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Interface Practices Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 145 2022

Test Method for Second Harmonic Distortion of Passives Using a Single Carrier

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1. Introduction

1.1. Executive Summary

This document details a simple circuit test setup which measures low level second harmonic distortions from various passive circuit elements using a single carrier generator.

1.2. Scope

The purpose of this document is to establish the standard methodology to measure second harmonic distortion in a Cable Telecommunication System passive at high signal level conditions (50 – 60 dBmV). Due to the difficulty in acquiring multi-carrier signal generators with both 55 dBmV output and intermod beats at –120 dBc, the test procedure will use a single carrier source test method.

The area of concern for most cable telecommunication systems are the high power signals sent in the return path. Therefore, this document limits the testing to signals in the return path range.

Second harmonic: A waveform generated at twice the frequency as the original. Such distortion can occur when one or more carriers pass through a nonlinear device.

Second Harmonic Distortion (SHD) is defined as the ratio of the second harmonic signal level to the fundamental carrier signal level at the Device Under Test (DUT) output.

Please note that this procedure is a very unique procedure for measuring second harmonic distortion of passives using a single carrier source test method and distinguishes itself from other similar procedures in the following ways:

- Designed for Passives
- Two port measurement
- Inject return frequency into input and measure 2nd harmonic at output
- Used to test for distortion caused by core saturation. Designed to be consistent with the mechanisms that have caused problems in outside plant -- large reverse carriers causing distortion in channels 2 through 5.

1.3. Benefits

This document describes a simple method for measuring the second order nonlinear properties of passive circuit elements. Because of tight channel spacing and demand for more channels increases, the effects of nonlinear distortion needs to be measured or otherwise the whole system performance may be susceptible to degradation.

1.4. Intended Audience

The intended audiences for this test procedure are manufacturers, evaluation laboratories, and end user technician and engineers with the proper equipment to perform this testing.

1.5. Areas for Further Investigation or to be Added in Future Versions

At this time, there are no areas for further investigation for this test procedure.

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 109 2019: Test Procedure for Common Path Distortion
- ANSI/SCTE 115 2019: Test Method for Reverse Path (Upstream) Intermodulation Using Two Carriers
- ANSI/SCTE 126 2019: Test Method for Distortion of 2-way Amplifiers Caused by Insufficient Isolation of Built in Diplex Filter
- ANSI/SCTE 144 2017: Test Procedure for Measuring Transmission and Reflection

NOTE: Each of the above procedures targets a different measurement for a unique purpose. They are independent, are specifically applicable to the device being measured, use the test equipment commonly available at the manufacturing sites used to make the device being tested, and directly measure the impairment that must be controlled. The key differences are whether they are designed for actives or passives and whether they are single port or two port measurements. Other differences are the types of distortion products being measured and the filters required to do so.

3.2. Standards from Other Organizations

- No informative references are applicable.

3.3. Published Materials

- No informative references are applicable.

4. Compliance Notation

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shall not	This phrase means that the item is an absolute prohibition of this document.
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5. Abbreviations

5.1. Abbreviations

dBmV	decibels relative to one millivolt
CW	continuous wave
DUT	device under test
SCTE	Society of Cable Telecommunications Engineers

6. Equipment

6.1. Carrier Generator

The device is used to generate a continuous wave (CW) carrier in the range of the upstream of interest up to a 64.5 dBmV signal level.

6.2. Spectrum Analyzer

The device[1] needs to be able to measure twice the return band frequency and have a 75 ohm impedance.

[1] "Devices that may be compliant include Keysight E4411B, Tektronix U3641/N, or the equivalent. This identification of products or services is not an endorsement of those products or services or their suppliers."

6.3. Diplexers

Diplexer (D1)

- Separates the carrier frequency from the second harmonic frequency. The diplexer low pass filter passes the carrier frequency under test.
- The upper band edge of the diplexer low pass filter is to be above the carrier frequency and below the carrier second harmonic frequency.
- The diplexer low pass filter insertion loss at the second harmonic frequency is to be large enough so that when the filter is connected to the generator, the second harmonic signal level is at least 120 dB lower than the carrier.

Band Pass Filter (B1)

- This design is used as alternative design as seen in Figure 1b. It passes the carrier frequency under test while it attenuates the second harmonic signal level to 120 dB below the carrier.

Diplexer (D2)

- The diplexer high pass filter passes the carrier second harmonic.
- The lower band edge of the diplexer high pass filter is to be above the carrier frequency and below the carrier second harmonic frequency.
- The diplexer high pass filter reduces the carrier signal by at least 30 dB. (The filter is used to prevent the carrier from over driving the spectrum analyzer and creating second harmonics in the analyzer.)

Alternatively, if the user does not have all the required diplex filters for the test, then a band pass filter with the characteristics described for the low pass filter in Diplexer (D1) can be used in instead of Diplexer (D1). However, Diplexer (D2) still needs to be a diplex filter in order to properly terminate the DUT.

6.4. 75 Ohm Terminators

Used to dissipate unwanted signals.

6.5. Attenuators

Attenuator A1

- Used to reduce signal strength into the spectrum analyzer

Attenuator A2

- Approximate the insertion loss of the device under test

7. Set-Up

7.1. Follow all calibration requirements recommended by the manufacturers for the carrier generator, and spectrum analyzer.

7.2. The diplexers in this document will be referred to as diplexer (D1) and diplexer (D2) as shown in Figure 1. In the alternate setup, the band pass filter will be referred to as B1 as shown in Figure 2.

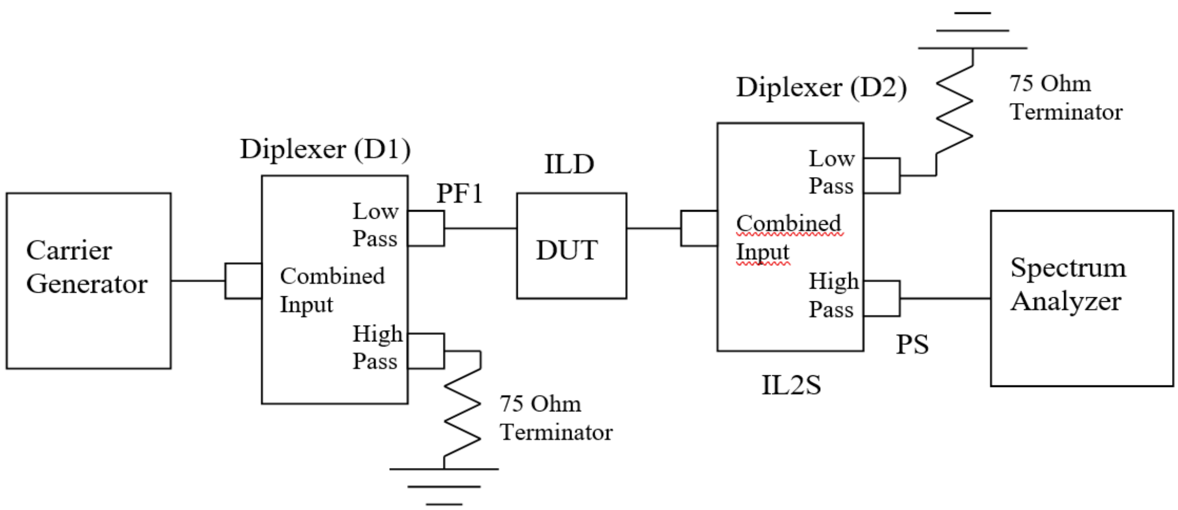

Figure 1 - Second Harmonic Distortion Test Set-Up

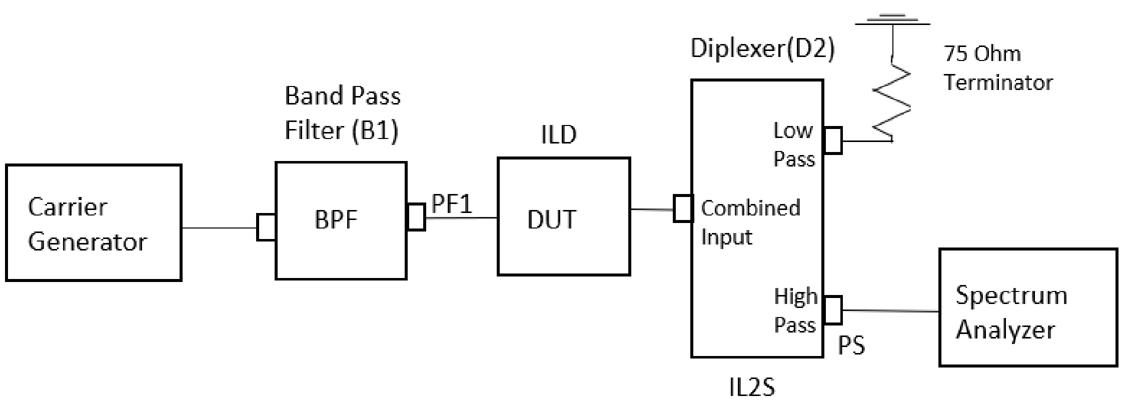

Figure 2 – Alternative Second Harmonic Distortion Test Set-Up

7.3. Measure and record the insertion loss for the following devices:

Device under test (DUT)

- Measure the insertion loss at the carrier frequency of interest and at the second harmonic frequency.
- Record the insertion loss at the frequency of interest as ILD

- Record the insertion loss at the second harmonic frequency as ILDS.

Diplexer (D2)

- Measure the insertion loss at twice the carrier frequency of interest from the combined input to the high pass output. During the insertion loss test a 75 ohm terminator should be connected to the diplexer (D2) low pass output port.
- Record the Diplexer (D2) insertion loss value as IL2S.

Attenuator (A1)

- Measure the insertion loss at the carrier frequency of interest
- Record the Attenuator (A1) insertion loss value as ILA1.

Attenuator (A2)

- Measure the insertion loss at the carrier frequency of interest and at the second harmonic frequency.
- Record the insertion loss at the frequency of interest as ILA2
- Record the insertion loss at the second harmonic frequency as ILA2S
- Confirm the insertion loss of attenuator (A2) at the carrier and second harmonic frequencies is similar to the DUT insertion loss to within 0.5 dB.

The insertion loss for the above items can be measured using either SCTE 144 or a signal generator and spectrum analyzer. Loss shall be recorded as a positive value.

8. Procedure

8.1. Connect the carrier generator output to the diplexer (D1) combined input.

8.2. Connect the diplexer (D1) high pass output to a 75 ohm terminator.

8.3. Set the spectrum analyzer settings as follows.

Center Frequency	**The carrier frequency under test**
Span	3 MHz
Detector	Peak
Resolution Bandwidth	30 kHz.
Video Bandwidth	30 Hz.

8.4. Place attenuator (A1) on the diplexer (D1) low pass (or low pass can be replaced by bandpass (B1)) output. (The attenuator must be large enough to prevent the carrier signal from over driving the spectrum analyzer.)

8.5. Attach the spectrum analyzer to the other end of the attenuator. See Figure 3.

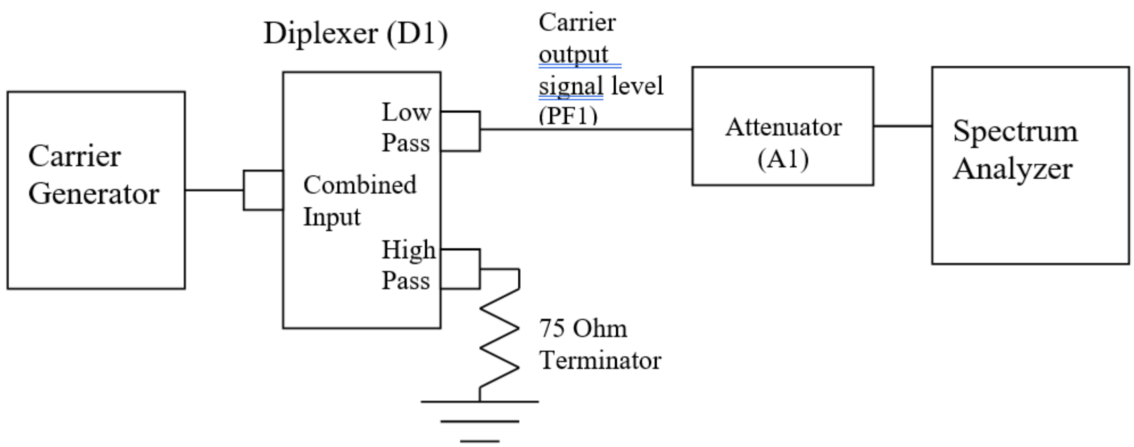

Figure 3 - Test Set-Up to Set and Verify Carrier Signal Level

8.6. Set the carrier generator to the return band frequency of interest and confirm the signal frequency is correct on the spectrum analyzer.

Record the carrier frequency in MHz.

8.7. PF1 is the signal level of the carrier coming from the diplexer (D1) low pass filter output. PA is the signal level of the carrier output to the spectrum analyzer

Using PF1= PA + ILA1, set the carrier generator for the specified signal level for the signal PF1.

Record PF1 in dBmV

8.8. Disconnect the spectrum analyzer and attenuator from the diplexer (D1).

8.9. Connect the diplexer (D2) combined input to the diplexer (D1) low pass output through a attenuator (A2).

8.10. Connect a 75 ohm terminator to the diplexer (D2) low pass output port.

8.11. Set the spectrum analyzer center frequency to twice the carrier frequency.

8.12. Connect the spectrum analyzer to the diplexer (D2) high pass output and measure the carrier second harmonic output signal level (PS2) in dBmV. See Figure 4.

The actual carrier second harmonic output signal level of interest (PS1) is the second harmonic output from the diplexer (D1) low pass output port.

Using PS1= PF1- (PS2+ ILA2+ IL2S), calculate the second harmonic distortion in the test setup relative to the fundamental carrier. Note that this is a positive number, expressed in -dBc. Refer to the Definitions and Acronyms section of ANSI/SCTE 96 2003 for a discussion of these units.

Verify that the second harmonic distortion, PS1 (expressed as a positive number), is at least 10 dB more than the second order distortion specification for which the user is testing.

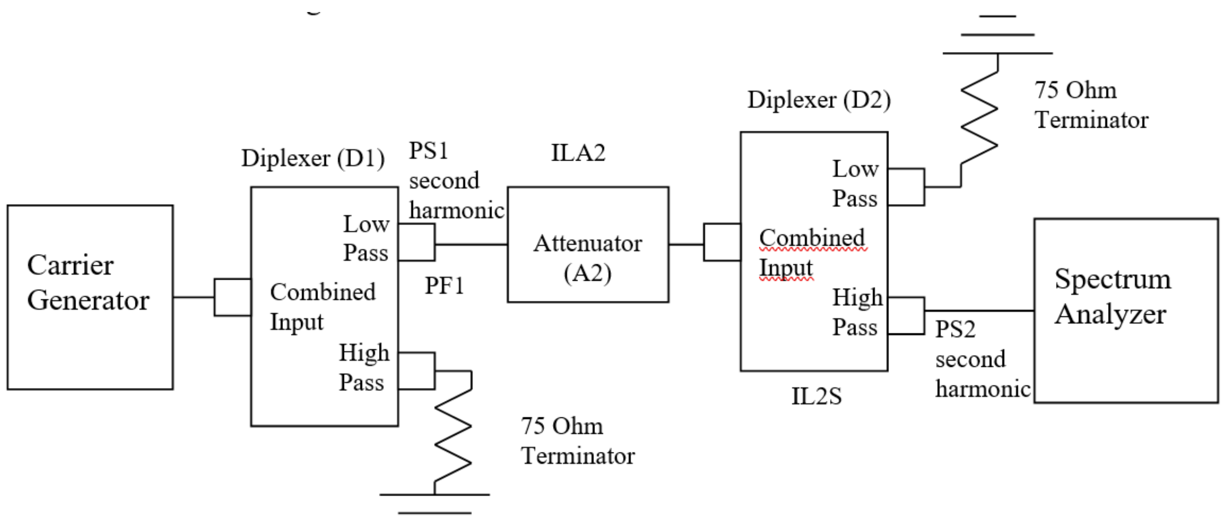

Figure 4 - Test Set-Up to Measure Level of Second Harmonic Distortion Present Without the Device Under Test (DUT).

8.13. In Figure 4, replace attenuator (A2) with the device under test (DUT) (between diplexer (D1) and diplexer (D2)) as shown in Figure 1a.

8.14. Measure the carrier second harmonic signal level out of diplexer (D2) and record the signal level as PS.

8.15. Second harmonic distortion (SHD) for the DUT is SHD= PF1- (ILD+PS2+ IL2S).   Calculate and record the DUT second harmonic distortion test results. Note that this is a positive number, expressed in -dBc. Refer to the Definitions and Acronyms section of SCTE 96 for a discussion of these units.

9. Passive Designs That Incorporate Ferrites

For passive designs that include the use of ferrites, a major cause of second harmonic distortion is due to the nonlinearity of the ferrites. This nonlinearity is caused either by magnetizing of the ferrites, or poor ability of the ferrites to handle high-level signals. In order to get the worst-case test results, the passive should be exposed to magnetization currents of the specified surge for the product, such as described in the American National Standard procedure ANSI/SCTE 81 2012. (Using ANSI/SCTE 81 2012, each port would be exposed to 4 alternate +/- 1kV 0.5 µs-100 kHz surges.) The test procedure for the passive is then exactly the same as described in section 8.0, Procedure. Unused ports of multiple output passives must be properly terminated during testing.

