Waveform distortions that are independent of signal amplitude are referred to as linear distortions. These distortions occur as a result of a system's inability to uniformly transfer amplitude and phase characteristics at all frequencies.

When fast signal components such as transitions and high-frequency chrominance are affected differently than slower line or field-rate information, linear distortions are probably present. These distortions are most commonly caused by imperfect transfer characteristics in the signal path. However, linear distortions can also be externally introduced. Signals such as power line hum can couple into the video signal and manifest themselves as distortions.

One method of classifying linear distortions involves grouping them according to the duration of the signal components that are affected by the distortion. Four categories, each corresponding to a specific television time interval, have been defined. These categories are:

SHORT TIME (125 nanoseconds to 1 microsecond)

LINE TIME (1 microsecond to 64 microseconds)

FIELD TIME (64 microseconds to 16 milliseconds)

LONG TIME (greater than 16 milliseconds)

This means of classification is convenient because it permits easy correlation of the distortions with what is seen in the picture or in a waveform display. A single measurement for each category takes into account both amplitude and phase distortions within that time range.

While the combination of these four categories covers the entire video spectrum, it is also convenient to have methods of simultaneously evaluating response at all frequencies of interest. Frequency response measurements look at the system's amplitude versus frequency characteristics while group delay measurements examine phase versus frequency. Unlike measurements classified by time interval, frequency response and group delay measurements permit separation of amplitude distortions from delay distortions.

The first two measurements discussed in this section specifically address the relationships between the chrominance and luminance information in a signal. Chrominance-to-luminance gain and delay measurements quantify a system's ability to process chrominance and luminance in correct proportion and without relative time delays.

Sine-squared pulses and rise times are used extensively in the measurement of linear waveform distortions. It may be helpful to review the information in Appendix B which discusses the use of sine-squared pulses in television testing. For more detailed information, a comprehensive technical discussion of linear waveform distortions is presented in IEEE Standard 511-1979, “Video Signal Transmission Measurement of Linear Waveform Distortion”.

Chrominance-to-Luminance Gain and Delay

DEFINITION

Chrominance-to-luminance gain inequality (relative chrominance level) is a change in the gain ratio of the chrominance and luminance components of a video signal. The amount of distortion can be expressed in IRE, percent, or dB. The number is negative for low chrominance and positive for high chrominance.

Chrominance-to-luminance delay inequality (relative chrominance time) is a change in the time relationship of the chrominance and luminance components of a video signal. The amount of distortion is expressed in units of time, typically nanoseconds. The number is positive for delayed chrominance and negative for advanced chrominance.

PICTURE EFFECTS

Gain errors most commonly appear as attenuation or peaking of the chrominance information which shows up in the picture as incorrect color saturation.

Delay distortion will cause color smearing or bleeding, particularly at the edges of objects in the picture. It may also cause poor reproduction of sharp luminance transitions.

TEST SIGNALS

Chrominance-to-luminance gain and delay measurements can be made with any test signal containing a 12.5T sine-squared pulse with 3.58 MHz modulation. Many combination signals, such as the composite signals shown in Figures 18 and 19, contain this pulse.

MEASUREMENT METHODS

Conventional chrominance-to-luminance gain and delay measurements are based on analysis of the baseline of a modulated 12.5T pulse (see Appendix B for further information). This pulse is made up of a sine-squared luminance pulse and a chrominance packet with a sine-squared envelope (see Figure 20).

Modulated sine-squared pulses offer several advantages. First of all, they allow evaluation of both gain and delay differences with a single signal. A further advantage is that modulated sine-squared pulses eliminate the need to separately establish a low-frequency amplitude reference with a white bar. Since a low-frequency reference pulse is present along with the high-frequency information, the amplitude of the pulse itself can be normalized.

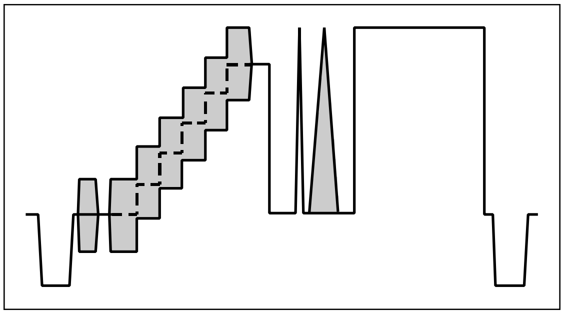


Figure 18. A composite signal (also known as FCC Composite) containing a modulated sine-squared sine pulse.

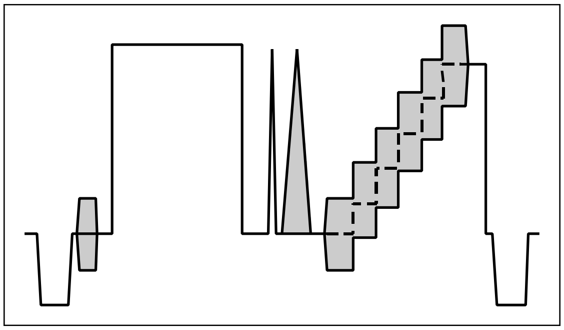


Figure 19. The composite signal specified in the EIA 250-C Standard (also known as NTC-7 Composite).

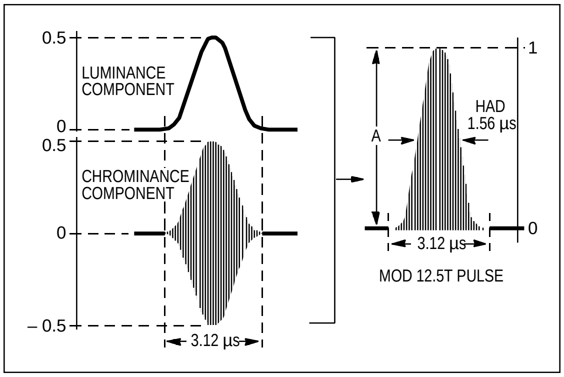


Figure 20. Chrominance and luminance components of the modulated 12.5T pulse.

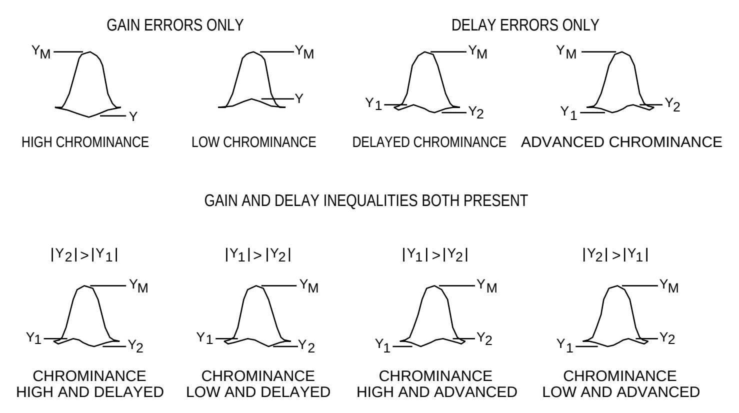


Figure 21. Effects of gain and delay inequalities on the modulated 12.5 T pulse.

The baseline of the modulated 12.5T pulse is flat when chrominance-to-luminance gain and delay distortion is absent. Various types of gain and delay distortion affect the baseline in different ways. A single peak in the baseline indicates the presence of gain errors only. Symmetrical positive and negative peaks indicate the presence of delay errors only. When both types of errors are present, the positive and negative peaks will have different amplitudes and the zero crossing of the baseline distortion will not be at the center of the pulse. Figure 21 shows the effects of various types of distortion.

The 12.5T modulated sine-squared pulse has a half amplitude duration (HAD) of 1.56 microseconds, or 12.5 times the NTSC System Nyquist interval (see Appendix B). The frequency spectrum of this pulse includes energy at low frequencies and energy centered around the subcarrier frequency. The HAD of 12.5T was chosen in order to occupy the chrominance bandwidth of NTSC as fully as possible and to produce a pulse with sufficient sensitivity to delay distortion.

Waveform Monitor and Nomograph. Chrominance-to-luminance inequalities are quantified by measuring the baseline distortion peaks of the 12.5T pulse. The amount of distortion is either calculated from these numbers or obtained from a nomograph.

With a traditional waveform monitor, a nomograph is most commonly used. To make a measurement, first normalize the 12.5T pulse height to 100 IRE. The baseline distortion can be measured either by comparing the waveform to a graticule or by using voltage cursors. Using a nomograph (see Figure 22), find the locations on the horizontal and vertical axes that correspond to the two measured distortion peaks. At the point in the nomograph where perpendicular lines drawn from these two locations would intersect, the gain and delay numbers may be read from the nomograph.

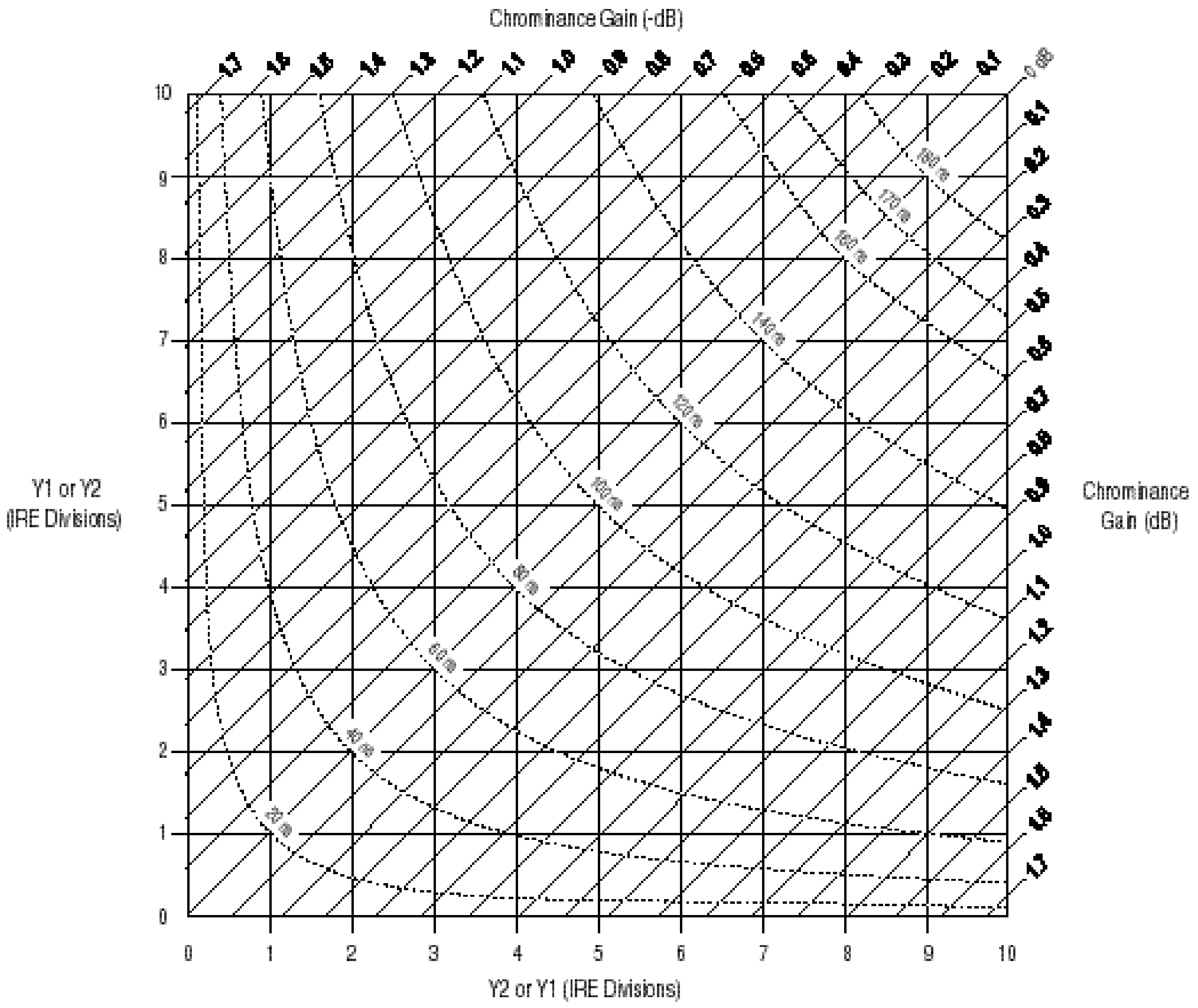


Figure 22. Chrominance-to-luminance gain and delay nomograph.

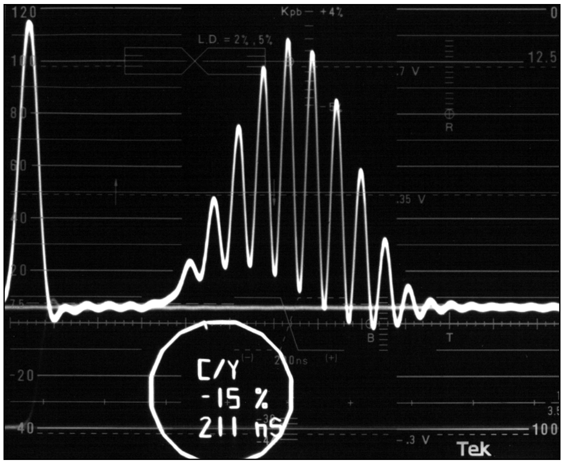


Figure 23. Results obtained with the CHROMA/LUMA selection in the 1780R MEASURE mode.

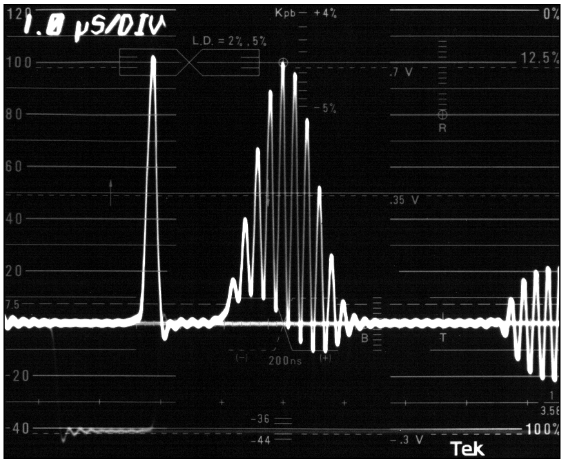


Figure 24. The 1780R graticule indicates that this signal has approximately 200 nanoseconds of chrominance-to-luminance delay.

1780R Semi-Automatic Procedure. The CHROMA/LUMA selection in the 1780R MEASURE menu eliminates the need for a nomograph. The on screen readout guides the user through cursor measurements of the various parameters required to obtain a number from a nomograph. After all parameters have been entered, the instrument calculates the results (see Figure 23). The accuracy and resolution of this method are roughly equivalent to using the graticule and a nomograph.

Waveform Monitor Graticule Approximations. When a system is free of significant nonlinearity and delay distortion is within certain limits, chrominance-to-luminance gain inequality can be measured directly by comparing the height of the 12.5T pulse to the white bar. This method and the nomograph will yield identical results when there is no delay distortion. It is generally considered a valid approximation for signals with less than 150 nanoseconds of delay and is accurate to within 2% for signals with up to 300 nanoseconds of delay.

The white bar amplitude must be normalized to 100 IRE for this measurement. Measure the amplitude difference between the 12.5T pulse top and the white bar in IRE. This number, times two, is the amount of chrominance-to-luminance gain distortion in percent. Note that when the pulse top is higher or lower than the bar, the bottom of the pulse is displaced from the baseline by the same amount. Thus the peak-to-peak difference between the 12.5T pulse and the bar is actually twice the difference between their peak values, hence the factor of two.

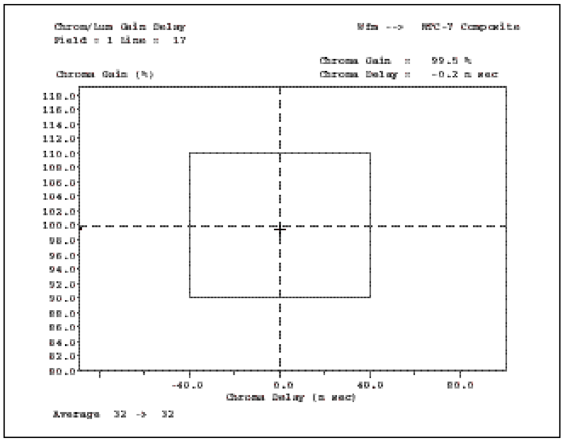
The graticules in waveform monitors such as the 1780R and the 1480 can be used to estimate chrominance-to-luminance delay errors. This method yields valid results only if gain errors are negligible and the baseline distortion is symmetrical. Normalize the 12.5T pulse height to 100 IRE and then center the pulse on the two graticule lines which cross in the center of the baseline. When the waveform monitor is in the 1 volt full scale mode, these lines indicate 200 nanoseconds of delay (see Figure 24). With X5 vertical gain (0.2 volts full scale) selected, the lines indicate 40 nanoseconds of delay.

VM700T Automatic Measurement. Chrominance-to-luminance gain and delay distortion can be measured by selecting CHROM/LUM GAIN DELAY in the VM700T MEASURE mode. The graph plots the error with respect to zero with numeric results given at the top of the display (see Figure 25). The X axis is the delay (positive or negative) and the Y axis is the gain inequality. Chrominance-to-luminance measurements are also available in the AUTO mode.

Calibrated Delay Fixture. Another method of measuring these distortions involves use of a calibrated delay fixture. The fixture allows incremental adjustment of the chrominance-to-luminance delay until there is only one peak in the baseline indicating that delay error has been nulled out. The delay value can then be read from the fixture and gain measured directly from the graticule. This method can be highly accurate but requires the use of specialized equipment.

NOTES

11. Harmonic Distortion. If harmonic distortion is present, there may be multiple aberrations in the baseline rather than one or two clearly distinguishable peaks. In this case, nomograph measurement techniques are indeterminate. The VM700T, however, is capable of removing the effects of harmonic distortion and will yield valid results in this case. Minor discrepancies between the results of the two methods may be attributable to the presence of small amounts of harmonic distortion as well as to the higher inherent resolution of the VM700T method.



Chrom/Lum Gain Delay
Field = 1 Line = 17

Wfm --> NTC-7 Composite

Chroma Gain = 99.5 %
Chroma Delay = -0.2 n sec

Average 32 -> 32

Figure 25. The Chrominance/Luminance Gain Delay display in the VM700T MEASURE mode.

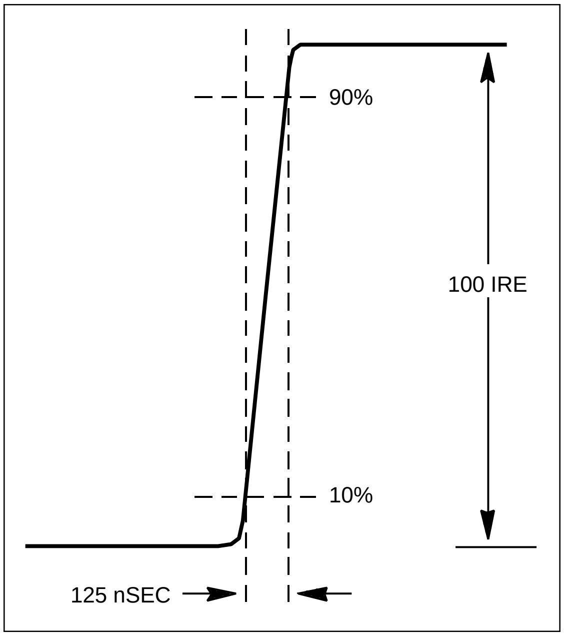


Figure 26. A T rise time bar has a 10% to 90% rise time of 125 nanoseconds.

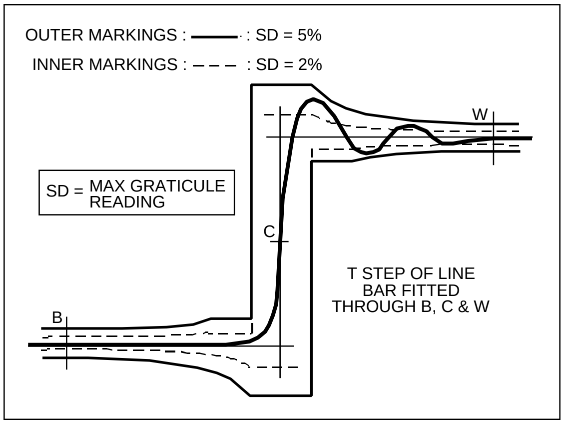


Figure 27. A short time distortion graticule.

DEFINITION

Short time distortions cause amplitude changes, ringing, overshoot, and undershoot in fast rise times and 2T pulses. The affected signal components range in duration from 0.125 microsecond to 1.0 microsecond. Errors are expressed in "percent SD", which is defined in the MEASUREMENT METHODS section below.

The presence of distortions in the short time domain can also be determined by measuring K_{2T} or $K_{pulse/bar}$ as described in the K Factor Ratings section of this publication.

PICTURE EFFECTS

Short time distortions produce fuzzy vertical edges. Ringing can sometimes be interpreted as chrominance information (cross color) causing color artifacts near vertical edges.

TEST SIGNALS

Short time distortion may be measured with any test signal that includes a T rise time white bar. A T rise time bar has a 10% to 90% rise time of nominally 125 nanoseconds (see Figure 26). The EIA-250-C composite signal includes a T rise time bar and some generators allow selection of T rise times for other signals. See Appendix B for a discussion of the time interval T.

It is very important a T rise time bar be used for this measurement. Many common test signals have 2T rather than 1T rise times and are not suitable for this measurement. It should also be noted that T rise time signals will suffer significant distortion when passed through a TV transmitter as they contain spectral components to 8 MHz which will be removed by the transmitter 4.2 MHz lowpass filter. Short time distortion measurements made on transmitted signals will therefore evaluate only those signal components in the 240 nanosecond to 1 microsecond range.

MEASUREMENT METHODS

Short time distortions are most noticeable in sharp transitions and appear as ringing, overshoot, or undershoot at the transition corners. The distortion is quantified by measuring these aberrations.

The distortion amplitudes are not generally quoted directly as a percent of the transition amplitude, but rather in terms of an amplitude weighting system that yields "percent SD". This weighting is necessary because the amount of distortion depends not only on the distortion amplitude but also on the time the distortion occurs with respect to the transition. The equation for NTSC systems is:

$$SD = at^{0.67}$$

where "a" is the lobe amplitude and "t" is the time between transition and distortion. In practice, special graticules or conversion tables are used to eliminate the necessity for calculations. An example of a short time distortion graticule is shown in Figure 27.

Waveform Monitor Graticule. Special external graticules for short time distortion measurements are provided with the 1780R and 1480. To make a measurement, first set the horizontal magnification to 200 nanoseconds (0.2 microseconds) per division. Points B (Black), C (Center) and W (White) are provided on the graticule to assist in positioning the waveform. Use the horizontal and vertical position controls to make sure the waveform passes through points B and C and the variable gain control to make the top of the pulse pass through W. Some adjustment iteration may be necessary.

Once the waveform is properly positioned, the amount of distortion can be determined by comparison to the graticule. Note where the waveform fails with respect to all parts of the graticule as the largest aberration is not necessarily the one which will determine the amount of distortion.

Since the graticule only shows limits for 2% and 5% SD, interpolation may be required. For measuring smaller distortions, select X5 vertical gain (0.2 volts full scale). At this gain setting the graticule lines indicate limits of 0.4% and 1%.

VM700T Automatic Measurement. Short time distortion can be measured by selecting SHORT TIME DISTORTION in the VM700T MEASURE mode. The VM700T automatically measures both short time distortion and bar rise time (see Figure 29). Short time distortion measurements are also available in the AUTO mode.

NOTES

12. Nonlinearities. If the device or system under measurement is free of nonlinear distortion, the rising and falling transitions will exhibit symmetrical distortion. In the presence of nonlinearities, however, the transitions may be affected differently. It is prudent to measure, or at least inspect, both the positive and negative transitions.

13. Pulse-to-Bar Ratios. The amplitude ratio between a 2T pulse and a line bar is sometimes used as an indication of short time distortion. To make a pulse-to-bar measurement with a waveform monitor, first normalize the bar amplitude to 100%. This can be done either by using the IRE graticule scale or voltage cursors in the RELATIVE mode. Now measure the pulse amplitude to obtain pulse-to-bar ratio reading in percent.

A pulse-to-bar measurement can be obtained from the VM700T by selecting K FACTOR in the MEASURE mode. The pulse-to-bar ratio is given in the upper right-hand corner (see Figure 30). This measurement is also available in the AUTO mode.

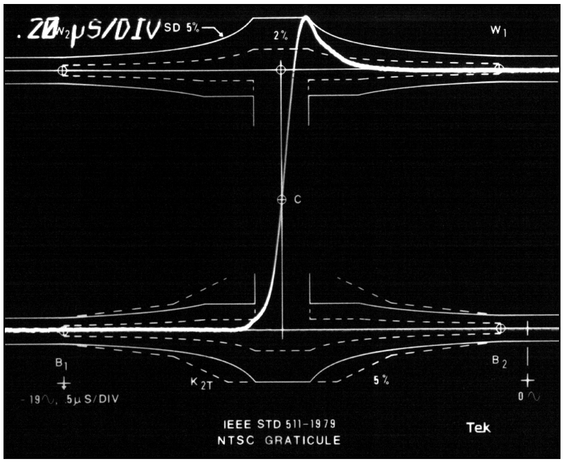
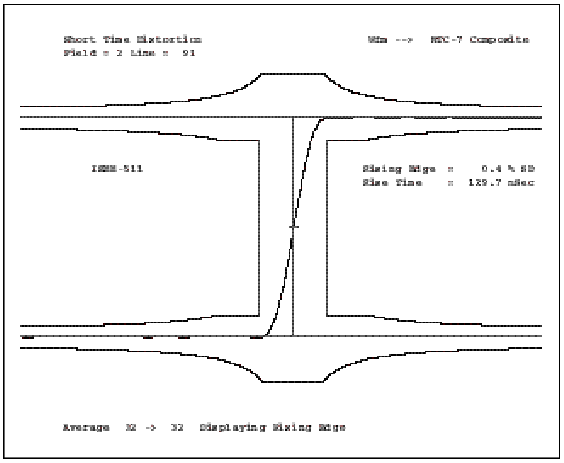


Figure 28. This waveform exhibits short time distortion of 5% SD.



Short Time Distortion
Field = 2 Line = 91

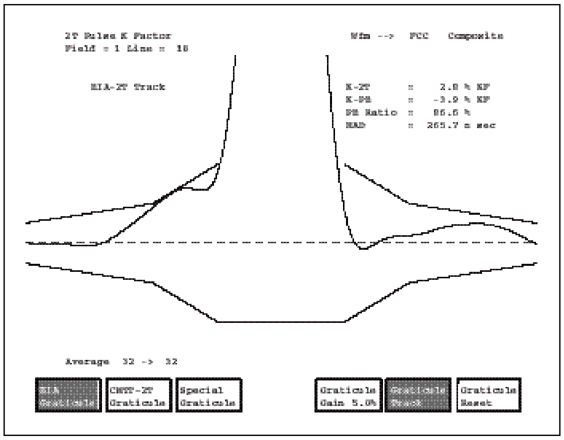
Wfm --> NTC-7 Composite

IEEE-511

Rising Edge = 0.4 % SD
Rise Time = 129.7 nSec

Average 32 -> 32 Displaying Rising Edge

Figure 29. VM700T Short Time Distortion display.



2T Pulse K Factor
Field = 1 Line = 18

Wfm --> FCC Composite

EIA-2T Track

K-2T = 2.8 % KF
K-PB = -3.9 % KF
PB Ratio = 86.6 %
HAD = 265.7 n sec

Average 32 -> 32

Figure 30. Pulse-to-bar ratio is given in the VM700T MEASURE mode K FACTOR selection.

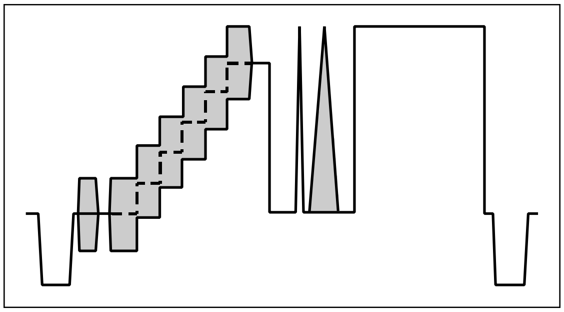


Figure 31. A composite signal (also known as FCC Composite).

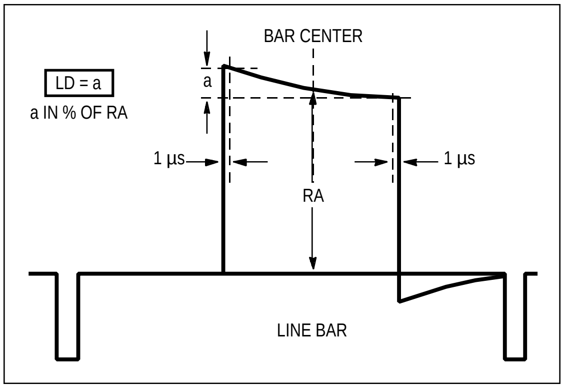


Figure 32. Parameters for measurement of line time distortion.

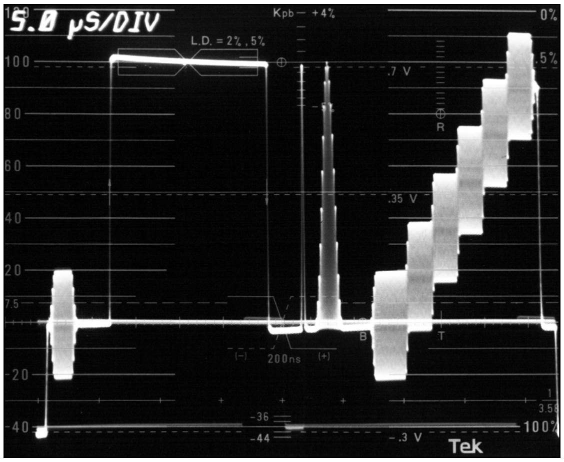


Figure 33. Using the waveform monitor graticule to measure line time distortion. A 3% distortion is shown here.

DEFINITION

Line time distortion causes tilt in line-rate signal components such as white bars. The affected components range in duration from 1.0 microsecond to 64 microseconds. The amount of distortion may be expressed in IRE or in percent of the line bar amplitude.

Distortions in the line time domain can also be quantified by measuring K_{bar} as discussed in the K Factor Ratings section of this booklet.

PICTURE EFFECTS

Line time distortion produces brightness variations between the left and right sides of the screen. Horizontal streaking and smearing may also be apparent. This distortion is most apparent in large picture detail.

TEST SIGNALS

Line time distortion may be measured with any test signal that contains an 18 microsecond, 100 IRE bar. The composite signals shown in Figures 31 and 33 both include such a bar. The window signal shown in the Field Time Distortion section of this booklet is also suitable. Rise time of the bar is not critical for this measurement.

MEASUREMENT METHODS

Line time distortion is quantified by measuring the amount of tilt in the top of the line bar. The peak-to-peak deviation of the tilt is generally quoted as the amount of distortion (see Note 14). The first and last microsecond of the bar should be ignored as errors near the transition are in the short time domain. Figure 32 illustrates line time distortion parameters.

Waveform Monitor Graticule. The 1780R and 1480 graticules are equipped with marks for measuring line time distortion. Note the box in the graticule upper left-hand corner labeled LD = 2%, 5%. To make a measurement, select a one line sweep and use the two arrows on the 50 IRE line to position the bar horizontally (see Figure 33). Make sure that the blanking level of the waveform is on the baseline, and that the bar top passes through 100 IRE at its midpoint. It may be necessary to use the variable gain control on the waveform monitor to normalize the gain. Use the ±2% and ±5% graticule marks to quantify the peak-to-peak deviation of any bar top tilt that occurs within the box. The box excludes the first and last microsecond of the bar.

The waveform monitor vertical gain can be increased for measurement of smaller errors. The graticule marks correspond to 0.4% and 1% limits when the X5 setting (0.2 volts full scale) is selected.

Although the special line time distortion graticule is convenient, this measurement can be made with any waveform monitor. To make a measurement, first use the variable gain control to normalize the center of the bar to 100 IRE. Ignoring the first and last microsecond, measure the peak-to-peak tilt of the top of the bar. Since the gain has been normalized, the tilt measurement in IRE is equal to the line time distortion in percent.

1780R Voltage Cursors. Waveform monitor voltage cursors in the RELATIVE mode can be used to measure line time distortion. Define the amplitude difference between blanking level and the bar center as 100%. Position both cursors to measure the peak-to-peak tilt. This number is the line time distortion. Remember to ignore the first and last microsecond of the bar.

The 1780R time cursors are convenient for locating the appropriate time interval in the center of the bar. Set the time separation to 16 microseconds and put the time cursors in the TRACK mode. Move the two cursors together until they are centered on the bar (see Figure 34).

VM700T Automatic Measurement. The VM700T provides a line time distortion measurement in the AUTO mode.

NOTES

14. Peak-to-Peak Versus Maximum Deviation. In this booklet, both line time and field time distortions are discussed in terms of peak-to-peak measurements. This definition is in keeping with IEEE Standard 511-1979. Some measurement standards, however, define the distortion as the maximum deviation from the center of the bar. If using that measurement definition, the measurement techniques can be adapted accordingly.

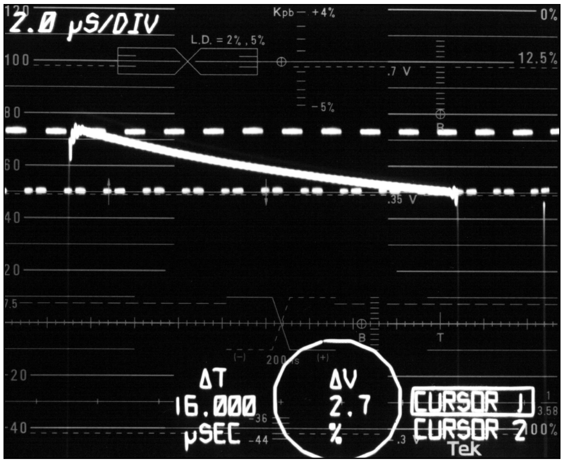


Figure 34. The 1780R voltage and time cursors can facilitate line time distortion measurements.

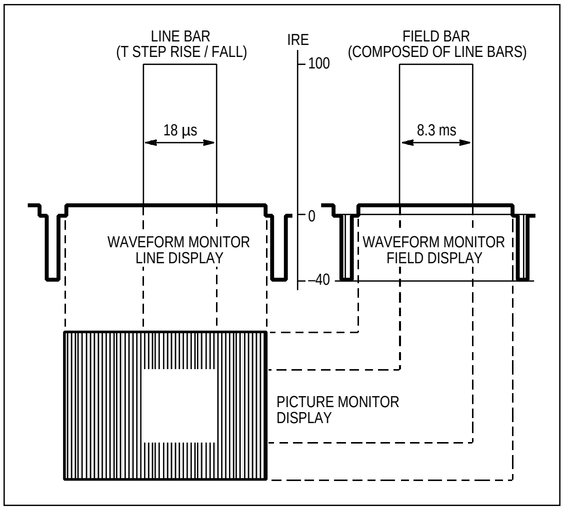


Figure 35. The window signal.

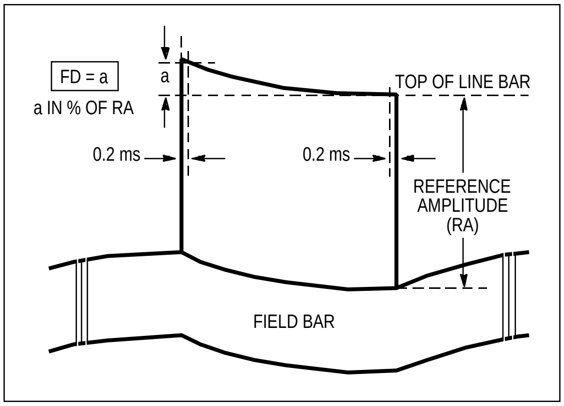


Figure 36. Parameters for measurement of field time distortion.

DEFINITION

Field time distortion causes field-rate tilt in video signals. The affected signal components range in duration from 64 microseconds to 16 milliseconds. The error is expressed in IRE or as a percentage of a reference amplitude which is generally the amplitude at the center of the line bar.

$K_{60\ Hz}$ measurements, which are discussed in the K Factor Ratings section of this booklet, provide another method of describing field time distortions.

PICTURE EFFECTS

Field time distortion will cause top-to-bottom brightness inaccuracies in large objects in the picture.

TEST SIGNALS

Field time distortion can be measured either with a window or field square wave test signal. As the two signals may yield different results, it is good practice to note which was used.

The window signal has approximately 130 lines in the center of the field that include an 18 microsecond line bar. On a picture monitor, this creates the "window" effect shown in Figure 35. This signal is also suitable for measuring line time distortions.

A field square wave is similar, but the lines in the center of the field are at 100 IRE for the entire line.

MEASUREMENT METHODS

Field time distortions are quantified by measuring the amount of tilt in the top of the bar. The peak-to-peak deviation of the tilt is generally quoted as the amount of distortion (see Note 14 on page 27). Field time measurement parameters are shown in Figure 36. The reference amplitude is usually the center of the line bar and the first and last 0.2 milliseconds (about 3 lines) of the field bar are ignored. Distortions in that region are not in the field time domain.

Waveform Monitor Graticule. The first step in making a field time distortion measurement is to normalize the gain. With the waveform monitor in a line rate sweep mode, use the variable gain control to set the center of the line bar to 100 IRE. This can be done most accurately with the waveform monitor FAST DC restorer selected. The DC restorer will remove the effects of field time distortion from the waveform monitor display, and therefore reduce the vertical blurring seen in the line rate display.

Select a field rate sweep and either the SLOW or OFF setting for the DC restorer. Measure the peak-to-peak tilt of the field bar, excluding the first and last 0.2 milliseconds. This IRE reading, expressed as a percentage, is the amount of field time distortion (see Figure 37).

1780R Voltage Cursors. The 1780R voltage cursors can be used in the RELATIVE mode to measure field time distortion. Select a one or two line sweep and define the center of the line bar (relative to blanking) as 100%. Remember to select the FAST DC restorer setting for this part of the measurement procedure.

Select a field rate sweep and set the DC restorer to SLOW or OFF. Ignoring the first and last three lines in the bar, place the cursors at the positive and negative excursions of the tilt (see Figure 38). The voltage cursor readout now indicates the amount of field time distortion.

VM700T Automatic Measurement. The VM700T provides a field time distortion measurement in the AUTO mode.

NOTES

15. Hum. Externally introduced distortions such as mains hum are also considered field rate distortions. Be sure to turn the DC restorer OFF or select the SLOW clamp speed when measuring hum.

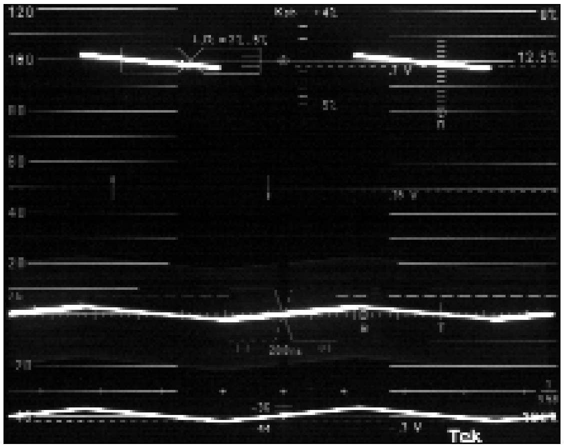


Figure 37. A 2-field waveform monitor display showing about 5% field time distortion.

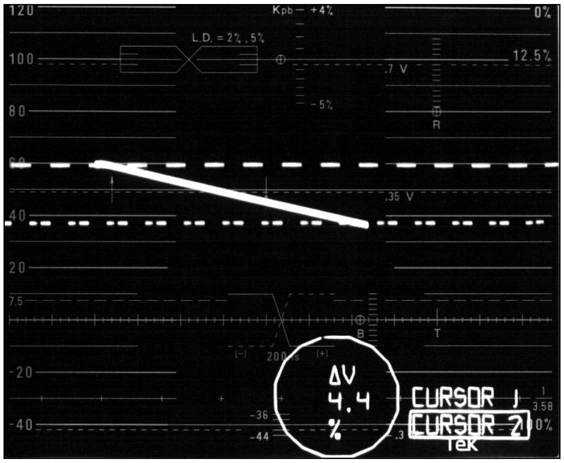


Figure 38. The 1780R voltage cursors can be used to measure field time distortion.

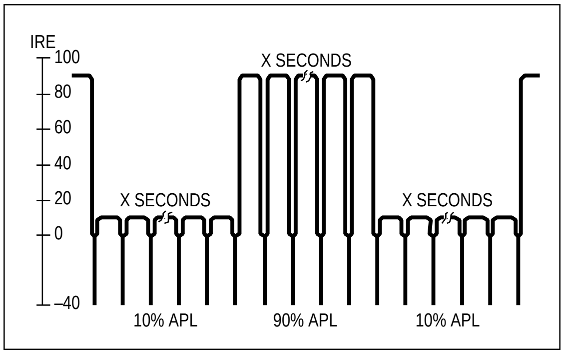


Figure 39. A flat field bounce signal.

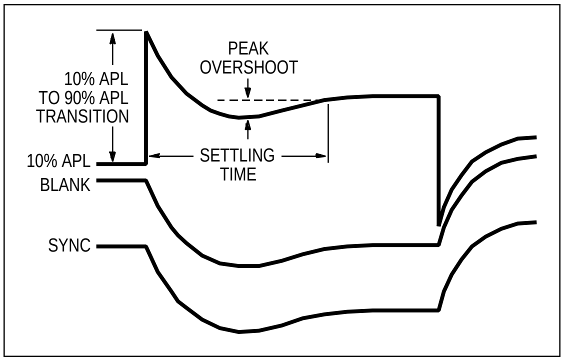
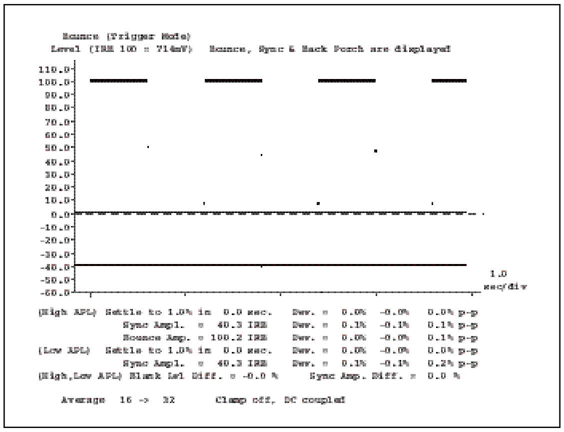


Figure 40. Long time distortion measurement parameters.



```
  Bounce (Trigger Mode)
 Level (IRE 100 = 714mV)   Bounce, Sync & Back Porch are displayed
```

```
(High APL) Settle to 1.0% in  0.0 sec.   Dev. =  0.0%  -0.0%   0.0% p-p
              Sync Ampl.  =  40.3 IRE    Dev. =  0.1%  -0.1%   0.1% p-p
              Bounce Amp. = 100.2 IRE    Dev. =  0.0%  -0.0%   0.1% p-p
(Low APL)  Settle to 1.0% in  0.0 sec.   Dev. =  0.0%  -0.0%   0.0% p-p
              Sync Ampl.  =  40.3 IRE    Dev. =  0.1%  -0.1%   0.2% p-p
(High,Low APL) Blank Lvl Diff. = -0.0 %     Sync Amp. Diff. =  0.0 %

    Average  16 ->  32      Clamp off, DC coupled
```

Figure 41. The VM700T Bounce display.

DEFINITION

Long time distortion is the low frequency transient resulting from a change in APL. This distortion usually appears as a very low frequency damped oscillation. The affected signal components range in duration from 16 milliseconds to tens of seconds.

The peak overshoot, in IRE, is generally quoted as the amount of distortion. Settling time is also sometimes measured.

PICTURE EFFECTS

Long time distortions are slow enough that they are often perceived as flicker in the picture.

TEST SIGNALS

Long time distortion is measured with a flat field test signal with variable APL. The signal should be "bounced", or switched between high and low APL (usually 90% and 10%), at intervals no shorter than five times the settling time (see Figure 39).

MEASUREMENT METHODS

Long time distortions are measured by examining the damped low-frequency oscillation resulting from a change in APL.

Waveform Monitor. It is usually necessary to use a storage oscilloscope or a waveform monitor in the SLOW SWEEP mode to measure long time distortion. A waveform photograph can be helpful in quantifying the distortion. When a stable display is obtained (or a photograph taken), measure the peak overshoot and settling time (see Figure 40).

VM700T Automatic Measurement. Select BOUNCE in the VM700T MEASURE mode to obtain a display of long time distortion (see Figure 41). Peak deviation and settling time are given at the bottom of the screen.

DEFINITION

Frequency response measurements evaluate a system's ability to uniformly transfer signal components of different frequencies without affecting their amplitude. This parameter, also known as gain/frequency distortion or amplitude versus frequency response, evaluates the system's amplitude response over the entire video spectrum.

The amplitude variation may be expressed in dB, percent, or IRE. The reference amplitude (0 dB, 100%) is typically the white bar or some low frequency. Frequency response numbers are only meaningful if they contain three pieces of information: the measured amplitude, the frequency at which the measurement was made, and the reference frequency.

PICTURE EFFECTS

Frequency response problems can cause a wide variety of aberrations in the picture, including all of the effects discussed in the sections on short time, line time, field time, and long time distortions.

TEST SIGNALS

Frequency response can be measured with a number of different test signals. Since there are significant differences between these signals, each one is discussed in some detail in this section.

Some test signals are available either as full amplitude or reduced amplitude signals. It is generally good practice to make measurements with both as the presence of amplitude nonlinearities in the system will have greater effect on measurements made with full amplitude signals.

Multiburst. The multiburst signal typically includes six packets of discrete frequencies that fall within the TV passband. The packet frequencies usually range from 0.5 to 4.1 or 4.2 MHz with frequency increasing toward the right side of each line (see Figure 42). This signal is useful for a quick approximation of system frequency response and can be used on an in-service basis as a VIT (Vertical Interval Test) signal.

Multipulse. The multipulse signal is made up of modulated 25T and 12.5T sine-squared pulses with high-frequency components at various frequencies of interest, generally from 1.25 to 4.1 MHz (see Figure 43). This signal can also be used as a VIT signal.

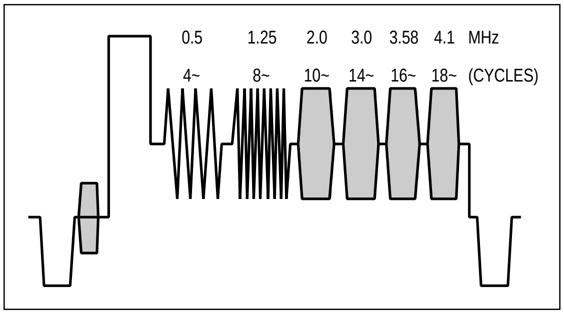


Figure 42. A reduced amplitude multiburst signal (also known as FCC Multiburst).

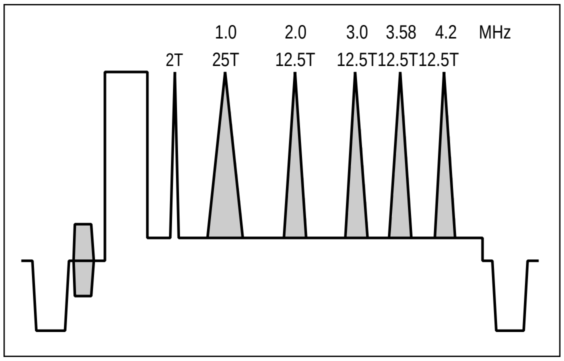


Figure 43. A 70 IRE multipulse signal.

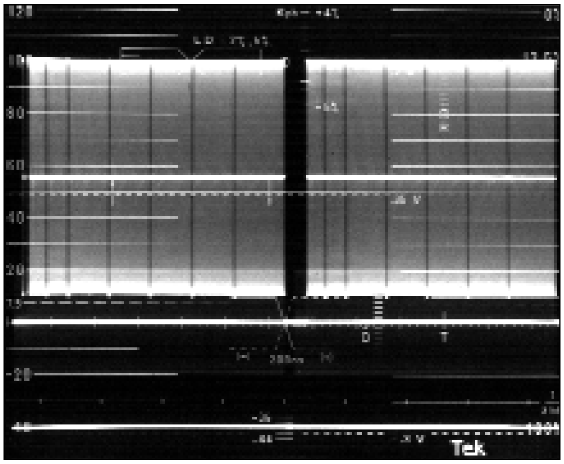


Figure 44. A 6 MHz field rate sweep signal with markers (2-field display).

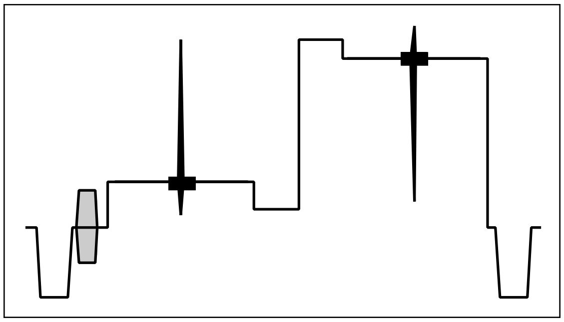


Figure 45. A time domain display of the (sin x)/x signal.

Modulated sine-squared pulses, which are also used to measure chrominance-to-luminance gain and delay errors, are discussed on pages 19 and 24. Although different high-frequency components are used in the multipulse, the same measurement principles apply. Bowing of the baseline indicates an amplitude error between the low frequency and high frequency components of that pulse. Unlike a multiburst, the multipulse facilitates evaluation of group delay errors as well as amplitude errors.

Sweep. It is sometimes recommended that line or field rate sweep signals be used for measuring frequency response. In a sweep signal, the frequency of the sine wave is continuously increased over the interval of a line or field. An example of a field sweep is shown in Figure 44. The markers indicate 1 MHz frequency intervals.

A sweep signal allows examination of frequency response continuously over the interval of interest rather than only at the discrete frequencies of the multiburst and multipulse signals. This can be useful for detailed characterization of a system but does not offer any significant advantages in routine testing. While the other signals discussed here can be used as VITS and therefore permit in-service testing, a field-rate sweep can only be used on an out-of-service basis.

(Sin x)/x. The (sin x)/x signal has equal energy present at all harmonics of the horizontal scan frequency up to its cutoff frequency (see Figures 45 and 50). The (sin x)/x is primarily designed for use with a spectrum analyzer or an automatic measurement set such as the VM700T. Very little information is discernible in a time domain display.

MEASUREMENT METHODS

Since each signal requires a different measurement method, separate discussions for the various test signals are presented in this section. The first three signals (multiburst, multipulse, and sweep) can all be measured with a waveform monitor using either the graticule or the voltage cursors to quantify any distortion. Measurement results are usually expressed in dB but IRE and percent of references are also used.

Waveform Monitor - Multiburst.

Frequency response measurements are made with the multiburst signal by measuring the peak-to-peak amplitude of the packets. There is very little agreement among measurement standards about what to use as the reference level for multiburst measurements. To ensure accurate and repeatable measurements, it is important to select one definition and use it consistently.

With a full amplitude multiburst, either the white bar or the first packet may be used as the reference. When a reduced-amplitude multiburst is used, some standards recommend normalizing the white bar to 100 IRE. The difference, in IRE, between the peak-to-peak amplitude of each packet and the nominal level is then taken as the distortion at that frequency. Alternatively, the amount of distortion may be quoted in dB or percent relative to the reference.

Figures 46 and 47 show the 1780R voltage cursors being used to determine that frequency response is down 3.25 dB at 4.1 MHz. The reference is the 125 KHz square wave at the beginning of the horizontal line. The error in dB is calculated as follows:

20 log10 (61.91/90) = -3.25 dB.

61.91 is the amplitude in IRE of the 4.1 MHz packet and 90 is the amplitude in IRE of the 125 KHz square wave reference.

Waveform Monitor - Multipulse. Frequency response distortion shows up in the multipulse signal as bowing of the pulse baseline (see Figure 48). Distortions are quantified by measuring the amount of baseline displacement in the pulse of interest. It is often easy to see which pulse exhibits the largest gain inequality so an overall result can be obtained by measuring that pulse only.

This measurement is most commonly made by using a waveform monitor graticule to measure the baseline distortion and then transferring the numbers for each pulse to a nomograph. The nomograph used for chrominance-to-luminance gain and delay measurements (see Figure 22) also applies to the multipulse. When making this measurement, normalize each pulse height to 100 IRE before measuring the baseline bowing.

If group delay distortion is also present, the pulse baseline distortion will be sinusoidal rather than a single peak. In this case, measure both distortion peaks and apply the numbers to the nomograph. It will yield correct frequency response results as well as a group delay measurement.

The CHROMA/LUMA selection in the 1780R MEASURE menu can also be used to make frequency response measurements with the multipulse. Repeat the cursor measurement procedure for the pulse corresponding to each frequency of interest.

It is also possible to estimate the amplitude error without using a nomograph. Normalize the white bar to 100 IRE, and then measure the displacement of the pulse top from the white bar. This number, times two, is the amount of frequency response distortion in percent. This method yields valid results even in the presence of some delay distortion. When delay distortion of more than about 150 nanoseconds is present, however, this method is not recommended.

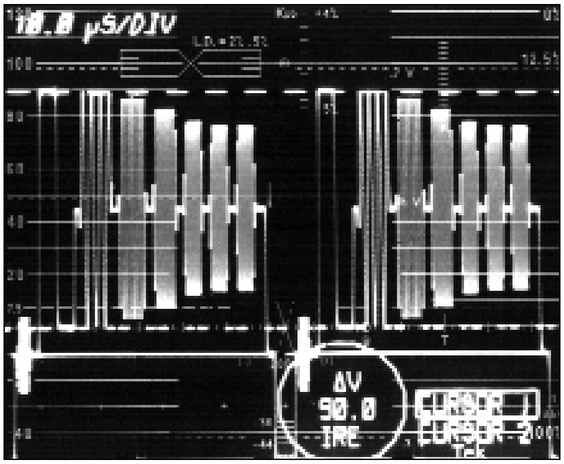


Figure 46. The square wave is measured as a reference.

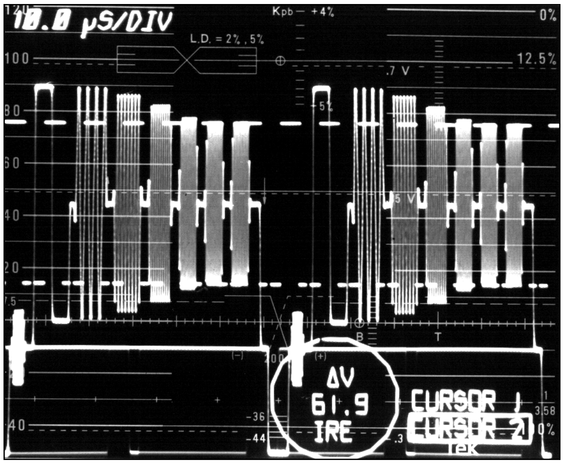


Figure 47. The peak-to-peak amplitude of the smallest packet is then measured.

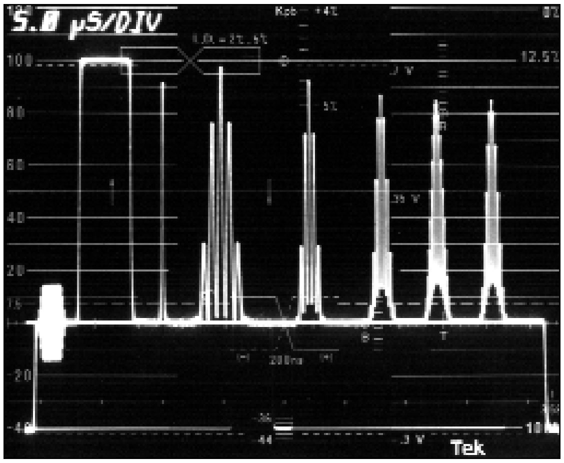


Figure 48. The multipulse signal exhibiting high frequency roll-off.

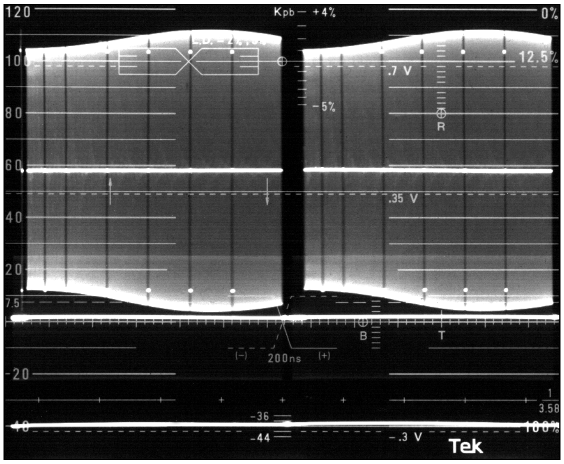


Figure 49. A field rate sweep signal showing frequency response distortion.

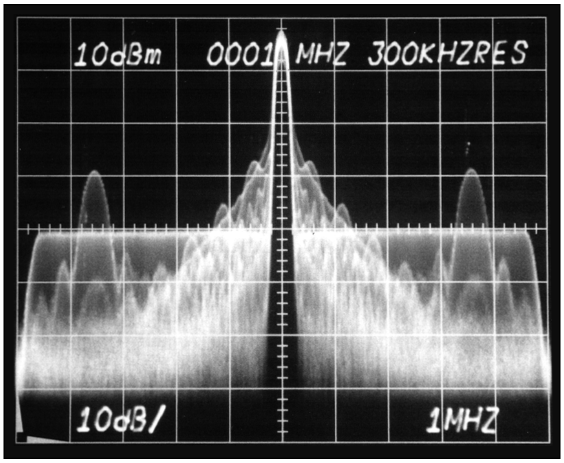


Figure 50. A spectrum analyzer display of a (sin x)/x signal with a cutoff frequency of 4.75 MHz.

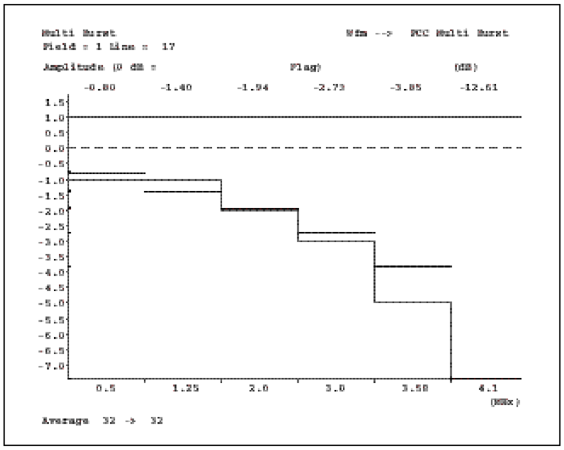


Figure 51. The VM700T Multiburst measurement.

Waveform Monitor - Sweep. Amplitude variations can be measured directly from a time-domain display when a sweep signal is used. Be sure to select a field-rate display on the waveform monitor when using a field sweep. Establish a reference at some low frequency and measure the peak-to-peak amplitude at the frequencies of interest (see Figure 49).

Spectrum Analyzer - (Sin x)/x. Frequency response testing with the (sin x)/x signal is done with a spectrum analyzer. Attenuation or peaking of the flat portion of the spectral display can be read directly off the analyzer display in dB (see Figure 50).

In a time domain display, high frequency roll off will reduce the pulse amplitude and the amplitude of the pulse lobes. It is difficult, however, to quantify the amount of distortion. The presence of amplitude nonlinearity in the system will cause asymmetrical distortion of the positive and negative pulses.

VM700T Automatic Measurement. The VM700T provides amplitude versus frequency response measurement for the multiburst (MULTIBURST in the MEASURE mode) and (sin x)/x (GROUP DELAY (SIN X)/X in the MEASURE mode) signals. These measurements are shown in Figures 51 and 52.

Multiburst measurements are also available in the AUTO mode.

NOTES

16. Chrominance Frequency Response. Special versions of the multiburst and multipulse signals have been developed to assist in accurately measuring the frequency response of the chrominance channel. Rather than examining the entire video passband, these signals contain frequencies centered around the nominal subcarrier frequency. Measurement procedures are very similar to those outlined for frequency response. In the VM700T, select CHROMA FREQUENCY RESPONSE in the MEASURE mode to evaluate this parameter (see Figure 53).

17. Multipulse and Nonlinear Distortions. The device or system under test must be reasonably free of nonlinear distortions, such as differential phase and gain, when using the multipulse signal. Large nonlinear distortions can cause erroneous readings of both frequency response and group delay.

18. More Information. Two Tektronix application notes are available for more information on frequency response testing. See “Using the Multipulse Waveform to Measure Group Delay and Amplitude Errors” (20W-7076-1) and “Frequency Response Testing Using a (Sin x)/x Test Signal and the VM700A/T Video Measurement Set” (25W-11149-0).

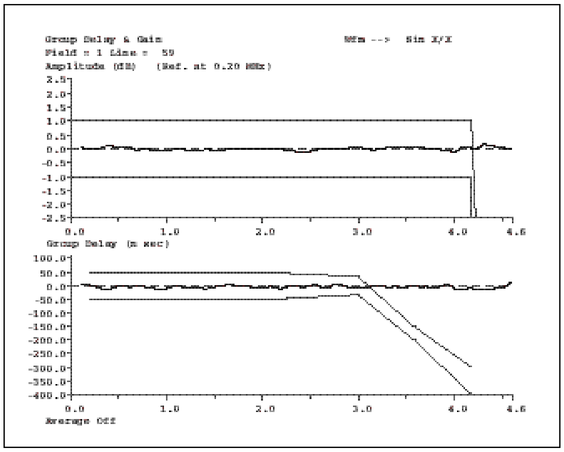


Figure 52. The VM700T Group Delay & Gain measurement also provides frequency response information.

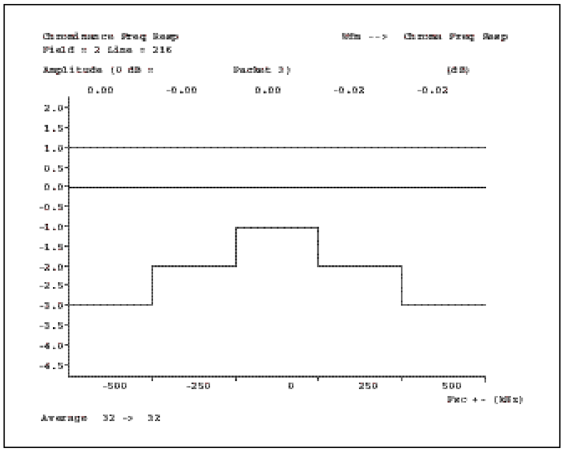


Figure 53. The VM700T Chroma Frequency Response measurement.

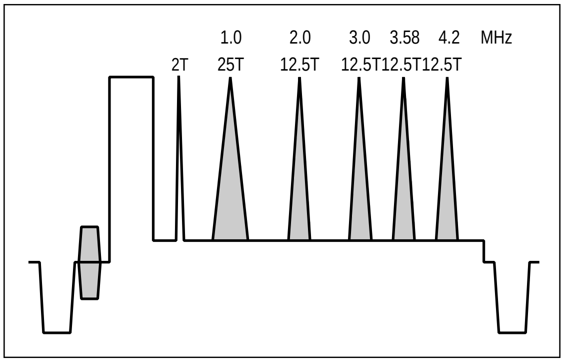


Figure 54. The multipulse signal.

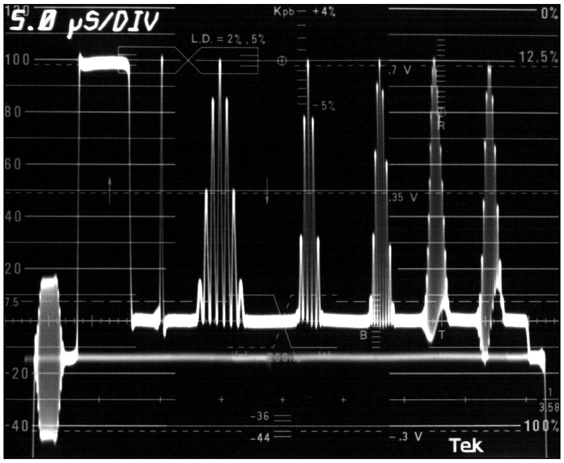


Figure 55. The multipulse signal exhibiting group delay distortion. Group delay differences between the low and high-frequency components of the pulse appear as sinusoidal distortion of the baseline.

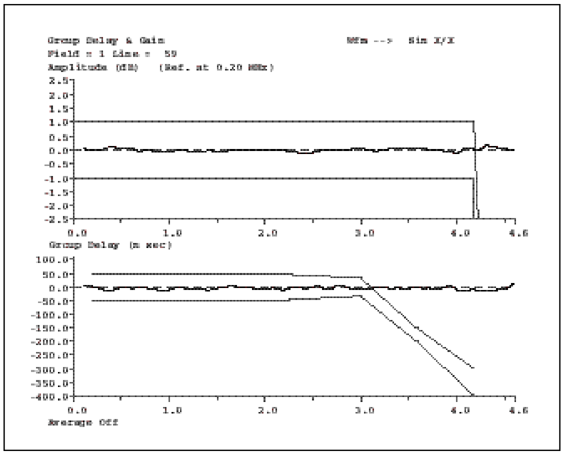


Figure 56. The VM700T Group Delay & Gain display.

DEFINITION

Group delay distortion is present when some frequency components of a signal are delayed more than others. Distortion is expressed in units of time.
The largest difference in delay between a reference low frequency and other frequencies is typically quoted as the amount of distortion.

PICTURE EFFECTS

Group delay problems can cause a lack of vertical line sharpness due to luminance pulse ringing, overshoot, or undershoot.

TEST SIGNALS

The multipulse signal (see Figure 54) is used to measure group delay distortion. It is also possible to measure group delay with the (sin x)/x signal but only with an automatic measurement set such as the VM700T.

MEASUREMENT METHODS

Group delay is measured by analyzing the baseline distortion of the modulated sine-squared pulses in the multipulse signal (see Figure 55). The measurement method is very similar to that used for chrominance-to-luminance delay differing only in the number of frequencies at which delay is measured.

Waveform Monitor and Nomograph. The baseline distortion of each pulse must be individually measured and applied to a nomograph (see Figure 22). Normalize each pulse height to 100 IRE and measure the positive and negative peaks of the baseline distortion. Apply the numbers to the nomograph to obtain a delay value. The largest delay measured is typically quoted as the amount of group delay distortion. In practice, it is often easy to see which pulse exhibits the most delay necessitating only one measurement when maximum delay is the value of interest.

The same nomograph works for any modulated 12.5T pulse, regardless of the modulation frequency. However, the first pulse in a multipulse signal is generally a 25T pulse rather than a 12.5T pulse. When this is the case, multiply the delay number from the nomograph by two to obtain the actual delay value.

1780R Semi-Automatic Procedure. Group delay can be measured with the CHROMA/LUMA selection in the 1780R MEASURE menu. Repeat the measurement procedure for each frequency of interest.

VM700T Automatic Measurement - (Sin x)/x. The VM700T uses the (sin x)/x signal to make group delay measurements. This method offers the advantage of providing delay information for a large number of frequencies, rather than just the six discrete frequencies included in multi-pulse. Select GROUP DELAY (SIN X)/X in the VM700T MEASURE mode (see Figure 56).

NOTES

19. Group Delay Definition. In mathematical terms, group delay is defined as the derivative of phase with respect to frequency ($d\varphi/d\omega$). In a distortion free system, the phase versus frequency response is a linear slope and the derivative is therefore a constant (see Figure 57). If the phase versus frequency response is not linear, then the derivative is not a constant and group delay distortion is present. The largest difference in $d\varphi/d\omega$ that occurs over the frequency interval of interest is the amount of group delay (see Figure 58).

20. Envelope Delay. The term "envelope delay" is often used interchangeably with group delay in television applications. Strictly speaking, envelope delay is measured by passing an amplitude modulated signal through the system and observing the modulation envelope. Group delay, on the other hand, is measured directly by observing phase shift in the signal itself. Since the two methods yield very nearly the same results in practice, it is safe to assume the two terms are synonymous.

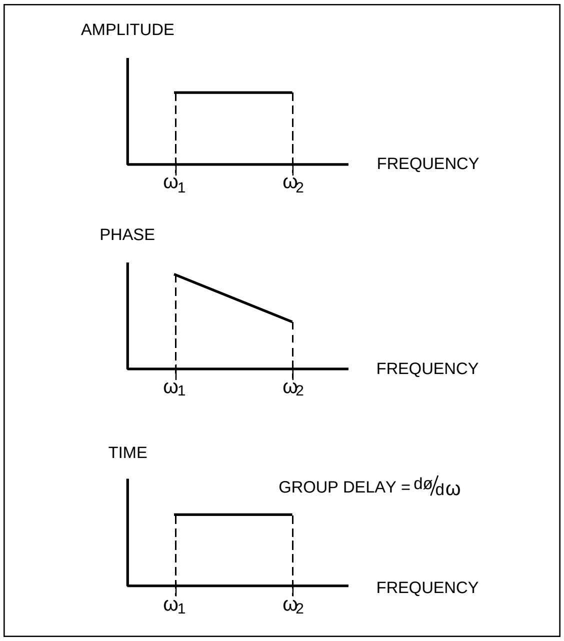


Figure 57. Response of a distortion free system.

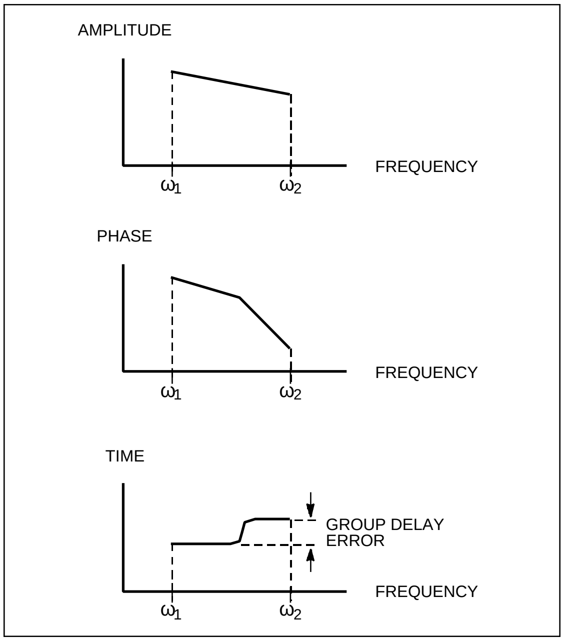


Figure 58. Response of a system with amplitude and phase distortion.

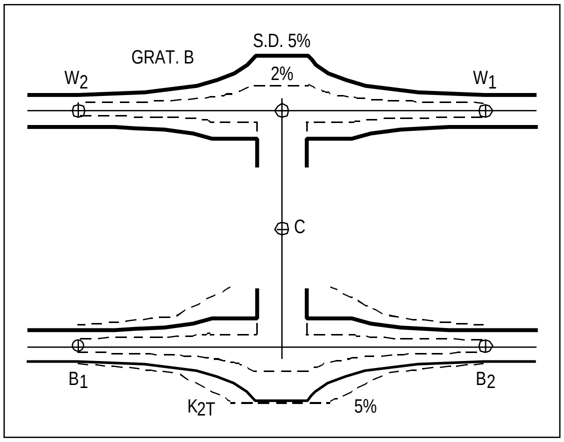


Figure 59. The outer dotted lines at the bottom of the 1780R external graticule indicate 5% K_{2T} limits.

DEFINITION

The K Factor rating system maps linear distortions of 2T pulse and line bar signals onto subjectively determined scales of picture quality. The various distortions are weighted in terms of impairment to the picture.

The usual K Factor measurements are $K_{pulse/bar}$, K_{2T} or K_{pulse} (2T pulse response), K_{bar}, and sometimes $K_{60\ Hz}$. The overall K Factor rating is the largest value obtained from all of these measurements. Special graticules can be used to obtain the K Factor number or it can be calculated from the appropriate formula. Definitions of the four K Factor parameters are as follows:

K_{2T}. K_{2T} is a weighted function of the amplitude and time of distortion occurring before and after the 2T pulse. In practice, a graticule is almost always used to quantify this distortion. Different countries and standards use slightly different amplitude weighting factors. The 1780R graticule is shown in Figure 59.

$K_{pulse/bar}$. Calculation of this parameter requires measurement of the pulse and bar amplitudes. $K_{pulse/bar}$ is equal to:

$^{1}/_{4}$[(bar-pulse)/pulse] X 100%.

K_{bar}. A line bar (18 microseconds) is used to measure this parameter. Locate the center of the bar time, normalize that point to 100%, and measure the maximum amplitude deviation for each half of the bar ignoring the first and last 2.5% (0.45 microsecond). The largest of the two tilt measurements is the K_{bar} rating.

$K_{60\ Hz}$. A field square wave is used to measure this parameter. Locate the center of the field bar time, normalize that point to 100%, and measure the maximum amplitude deviation for each half of the bar ignoring the first and last 2.5% (about 200 microseconds). The largest of the two tilt measurements, divided by two, is the $K_{60\ Hz}$ rating.

PICTURE EFFECTS

All types of linear distortions affect K Factor rating. Picture effects may include any of the aberrations discussed in the sections on short time, line time, field time, and long time distortions.

Since overall K factor rating is the maximum value obtained in the four measurements, the picture effects corresponding to a given K Factor rating may vary widely. However, the subjective impairment is assumed to be equivalent.

TEST SIGNALS

K parameters (except $K_{60\ Hz}$) can be measured with any test signal containing a 2T pulse and an 18 microsecond line bar. A field square wave is required for measurement of $K_{60\ Hz}$. The composite signal shown in Figure 60 includes the required elements.

MEASUREMENT METHODS

Waveform Monitor. The short time distortion external graticule (Graticule B) provided with 1780R and 1480 waveform monitors also includes a 5% K_{2T} limit. To make a measurement, use the variable gain control to set the top of the 2T pulse to the small circle on the graticule (see Figure 61). Set the horizontal magnification to 200 nanoseconds (0.2 microseconds) per division. Under these conditions, the outer dotted lines at the bottom of the graticule represent 5% K. Enabling the X5 vertical gain, in addition to the variable gain required to normalize the pulse height, will change the graticule indication to 1% K limit. Other K Factor readings may be interpolated.

The 1780R is also equipped with an electronic K_{2T} graticule. Select K FACTOR in the MEASURE menu and set the horizontal magnification to 200 nanoseconds (0.2 microseconds) per division. Set the pulse amplitude to 100 IRE which corresponds to the small cross drawn with the beam. Use the large knob to adjust the graticule size until it just touches the waveform. The K_{2T} distortion, in percent, is then shown on the readout (see Figure 62).

The standard internal graticule for the 1780R and 1480 includes $K_{pulse/bar}$ marks in the center near the top. To use this graticule, first normalize the bar amplitude to 100 IRE. Then compare the amplitude of the 2T pulse to the Kpb scale, and obtain a K Factor reading in percent (see Figure 63).

The other K factor measurements can be made either with the graticule or with the voltage cursors. Refer to the definitions on page 38 for general procedures.

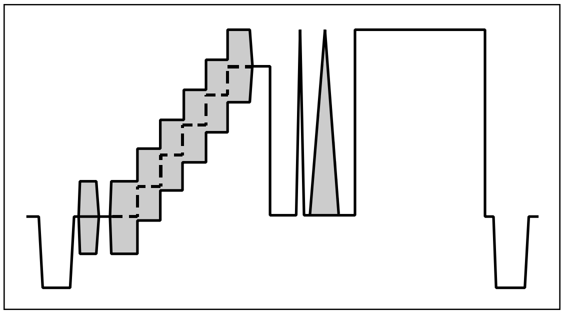


Figure 60. A composite signal (also known as the FCC Composite) with the elements required for K Factor measurements.

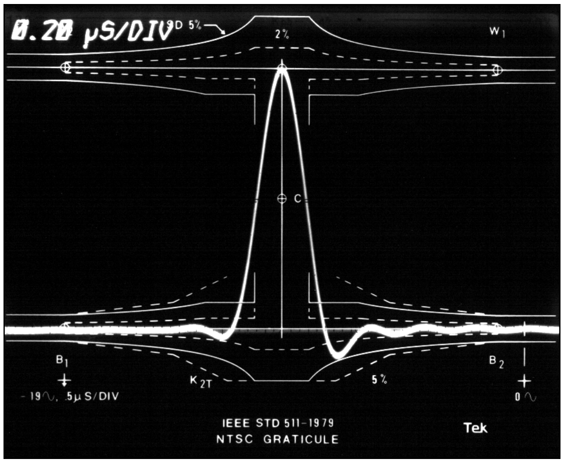


Figure 61. A 2T pulse properly positioned for a K_{2T} measurement with the 1780R external graticule.

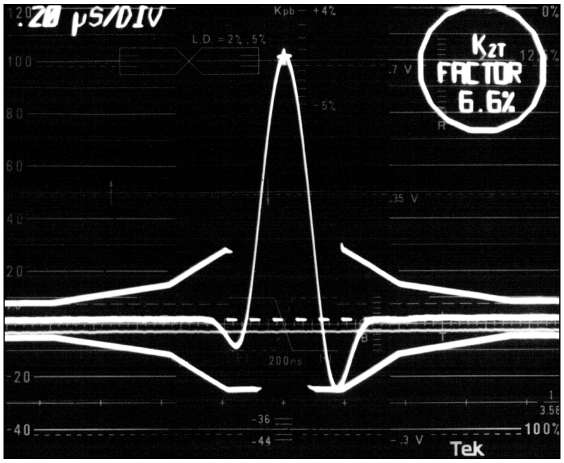


Figure 62. The 1780R electronic K Factor graticule.

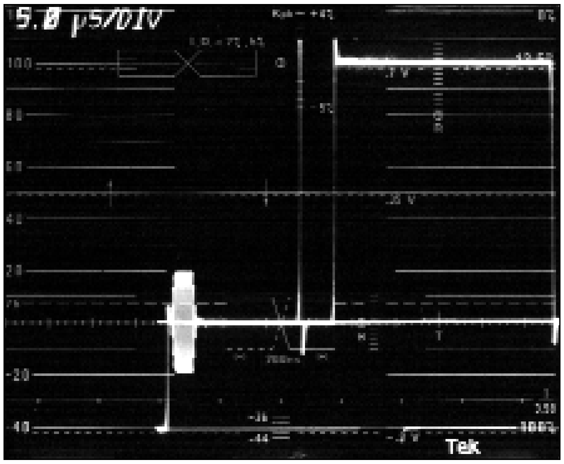
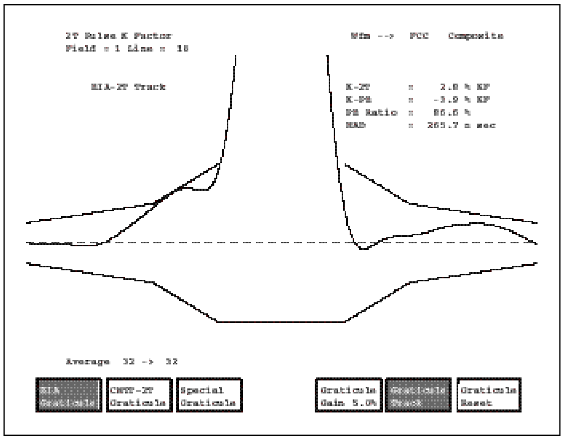


Figure 63. The 1780R graticule indicates 2% $K_{pulse/bar}$.



2T Pulse K Factor
Field = 1 Line = 18

Wfm --> FCC Composite

EIA-2T Track

K-2T = 2.0 % KF
K-PB = -3.9 % KF
PB Ratio = 86.6 %
HAD = 265.7 n sec

Average 32 -> 32

Figure 64. The VM700T 2T Pulse K Factor measurement display.

VM700T Automatic Measurement. Select K FACTOR in the VM700T MEASURE mode to obtain a measurement of K_{2T}. Either an EIA or a CMTT graticule may be used for the measurement. The graticule can be set to automatically track the waveform or adjusted manually with the front panel knob. This display also provides numeric K_{2T} results and a pulse-to-bar ratio reading (see Figure 64). This pulse-to-bar ratio is not a $K_{pulse/bar}$ reading (see Note 21). These measurements are also available in the VM700T AUTO mode.

NOTES

21. Pulse-to-Bar Definitions. There are several different methods of expressing the relationship between the pulse and bar amplitudes and it is important to understand the difference between methods and which is being specified. Three of the most common definitions are given below.

PULSE-TO-BAR RATIO =
(pulse/bar) X 100%

PULSE-BAR INEQUALITY =
(pulse-bar) X 100%

$K_{pulse/bar}$ =
$^{1}/_{4}$[(bar-pulse)/pulse] X 100%