Society of Cable Telecommunications Engineers

ENGINEERING COMMITTEE
Interface Practices Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 45 2007

Test Method for Group Delay

NOTICE

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1.0 SCOPE AND DEFINITIONS

1.1 The purpose of this test is to measure the group delay and group delay variation of a properly terminated device. This procedure is applicable to testing of 75Ω components.

1.2 Definitions

1.2.1 Group Delay: the negative derivative of transmission radian phase angle with respect to radian frequency, $-d\phi/d\omega$. In practical terms, group delay is the time required for a signal at a single frequency to pass through a device. Group delay is affected by the physical length and propagation velocity of the circuits involved and by frequency selective components, such as L-C filters. A vector network analyzer calculates group delay by making transmission phase measurements at multiple frequencies, then divides the phase difference between two adjacent points by the frequency difference of those points. The frequency interval over which the phase difference measurement is made must be specified. The dimension of group delay is time, with the units typically given in nanoseconds. Group delay is also called envelope delay, absolute delay, propagation delay, transit delay and absolute group delay. Group delay through the transmission equipment contributes to latency in a communication system.

1.2.2 Group Delay Variation: the difference between the maximum and minimum group delay measured between two different frequencies. In many cases the absolute group delay of a device is not as important as the variation of group delay over frequency. The dimension of group delay variation is time, and the units are typically nanoseconds. The frequency interval over which the difference measurement is made must be clearly stated. The interval used will depend on the desired application. The term “group delay” is often used in the same context as group delay variation, but for the purposes of this procedure, only group delay variation will be used. Group delay variation is also called differential group delay, difference group delay and group delay deviation.

1.2.3 Chrominance-to-Luminance Delay: the difference in group delay measured at the video carrier and the color carrier of an analog video signal. For broadcast NTSC, the video and color carriers are 3.58 MHz apart. The units of chrominance-to-luminance delay are nanoseconds.

2.0 EQUIPMENT

2.1 The Test Procedure Introduction document, ANSI/SCTE 96 2003, describes and specifies some of the basic test equipment which may be required.

2.2 Vector Network Analyzer

2.2.1 Hewlett Packard 8753C/D/E with option 075 (75Ω system impedance), or equivalent.

2.2.2 Hewlett Packard 85036B Type N Calibration Kit, 75Ω or Hewlett Packard 85039B Type F Calibration Kit or equivalent.

2.3 RF Attenuators

In-line attenuators with 75Ω impedance and better than 25 dB return loss from 5 MHz to 1 GHz (not required if variable attenuators are installed as an option in network analyzer).

2.4 Power Supply: AC or DC, as appropriate for the device under test (DUT).

3.0 SET-UP

3.1 Follow all calibration requirements recommended by the manufacturers of the test equipment, including adequate warm-up and stabilization time.

3.2 Set the start and stop frequencies of the network analyzer for the frequency range of interest.

3.3 Set the number of measurement points so that there are eight measurement points per MHz.

3.4 Add RF attenuators as required between the network analyzer output and DUT input and between the DUT output and the network analyzer input. These attenuators should be chosen to prevent overdriving the DUT and exceeding the input range of the network analyzer.

3.5 Connect the cables, attenuators and adapters that will be used to connect and adapt the DUT to the network analyzer as shown in Figure 1. Disconnect the DUT and follow the manufacturer's instructions for a full 2-port calibration using the appropriate calibration kit.

3.6 Connect the DUT to the network analyzer. If the DUT has additional ports, all unused ports should be properly terminated. If the DUT is a powered device, power it for normal operation.

3.7 Set the network analyzer to measure transmission. Set the format to Delay.

3.8 Activate the smoothing function and set the smoothing aperture to 625 kHz.

Note: The actual entry for the network analyzer is a smoothing percent, which is the smoothing aperture in terms of total span. This percentage can easily be obtained using the formula:

Smoothing % = 100 x 0.625 / frequency span (MHz).

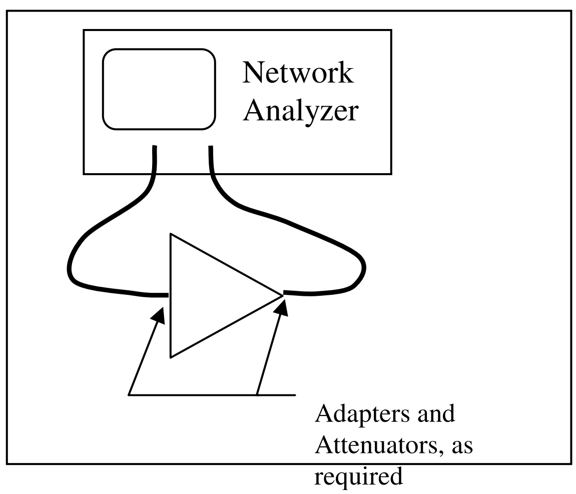

Figure 1. Network Analyzer Setup

4.0 PROCEDURE

4.1 Measure the group delay over the frequency range of interest. Adjust the vertical scale and reference level so that the delay plot can be observed on the analyzer display, as shown in Figure 2.

4.2 Record the group delay at the desired frequency points.

4.3 Calculate group delay variation by subtracting the minimum from the maximum group delay measured between two frequency points.

4.4 Record the group delay variation and the frequency interval over which it was measured.

4.5 Record the chrominance-to-luminance delay as the group delay at the color carrier frequency subtracted from the group delay at the video carrier frequency for the channel of interest.

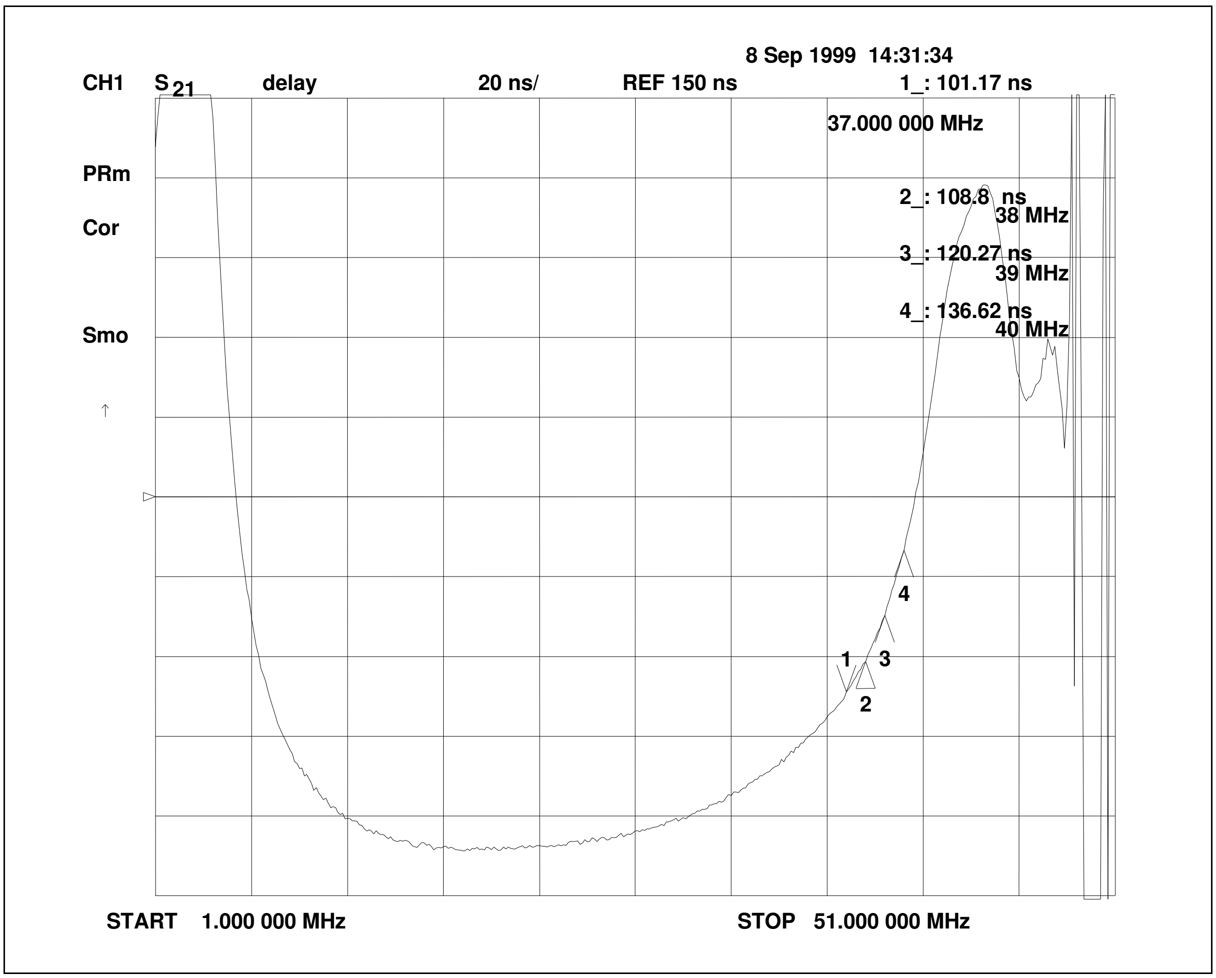

Figure 2: Typical Reverse Path Group Delay Measurement

5.0 EXAMPLES

5.1 Typical setup for forward path chrominance-to-luminance delay measurement:

Start Frequency	50 MHz
Stop Frequency	100 MHz
Number of Points	401
Marker Frequencies	55.25 MHz, 58.83 MHz, 61.25 MHz, 64.38 MHz, 67.25 MHz, 70.83 MHz

5.2 Typical setup for reverse path group delay variation:

Start Frequency	1 MHz
Stop Frequency	51 MHz
Number of Points	401
Marker Frequencies	37 MHz, 38 MHz, 39 MHz, 40 MHz

5.3 For the example shown in Figure 2, the results for group delay are:

Frequency	Group Delay
37 MHz	101.17 ns
38 MHz	108.8 ns
39 MHz	120.27 ns
40 MHz	136.62 ns

5.4 For the example shown in Figure 2, the results for group delay variation are:

Frequency Interval	Group delay variation
37 - 38 MHz	7.63 ns
38 - 39 MHz	11.47 ns
39 - 40 MHz	16.35 ns

6.0 DISCUSSION

The spacing of measurement frequencies, the averaging over frequency (smoothing) and the measurement frequency interval are critical to the accuracy and repeatability of group delay measurements. An understanding of how the measurement is made, its impact on the signals carried over a transmission network and good engineering judgement should guide the choices of these three parameters.

The density of the measurement points must be chosen so that the delay performance of the DUT is accurately represented. Using too few points will obscure rapid changes in delay, thus giving an overly optimistic result. In cases where the slope of the delay increases or decreases with frequency, using too few points will give a pessimistic result, since the network analyzer will draw a straight line between adjacent points. One must ensure that the phase change between two adjacent measurement points is less than 180° in order for the network analyzer to correctly calculate group delay. This is typically only a problem if few measurement points are used and the DUT is electrically very long. However, using too many points may cause the measurement time to be unreasonable. Finally, the points near the edges of the network analyzer display should not be used, since there are no adjacent points with which to calculate a discrete phase difference.

The frequency smoothing interval must also be chosen carefully. If no smoothing is used or the smoothing aperture is too small, noise in the network analyzer's phase measurement will render the delay results meaningless, as shown in Figure 3. On the other hand, too much smoothing will affect the measurement by wiping out rapid changes in delay or including undesired frequencies in the measurement, such as the stopband of a diplex filter. Figure 4 illustrates a case where the slope of the group delay is increasing at the cutoff frequency of a filter.

The impairments caused by group delay variation are different for analog video and digital signals. The chrominance-to-luminance delay measurement of an analog video channel measures the delay difference between the video carrier and the color carrier. If this difference is too large, the color information will be offset from the black and white image. Thus the markers should be placed at the same frequencies as the video carriers and color carriers of the channels under consideration. The primary concern in a digital transmission system that uses adaptive equalization is whether the equalizer has enough range to balance the delay across the receiver bandwidth. Therefore, it is the maximum variation in delay across the passband, and not the steepest slope, that should be recorded. If the maximum variation exceeds the ability of the adaptive equalizer to compensate, or if no adaptive equalization is used, intersymbol interference will cause errors in the data stream. The frequency interval should be appropriate for the receiver bandwidth of the system under consideration. If a variable symbol rate system is to be used, such as DOCSIS, an arbitrary interval must be chosen. Intervals of 1 MHz and 1.5 MHz are typical for reverse channel measurements.

It should also be noted that this is a low resolution measurement intended to measure group delay on the order of nanoseconds, such as would be found in devices that contain some type of filtering or at a band edge. This procedure will not yield accurate results in the passband of a gain device or other devices where the group delay is on the order of tens of picoseconds. For these cases, a higher resolution measurement is needed.

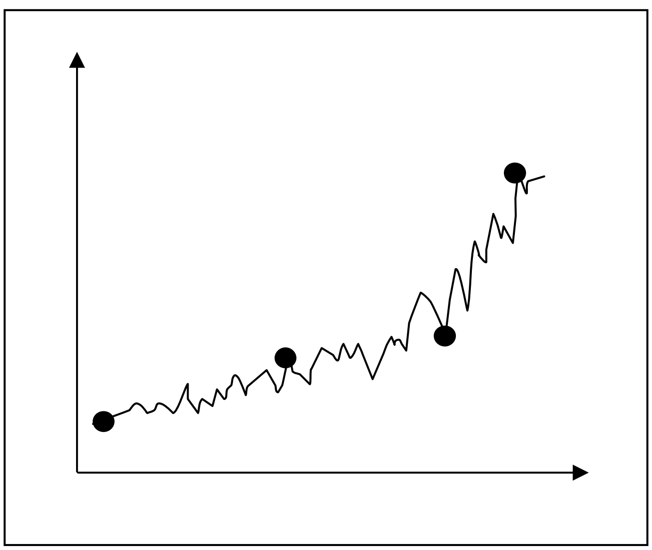

Figure 3: Insufficent Frequency Smoothing

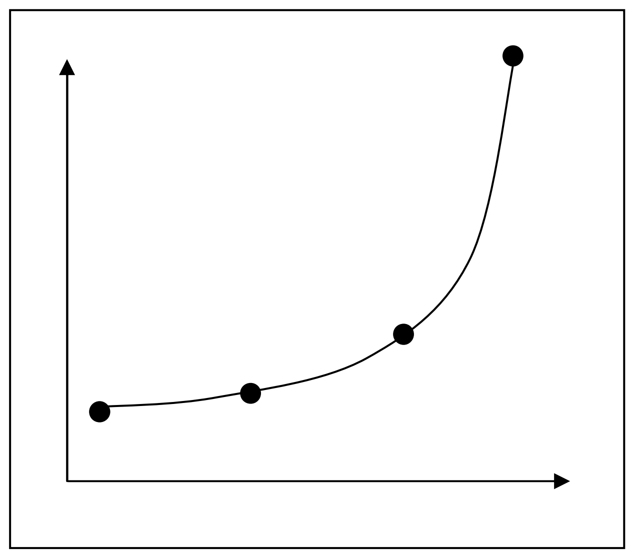

Figure 4: Increasing Slope of Group Delay