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Interface Practices Subcommittee

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**Test Method for Distortion of 2-way Amplifiers Caused
by Insufficient Isolation of Built in Diplex Filter**

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NO TABLE OF FIGURES ENTRIES FOUND.

1. Introduction

1.1. Executive Summary

This test procedure applies as a method to measure distortion created in a 2-way amplifier caused by an upstream signal.

1.2. Scope

The purpose of this document is to establish the standard methodology to measure an amplifier's distortion caused by an upstream signal leaking through the diplex filter that is built inside of the amplifier of a Cable Telecommunications System (see Figure 1).

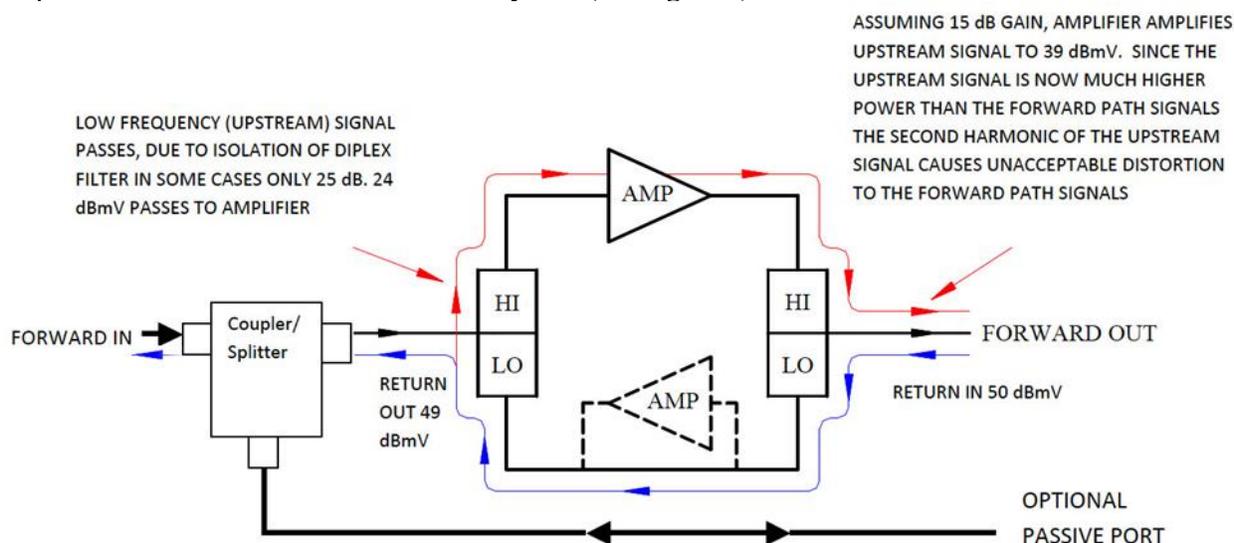


Figure 1 – Amplifier with diplex filters

In a two way Cable Telecommunication Systems, amplifiers are commonly used to amplify downstream signals. These amplifiers are designed as shown in Figure 1. They consist of two diplex filters with amplifier inserted in the high pass path, also known as the forward or downstream path. The low pass path (return or upstream) in most cases needs no amplification, and is used for upstream communication of modems, telephony, etc. In some cases, a return amplifier is used. Upstream communication uses high-level signals, reaching in some cases up to 55 dBmV. Serious problems with second harmonics can arise due to insufficient diplex filter isolation of amplifiers, as it can be seen in Figure 1. Diplex filter isolation is usually the worst in the last 2 MHz. of the high frequency end of the upstream pass band. If high-level signals are applied at these frequencies, second harmonics can be created causing distortion on the corresponding channel. If the amplifier also has a built in return amplifier, distortion problems can be even more serious, since the harmonic levels are higher by the gain of the return amplifier.

Measurement of this distortion is most practical by measuring the 2nd harmonic of a CW carrier, since signal generators and spectrum analyzers are commonly used in many other test procedures.

Please note that this procedure is a very unique procedure for testing 2-way amplifiers and distinguishes itself from other similar procedures in the following ways:

It is designed for two-way active measurement, is single port, measures energy that leaks around the loop, injects reverse frequency into reverse input (forward output), measures 2nd harmonic distortion at the same port, and is designed to measure leakage due to insufficient isolation of built-in diplex filter.

The procedure requires measurements at multiple frequencies because this is a very frequency sensitive measurement.

For similar procedures, please reference the following:

- ANSI/SCTE 115 2011: Test Method for Reverse Path (Upstream) Intermodulation Using Two Carriers
- ANSI/SCTE 145 2015: Test Method for Second Harmonic Distortion of Passives Using a Single Carrier
- ANSI/SCTE 109 2016: Test Method for Common Path Distortion

Each of these 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.

1.3. Benefits

This test procedure provides a common method that can be used by both manufacturers and end users to test whether a 2-way amplifier meets second order distortion specifications when an upstream signal is input to the amplifier. Without such a common test procedure the testing used to prove amplifier distortion performance can vary and lead to uncertainty as to whether the amplifier distortion specifications are being met.

1.4. Intended Audience

The intended audience for this test procedure are manufacturers, evaluation laboratories, and end user technicians 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

- ANSI/SCTE 81 2012: Surge Withstand Test Procedure
- ANSI/SCTE 96 2013: Cable Telecommunications Testing Guidelines

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 115 2011: Test Method for Reverse Path (Upstream) Intermodulation Using Two Carriers
- ANSI/SCTE 145 2015: Test Method for Second Harmonic Distortion of Passives Using a Single Carrier
- ANSI/SCTE 109 2016: Test Method for Common Path Distortion

3.2. Standards from Other Organizations

- No informative references are applicable.

3.3. Published Materials

- No informative references are applicable.

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| | |
|-------------------|---|
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| <i>forbidden</i> | This word means the value specified shall never be used. |
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| <i>deprecated</i> | 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

| | |
|----------|---|
| AMP | amplifier |
| ANSI | American National Standards Institute |
| ATT | attenuator |
| CW | continuous wave |
| dB | decibel |
| dBc | decibel carrier |
| dBmV | decibel millivolt |
| div | division |
| DUT | device under test |
| Hz | hertz |
| kHz | kilohertz |
| log | logarithm |
| MHz | megahertz |
| ISBE | International Society of Broadband Experts |
| SCTE | Society of Cable Telecommunications Engineers |
| Ω | ohm |

5.2. Definitions

| | |
|------------|--|
| Distortion | Undesired change in the electrical signal |
| Downstream | Information flowing from the hub to the user |

| | |
|----------|--|
| Forward | Information flowing from the hub to the user |
| Return | Information flowing from the user to the hub |
| Upstream | Information flowing from the user to the hub |

6. Equipment

Some test equipment is listed only as optional and is used only if necessary as is explained in later sections.

6.1. Spectrum Analyzer

Agilent 8591C with 75 Ω input option and built in preamplifier, or equivalent. If a spectrum analyzer without a 75 Ω input option and preamplifier is used, an external preamplifier may be required.

6.2. Signal Generator

Variable frequency signal generator capable of delivering up to 60 dBmV (2nd harmonic distortion at least -40 dBc), at frequencies in the last 2 MHz. at the high frequency end of the upstream pass band, Agilent 8648C, or equivalent.

6.3. 50 to 75 Ω matching circuitry, either transformer or Minimum Loss Pad (MLP)

6.4. Attenuator

Any 6 dB, 75 Ω attenuator can be used, such as Holland Electronics FAM-6HR or equivalent. The value can be lowered if the level at point "A" (Figure 2) cannot reach the required level.

6.5. Diplex Filter

Any diplex filter with the following specifications can be used:

High Pass Side: Pass band includes second harmonic of upstream frequency of interest.

Low Pass Side: Pass band includes the upstream frequency of interest

Return Loss > 16 dB

Isolation > 45 dB

Pass band IL < 1.5 dB

6.6. Low Pass Filter- Optional

This filter is used if the second harmonic distortion of the signal generator is too high and appears on spectrum analyzer when testing of the setup, described later in this document, is performed. The intention is to remove the second harmonic of the carrier; so any appropriate low pass filter with a pass band that includes signal generator upstream frequency output, and a stop band that covers the signal generator second harmonic frequency with an attenuation of at least 30 dB can be used.

6.7. Band Pass or High Pass Filter- Optional

This filter is used if the duplex filter used does not have enough isolation to attenuate the main CW carrier in order not to overload the spectrum analyzer. Any high pass filter with a pass band that includes the CW carrier second harmonic frequency and a stop band that covers the CW carrier frequency with attenuation of at least 30 dB can be used.

6.8. Amplifier - Optional

Required if the level out of the signal generator is not sufficient to reach the required level at the DUT.

For multiple output amplifier testing, the surge generator described in ANSI/SCTE 81 2012 is required.

7. Set-Up

- 7.1. Follow all manufacturer recommended calibration requirements for the spectrum analyzer and signal generator.
- 7.2. Connect all test equipment as shown in Figure 2, except for the connection between point “A” and the DUT.

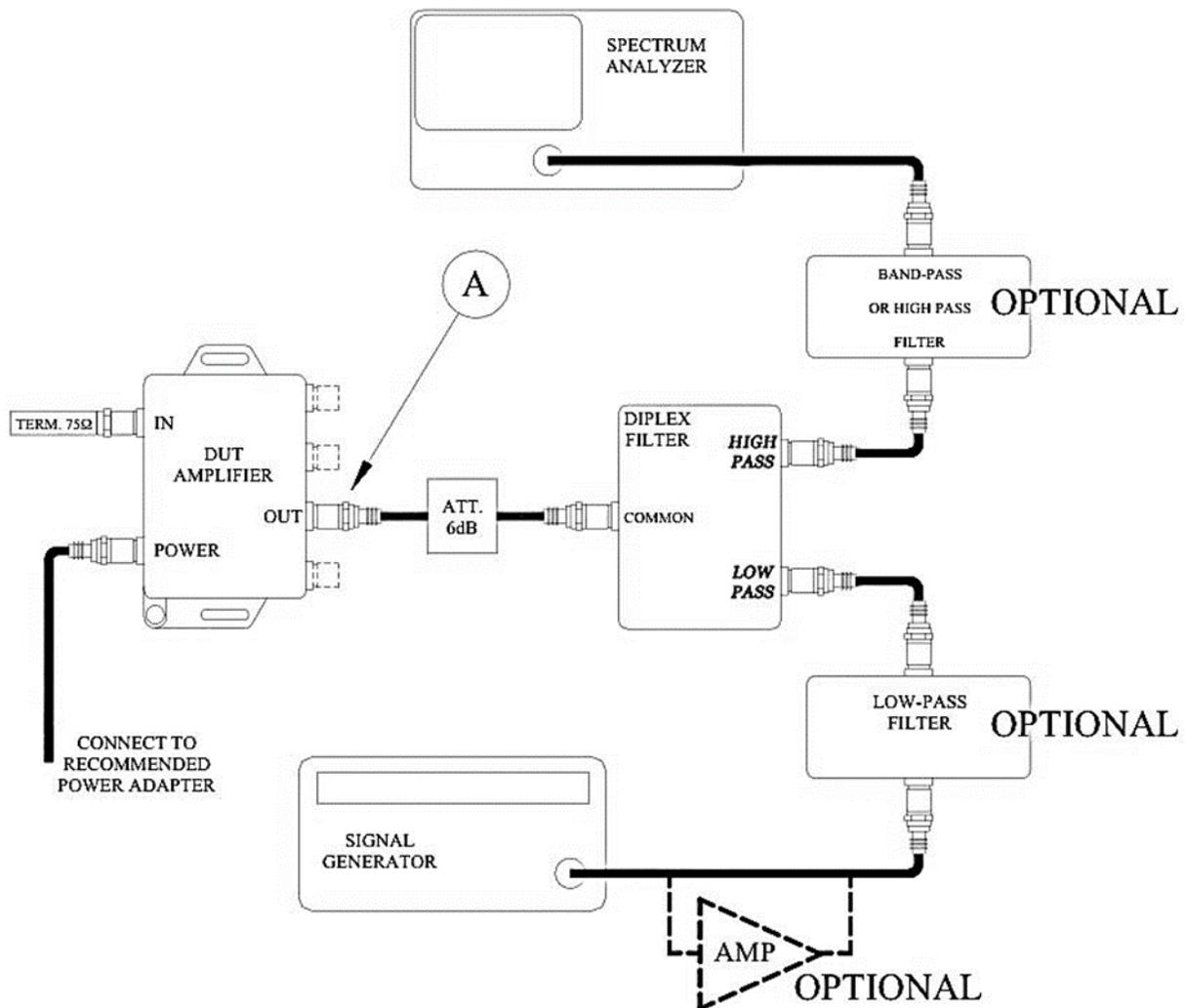


Figure 2 – Setup for measuring distortion

7.3. 2nd Harmonic Distortion Verification

7.3.1. Use setup described in Figure 2

7.3.1.1. Disconnect Spectrum Analyzer from the high-pass port of the duplex filter (or from optional band-pass filter) and terminate the filter with a $75\ \Omega$ termination. Disconnect the cable from the DUT at point “A” and connect to the spectrum analyzer.

7.3.1.2. Adjust the signal generator to the required test frequency.

7.3.1.3. Adjust the signal generator power to get the specified Power Level “PL” at point “A”. If the signal generator does not have enough output power, the optional amplifier must be used.

Caution: Be sure to use the appropriate spectrum analyzer attenuator setting to avoid damaging the spectrum analyzer

7.3.2. Adjust spectrum analyzer as follows:

Center Frequency: 2x the test frequency of signal generator

Span: 20 kHz

RBW: 1 kHz

VBW: 30 Hz

Attenuation: 0 dB

Internal Amplifier: ON

Scale 10 dB/div

Reference Level 0 dBmV (provides ≥ 80 dB display range)

7.3.3. Connect a $75\ \Omega$ terminator to the 6dB attenuator at point “A”. There should be no second harmonic distortion visible on spectrum analyzer. If the second harmonic distortion is visible, optional filters depicted in Figure 2 should be installed.

7.4. Determination of Correction Setup Constant (CSC)

In order to get accurate readings during measurements, the insertion loss of the test setup from point “A” to the spectrum analyzer must be known and if an internal amplifier is used, the gain of the internal amplifier must be known. Inserting a known signal at the point “A” and reading the level of this signal on spectrum analyzer can determine this. The following procedure can be used:

- 7.4.1. Connect the signal generator directly to the spectrum analyzer; adjust signal generator frequency to the CW carrier second harmonic frequency of interest.
- 7.4.2. Adjust spectrum analyzer as described in 7.3.2, except with a center frequency set to the CW carrier frequency second harmonic of interest and Internal Amplifier “OFF”.
- 7.4.3. Adjust the signal generator level to get a reading of –30 dBmV on spectrum analyzer.
- 7.4.4. Apply this level from the signal generator to the 6dB attenuator at point “A” of the test setup in Figure 2. With the spectrum analyzer adjusted exactly as described in 7.3.2, but with the center frequency set to the CW carrier frequency second harmonic of interest, read the measured power value. If the internal amplifier is being used, make sure it is on.
- 7.4.5. The difference between the value read and –30 dBmV is the Correction Setup Constant “CSC”, and must be used in calculations of second harmonic distortion.

$$\text{CSC [dB]} = -30 \text{ dBmV} - \text{Value read [dBmV]}$$

- 7.4.6. Determination of the test setup correction constant can be done at different frequencies if there is a suspicion that the response of duplex filter and/ or optional filters vary greatly between the CW carrier frequency and the CW carrier frequency second harmonic.

8. Test Procedure

- 8.1. Connect equipment as specified in Figure 2. The signal Power Level “PL” must be adjusted as specified in paragraph 7.3.1.
- 8.2. Adjust the signal generator to the test frequency and the spectrum analyzer to the same setup as described in 7.3.2
- 8.3. Use the “Peak Search” function of the analyzer to read the Second Harmonic Level “SHL”. The “SHL” must be corrected using the Correction Setup Constant determined in 7.4.5

$$\text{CSHL [dBmV]} = \text{SHL [dBmV]} + \text{CSC [dB]}$$

In case the CSHL level is 10 dB or less above the noise floor of the spectrum analyzer, do the following:

Record the Noise Floor Level as the level of the noise floor in a flat portion of the spectrum displayed on the SA.

Compute Noise Floor Delta = CSHL Level – Noise Floor Level. If the Noise Floor Delta is less than 2 dB, it is recommended that the optional post-amplifier be added to the system. The measurement should then be made again. If, however, the Noise Floor Delta remains less than 2 dB, refer to ANSI/SCTE 96

2013, Section 8.2 for the proper Noise-Near-Noise Correction. If the Noise Floor Delta is greater than 2 dB, the following Noise Floor Correction Factor should be calculated:

$$\text{Noise Floor Correction Factor: } 10 * \left| \log \left(1 - 10^{-\left(\frac{\text{Noise Floor Delta}}{10}\right)} \right) \right|$$

A table of values calculated from this equation is presented in ANSI/SCTE 96 2013, Section 8.2.

Compute Corrected CSHL as:

Noise-adjusted CHSL = CHSL + Noise Floor Correction Factor

- 8.4. For comparison reasons, it is important to also calculate the relative value of Second Order Distortion (SOD) with reference to input Power Level (PL) as follows:

$$\text{SOD [dBc]} = \text{PL [dBmV]} - \text{CSHL [dBmV]}$$

Use either CHSL or Noise-adjusted CHSL as appropriate as calculated in section 8.3

- 8.5. Suggested test frequencies, power levels, and recording tables are described in section 10, “RESULTS RECORDING, TEST FREQUENCIES AND LEVELS”.

9. Amplifiers With Integral Output Splitters Or A Passive Coupled Output Port

In addition to creating second harmonic distortion as described in section 1.0, multiple output amplifiers that utilize splitters at the output of the final stage of amplification or a coupled passive port that utilizes a coupler or splitter at the input to the amplifier create second harmonic distortion also due to nonlinearity of the ferrites used in the coupler or splitter. This nonlinearity is caused either by magnetizing of the ferrites, or poor ability of the ferrites to handle high-level signals. The second harmonic distortion determined in this test is either caused by insufficient isolation of the diplex filter, or nonlinearity of ferrites, or combination of both. For these reasons, in order to get the worst-case test results; the multiple output amplifiers must be exposed to magnetization currents of the specified surge for the product, as described in American National Standard procedure ANSI/SCTE 81 2012. There is no need to surge the amplifier with the full surge test as described in section 6.4 of ANSI/SCTE 81 2012, since this is not a surge withstand test, but a ferrite magnetization stimulation. Each output port must be exposed to 4 alternate $\pm 1\text{kV } 0.5 \mu\text{s}$ -100 kHz surges as defined in the standard mentioned above. The test procedure is then exactly the same as described in section 8F.0, Test Procedure. Unused ports of the multiple output amplifier must be properly terminated during testing.

10. Results Recording, Test Frequencies And Levels

The table below shows a suggested test result recording format when measuring an amplifier's distortion caused by diplex filter isolation. In this table we refer to HF as the high frequency end of the upstream pass band.*

| Test Frequency f [MHz] | Power Level adjusted at "A" PL [dBmV] | 2nd Harmonic Frequency f [MHz] | Correction Setup Constant CSC [dB] | Second Harmonic Level SHL [dBmV] | Corrected Second Harmonic Level CSHL [dBmV] | Second Order Distortion SOD [dBc] |
|------------------------|---------------------------------------|--------------------------------|------------------------------------|----------------------------------|---|-----------------------------------|
| HF-1.5 | 50 | | | | | |
| HF-1.0 | 50 | | | | | |
| HF-0.5 | 50 | | | | | |
| HF | 50 | | | | | |
| HF-1.5 | 55 | | | | | |
| HF-1.0 | 55 | | | | | |
| HF-0.5 | 55 | | | | | |
| HF | 55 | | | | | |

*Required power levels and test frequencies should be obtained from the specifications