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AM CROSS MODULATION MEASUREMENTS

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140 Philips Road

Exton, PA 19341

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1.0 PREFACE

This document describes a test procedure for the laboratory and production measurement of Amplitude Modulation Cross Modulation (or AM-XMOD) that is present in Broadband Systems which carry Frequency Division Multiplexed (FDM), amplitude modulated, analog video channels. In general there are two components to the cross modulation generated in such systems; namely, cross modulation of the direct Amplitude Modulation (AM-XMOD) type and cross modulation of the less obvious Phase Modulation (PM-XMOD) type. In the past, the PM-XMOD component was not directly considered, for many pertinent reasons. With the advent of larger cable telecommunications systems (e.g. more video channels with carrier placement at higher frequencies), and the implementation of different equipment and technology (such as fiber optics in the distribution path), it has become necessary that the PM-XMOD at least be described. The physical processes by which the two components of cross modulation are generated have some fundamental differences. However, the resultant video impairment to the viewer can be the same if the proper conditions exist. (That is, both of these components have been shown to cause similar visual disturbances in the desired picture when the proper conditions exist and hence are considered to be true impairments.) **The issue of how each component of cross modulation is detected at the subscriber's terminal (i.e. "set-top receiver") and the subsequent perceptibility levels that should be specified will NOT be addressed in this document.**

The procedure described in this document for measuring the 'AM-XMOD Distortion Ratio' uses an RF Receiver, to detect the modulation, and a Baseband Analyzer, to measure the detected modulation signal levels. The test method, as given, is meant to mitigate the effects that PM-XMOD has upon the accurate detection of AM-XMOD. A common alternative to this measurement technique is to measure the AM-XMOD using a specific instrument, namely the 'Spectrum Analyzer'. The Spectrum Analyzer has the capability to both detect and measure the magnitude of the modulation level (i.e. the levels of the sidebands) in the frequency domain. An AM-XMOD measurement that uses this "frequency domain" technique will be different from a measurement made using the technique described in this procedure, because the Spectrum Analyzer can not discriminate AM and PM sidebands. The type of detector used in the RF Receiver, as well as the method of detection used in the Baseband Analyzer to measure the sideband energy of the modulation, will be specified.

The detectors used in the RF Receiver and the Baseband Analyzer instruments are different than those used in a typical Spectrum Analyzer. Therefore, a Spectrum Analyzer, where used in this document, is understood to be a separate instrument from either an RF Receiver or a Baseband Analyzer. However, it is generally understood that a Spectrum Analyzer can be used as a receiver instrument, whereby either the IF output is taken and RF demodulation is accomplished externally by a separate detector, or the Spectrum Analyzer's (Linear) demodulator is used. In either approach, after demodulation, a Baseband Analyzer then detects the video modulation.

2.0 **SCOPE**

- 2.1 This document describes a test procedure for the laboratory and production measurement of Amplitude Modulation Cross Modulation (or AM-XMOD) that is present in Broadband Systems which carry Frequency Division Multiplexed (FDM), amplitude modulated, analog video channels.
- 2.2 A measurement procedure for AM-XMOD will be given.
- 2.3 The measurement procedure for PM-XMOD will NOT be given.
- 2.4 A more in-depth theoretical discussion of cross modulation, including a description of the physical generation and manifestations, is given in Appendix A. An outline of a derivation for an expression of PM-XMOD is given therein.
- 2.5 The baseband detection of the AM-XMOD component, and the differences between detection methods, is handled in Appendix B.
- 2.6 The PM-XMOD component's effect on the measurement of AM-XMOD, including the resulting errors in measurements of the magnitude of the detected amplitude modulation, is explained in Appendix B.

3.0 **DEFINITIONS**

- 3.1 Amplitude Modulation (AM) is defined as “a low frequency (i.e. baseband) signal, which is multiplied with a high frequency (i.e. carrier) sinusoidal signal, in order to modulate the peak amplitude levels of the carrier signal by 100% or less. For analog video Cable Telecommunications systems, the modulation characteristic is described as ‘downward only modulation’.” The signal has the form:

$$F_{AM}(t) = V_{pk} \mu m(t) \cos(\omega_c t + \theta)$$

Where:

V_{pk} $\equiv$ The peak amplitude of the carrier signal.

μ $\equiv$ The index of (amplitude) modulation: $0 \leq \mu \leq 1$

$m(t)$ $\equiv$ The baseband signal whose highest frequency component is ω_m ($\omega_m \ll \omega_c$): $1 \geq m(t) \geq 0$, for all t .

ω_c $\equiv$ The instantaneous radian frequency of the carrier signal, considered as constant.

θ $\equiv$ Arbitrary phase constant of the (sinusoidal) carrier signal.

- 3.2** Cross Modulation can be broadly defined as “a distortion, resulting from the non-linearity of a system, which causes a carrier in the system to be modulated by the various desired signals carried on the other channels in the same system.” This general definition will cover both components of Cross Modulation distortion, AM-XMOD and PM-XMOD.
- 3.3** The “Amplitude Modulation Component” of the cross modulation, or AM-XMOD, was traditionally defined in the same manner as the definition of cross modulation given above in Section 3.2. However, in this document, an additional clarification is made. “AM-XMOD is specifically defined as the ratio of the peak to peak amplitude modulation on the test carrier, caused by the modulating signals on the other carrier signals in the system, to the peak to peak amplitude modulation on a 100% modulated test carrier. It is a measure of the relative magnitude of the voltage of the undesired modulation, to that of the desired modulation, at the fundamental frequency of the modulating signal.”
- 3.4** The conditions for the test define the modulation type, as follows:
All test carriers are to be 100%, downward only, amplitude modulated by a synchronous square-wave signal (i.e. the same baseband signal synchronously modulates all carriers in the system), possessing a modulating frequency equal to the desired video format’s horizontal sync pulse, with a duty cycle of 50%. For the NTSC video signal format, this frequency is approximately 15.75 kHz. (Note: this will be the frequency of modulation used throughout this procedure.) However, for testing of fiber optic equipment, approximately 5% of the carrier signals may remain unmodulated in order to provide a minimum signal level within the active fiber optic components. The number, channel and frequency location of these unmodulated signals shall be included as part of the test data.
- 3.5** “Downward modulation” is understood to be amplitude modulation of a carrier from a reference carrier amplitude level such that the reference carrier amplitude level is never exceeded. (In fact, this is what is intended in the definition in section 3.1 above, as “ $1 \geq m(t) \geq 0$ ”.)
- 3.6** Refer to the Glossary and Definitions section of ANSI/SCTE 96 2007 for other definitions.

4.0 EQUIPMENT

- 4.1** The general equipment required for this test is shown in Figure 1a or 1b. ANSI/SCTE 96 2007 describes and specifies all of this equipment.
- 4.2** The multi-tone signal generator for this test must have the characteristics listed below. Refer to ANSI/SCTE 96 2007 for specifications of acceptable generators.
 - 4.2.1** The capability to produce signals on all nominal visual carrier frequencies for all of the channels in the frequency band to be tested.
 - 4.2.2** The capability to set power levels individually and to adjust the total spectrum of input signals to the proper input power level for the device to be tested.
 - 4.2.3** The capability of synchronously downward amplitude modulating all channels 100%, at a modulating frequency equal to the desired video format's horizontal sync pulse, with a duty cycle of 50%. (Note, for an NTSC video signal, this frequency is approximately 15.75 kHz.)
 - 4.2.4** The capability to turn the modulation off for individual channels.
 - 4.2.5** Spurious signals generated from within the signal source itself must be at least 10 dB below the distortion levels, to be measured. Note that, if the internal AM Cross Modulation generated by the signal source is produced in a manner similar to that produced by the "Device Under Test" (or DUT), then the levels of those distortion products must be at least 20 dB below the levels produced by the DUT to insure measurement certainty.
- 4.3** An RF Receiver is required for this measurement. Several different instruments may be used, but regardless of the specific form of the instrument the RF Receiver must have the characteristics listed below. Note: Most Spectrum Analyzers, with the appropriate Resolution Bandwidth Filter setting, can be used for this application. Refer to ANSI/SCTE 96 2007 for specifications of acceptable RF Receivers.
 - 4.3.1** The capability of tuning to the (video) carrier frequency of measurement.
 - 4.3.2** The capability of rejecting energy from image frequencies associated with the (internal) down-converting active devices of the instrument.

- 4.3.3 The capability of providing a “bandwidth selectable” Band Pass IF Filter (i.e. a ‘Resolution Bandwidth’ filter) at the input to the receiver’s RF detector. The filter is to provide selectivity to the modulated video carrier of interest and it must therefore provide adequate rejection of adjacent carrier signal energy. However, the filter must also have a bandwidth large enough to pass the modulation signal under test, so that the amplitude modulation sideband energy is properly passed through to the detector. (Namely, no significant energy of the AM sideband is to be rejected, and the conversion of phase modulation energy to AM energy, due to slope detection, is to be prevented.) Typically this is a RBW = 1 MHz.
- 4.3.4 The capability of detecting modulation via “Linear Amplitude”, or “Linear Envelope” detection, for the measurement of AM-XMOD. (Specifically, the detector chosen must be capable of providing an output voltage that is directly proportional to the magnitude of the envelope of the carrier signal.) Alternatively, a “Square Law”, or “True RMS” detector can be used. Note however, that a correction factor must then be applied, in accordance with the resulting difference in magnitude between the methods. This is a linear factor of “2”, which would result in an additional 6 dB level, assuming the units of display utilized by the Baseband Analyzer are given in ‘20*LOG(measured voltage)’.
- 4.3.5 The capability of providing an output voltage for the baseband signal, that is directly proportional to the magnitude of the detected signal.
- 4.4 A "Baseband Analyzer" is also required for this measurement. Several different instruments may be used, but regardless of the specific form of the instrument, the Baseband Analyzer must have the characteristics listed below. Refer to ANSI/SCTE 96 2007 for specifications of acceptable Baseband Analyzers.
 - 4.4.1 The capability to measure the signal level at a frequency of the modulation (which for NTSC video is 15.75 kHz).
 - 4.4.2 The capability of providing a peak voltage measurement, for the measurement of AM-XMOD.
 - 4.4.3 The capability of providing a “Resolution Bandwidth” Filter, either at the input to the detector or incorporated into the method of detection, in order to provide a measurement dynamic range at least 10 dB better than the AM-XMOD distortion levels to be measured. The Resolution Bandwidth must be operated with a $BW \leq 100$ Hz. [Note: Narrower resolution bandwidths can be used and allow better measurement repeatability, but at the expense of longer measurement time.]

4.4.4 The use of a separate RF Spectrum Analyzer for this application may be unsatisfactory, even if it is specified to operate at the desired frequency of 15 kHz. Typical low frequency Baseband (Spectrum) Analyzers using ‘Fast Fourier Transform’ signal processing have a noise level at least 50 dB lower than most RF Spectrum Analyzers.

4.5 The band pass filters (BPF) for this test must meet the specifications listed in ANSI/SCTE 96 2007.

5.0 SET-UP

5.1 Follow all calibration requirements recommended by the manufacturers of the Signal Generator, RF Receiver and Baseband Analyzer equipment, including adequate warm-up and stabilization time.

5.2 Connect the test equipment as shown in Figures 1a and 1b.

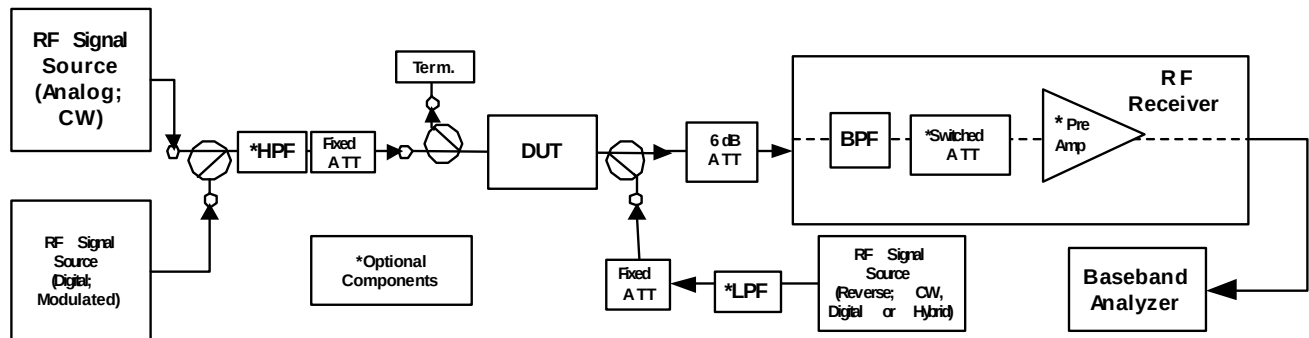


Figure 1a

Or,

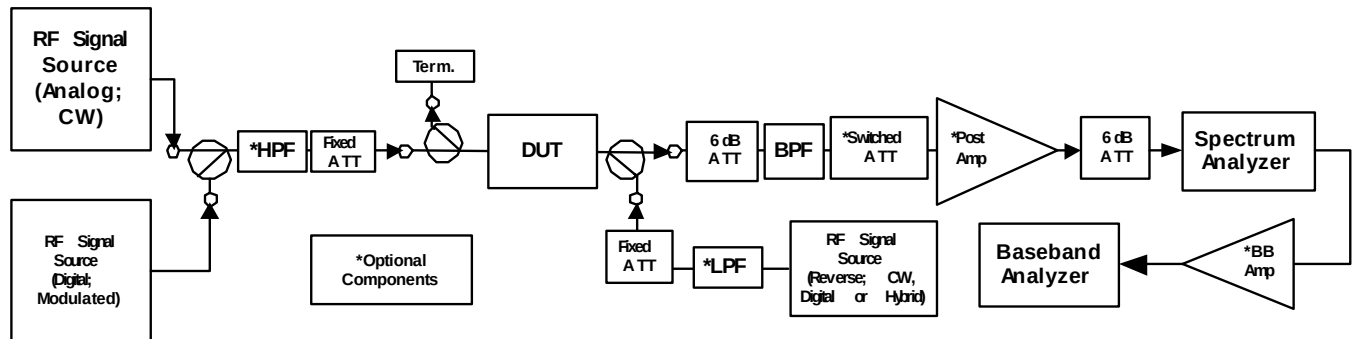


Figure 1b

- 5.3 If appropriate, power the Device Under Test (DUT) in a manner consistent with its use. Note that the DUT may consist of a single device or a group of devices connected together as a system.
- 5.4 Connect the video output of the RF Receiver to the input of the Baseband Analyzer.
- 5.5 Set the signal generator(s) to provide all of the signals needed for the test, as defined by the applicable frequency plan.
- 5.6 Set the appropriate signal level for each carrier, using the techniques described in ANSI/SCTE 96 2007.

6.0 **PROCEDURE**

- 6.1 Adjust and/or tune the BPF so that its pass-band response is centered on the carrier to be measured.

- 6.2** Set the RF Receiver to the settings indicated in Table 1, below. Note: If an RF Spectrum Analyzer is used as a tuned receiver, then the Span should be set to ZERO Hertz, the vertical scale should be set to LINEAR and the Reference Level adjusted until the display is near full scale.

Center Frequency	Carrier Frequency under test
Detector	LINEAR (or RMS)
Resolution Bandwidth	1 MHz
Video Bandwidth (if applicable)	≥ 1 MHz
Input Attenuation	≥ 10 dB*
Sweep Time	Auto**
Vertical Scale	Linear***

Table 1

- * The RF Receiver input attenuation may be manually set to 0 dB to improve the dynamic range of the measurement, but only when one can be certain that the equipment will not be overdriven.
- ** The “Sweep Time” used should depend upon the instrument’s limits of calibrated operation, as well as the minimum acceptable measurement speed desired by the user.
- *** See comments in paragraph 6.2 above.

- 6.3** Turn the synchronous 15.75 kHz square-wave, 100% downward AM modulation ON for all channels.
- 6.4** Tune the Baseband Analyzer to the modulating frequency, 15.75 kHz. Ensure that the signal displayed on the Baseband Analyzer is at the full scale of the display. Ensure that the Resolution Bandwidth of the Baseband Analyzer is ≤ 100 Hz. (Note that a narrower baseband measurement bandwidth will produce a lower measurement noise floor and thus a more stable, more repeatable measurement.)
- 6.5** Record the peak level of the 15.75 kHz signal measured on the Baseband Analyzer as ***Reference Sideband Level***.

- 6.6 Turn the modulation OFF for the carrier under test.
- 6.7 Record the level of the 15.75 kHz signal measured by the Baseband Analyzer as the **RAW AM-XMOD Level**.
- 6.8 Tune the Baseband Analyzer slightly off the 15.75 kHz signal, to a flat portion of the spectrum, within the RF Receiver's video bandwidth.
- 6.9 Record the level measured by the Baseband Analyzer as **Noise Floor Level**. Compute the following:

$$\text{Noise Floor Delta} = \text{RAW AM-XMOD Level} - \text{Noise Floor Level}.$$

If the *Noise Floor Delta* is less than 2 dB, the bandwidth of the Baseband Analyzer can be reduced, or an appropriate post-amplifier can 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 2007 for the proper **Noise Floor Correction Factor**.

- 6.10 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 2007.

- 6.11 Compute the “corrected AM Cross Modulation” as:

$$\text{Corrected AM Cross Modulation, referenced to sideband} =$$

$$\text{Reference Sideband Level} - \text{RAW AM-XMOD Level} + \text{Noise Floor Correction Factor} + (6 \text{ dB, if using an RMS detector})$$

Note that this is a positive number, expressed in ‘-dB’ (i.e. negative dB), in accordance with the definition given in section 3.3. (If necessary, refer to the Glossary and Definitions section of ANSI/SCTE 96 2007 for a discussion of these units.)