandlibrary.com/return-loss/

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.
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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

NA	network analyzer
SRL	structural return loss

5.2. Definitions

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. Structural Return Loss (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[1], including fixed impedance (75 ohm) test bridge, if required.
2. Calibration Kit[2]
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. 3 GHz, Precision test connectors (2 Needed, Test port to cable adaptor) for the size of cable under test.

[1] Network analyzers that may be compliant are Agilent ENA Series or the equivalent. This identification of products or services is not an endorsement of those products or services or their suppliers.
[2] Calibration kit that may be compliant is Agilent 85036B or the equivalent. This identification of products or services is not an endorsement of those products or services or their suppliers.

6. Equipment setup is shown in Figure 1.

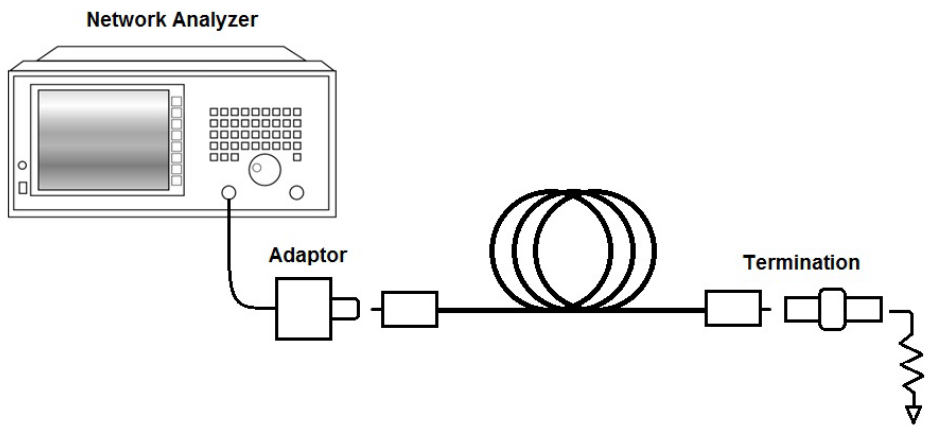

Figure 1 – Instrument Setup for Fixed Bridge Method

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 3000 MHz, choose the maximum number of points (e.g., 19,212). 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 worst 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 twelve 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 12segments 5-250 MHz, 251-500 MHz, 501-750 MHz and 751-1002 MHz. 1002-1250 MHz, 1250-1500 MHz, 1500-1750 MHz, 1750-2000 MHz, 2000-2250 MHz, 2250 – 2500 MHz, 2500 – 2750 MHz, 2750 – 3000 MHz may use 1601 points of each band segment. Some newer network analyzers have capability of higher number of points (e.g., 19,212) and can make the measurement in one sweep from 5- 3000 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.

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 [SCTE 66] .

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
$Z_0 = 75\Omega$
$Z_{in}(\omega)$ = 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, For more information, see [SCTE 66] 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 (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 $P_{reflected} < P_{incident}$.

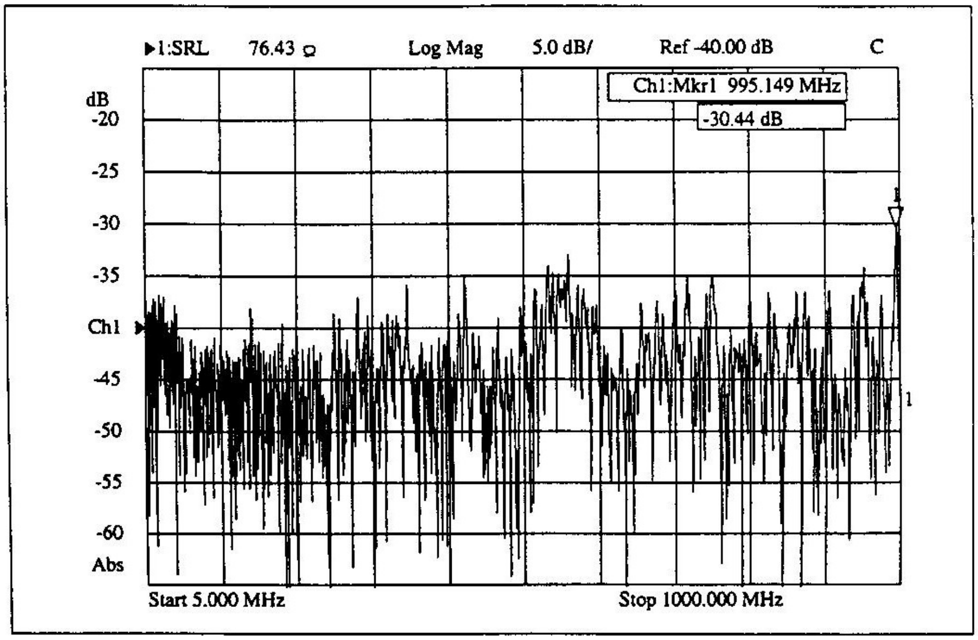

Figure 2 – Example Display of Structural Return Loss – Fixed Bridge Method

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.