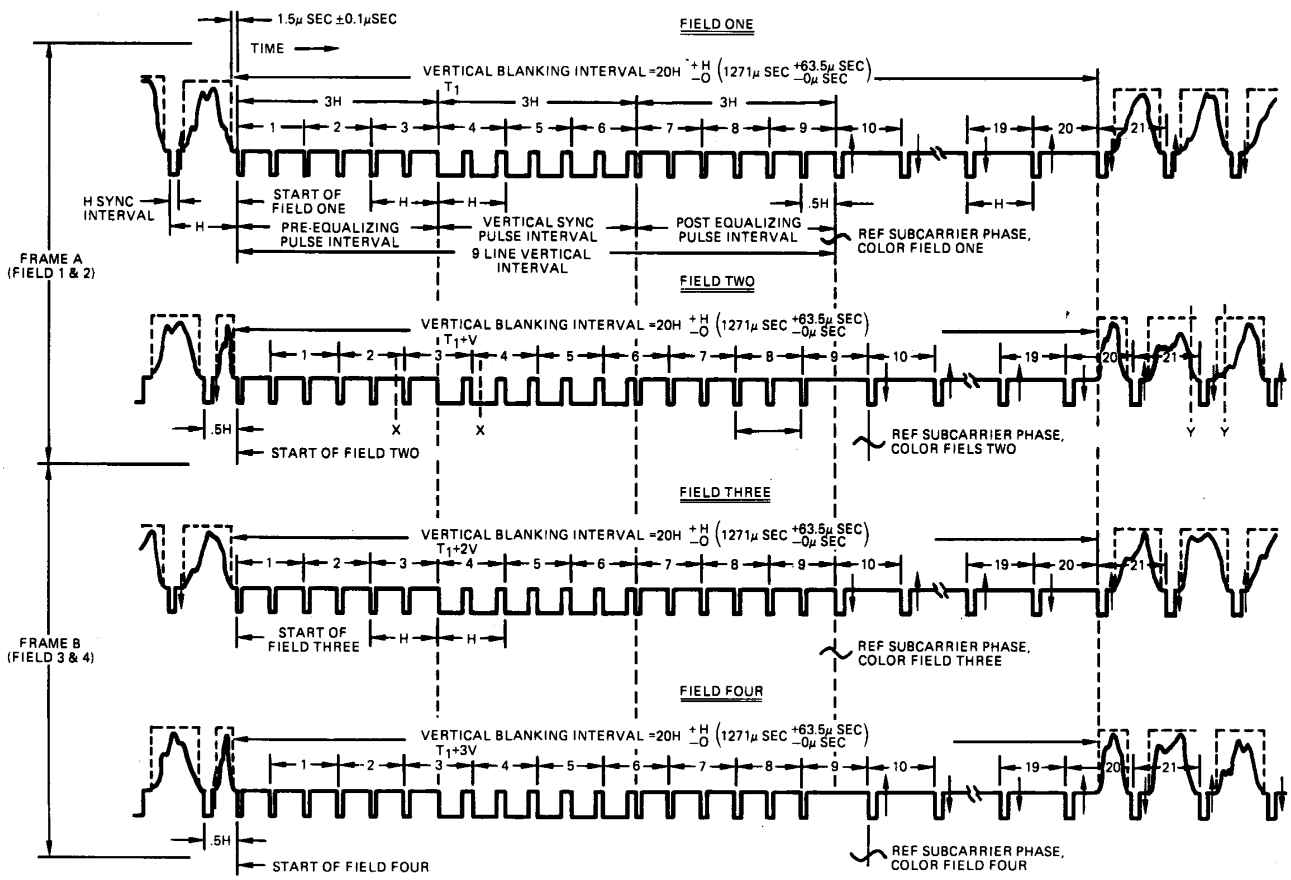
Tektronix

Television Measurements

NTSC Systems



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Preface

To characterize television system performance, an understanding of signal distortions and measurement methods as well as proper instrumentation is needed. This booklet provides information on television test and measurement practices and serves as a comprehensive reference on methods of quantifying signal distortions. This publication deals with NTSC composite analog signals. Analog component, digital composite and component, and HDTV measurements are outside its scope.

New instruments, test signals, and measurement procedures are introduced as television test and measurement technology evolves. This booklet encompasses both traditional measurement techniques and newer methods. After a discussion of good measurement practices, five general categories of television measurements are addressed:

I. Video Amplitude and Time Measurements

II. Linear Distortions

III. Nonlinear Distortions

IV. Noise

V. Transmitter Measurements

A basic knowledge of video is assumed and a glossary of commonly used terms is included as a refresher and to introduce new concepts. This booklet does not provide detailed instructions on how to use particular instruments. The basics of waveform monitor and vectorscope operation are assumed. Consult the instrument manuals for specific operating instructions.

EQUIPMENT REQUIREMENTS

Television system performance is evaluated by sending test signals with known characteristics through the signal path. The signals are then observed at the output (or at intermediate points) to determine whether or not they are being accurately transferred through the system. Two basic types of television test and measurement equipment are required to perform these tasks. Test signal generators provide the stimulus and specialized oscilloscopes, known as waveform monitors and vectorscopes, provide the tools for evaluating the response.

Test Signal Generators. Television signal generators provide a wide variety of test and synchronization signals. Two key criteria in selection of a test signal generator for precision measurements are signal complement and accuracy. The generator should provide all of the test signals to support the required measurements and the signal accuracy must be better than the tolerances of the measurements to be made. If possible, the generator accuracy should be twice as good as the measurement tolerance. For example, differential gain measurement to 1% accuracy should be made with a generator having 0.5% or less differential gain distortion.

Television equipment and system performance is generally assessed on either an out-of-service or in-service basis. In broadcast television applications, measurements must often be made during regular broadcast hours or on an in-service basis. This requires a generator capable of placing test signals within the vertical blanking interval (VBI) of the television program signal. Out-of-service measurements, those performed on other than an in-service basis, may be made with any suitable full field test signal generator.

For out-of-service measurements, the Tektronix TG2000 Signal Generation Platform with the AVG1 and AGL1 modules is the recommended product. The AVG1 Analog Video Generator provides comprehensive signal sets and sufficient accuracy for virtually all measurement requirements. The AVG1 is also a multiformat unit capable of supporting measurements in other composite and analog component formats. This eliminates the need for additional signal generation equipment where there is the requirement for measurements in multiple formats. For synchronization of the equipment under test, a black burst reference signal is provided by the TG2000 mainframe. For applications requiring the test signal source be synchronous with existing equipment, the AGL1 Analog Genlock module provides the interface needed to lock the TG2000 to an external black burst reference signal.

For in-service measurements, the Tektronix VITS200 Generator and Inserter is the recommended product. The VITS200 provides a full complement of NTSC test signals and high degree of flexibility in placement of these signals within the VBI. Signal accuracy is adequate for most transmission and transmitter measurement requirements.

Both the TG2000 and VITS200 fully support the measurement capabilities of the 1780R and VM700 Series Video Measurement Sets.

Waveform Monitors and Vectorscopes. The instruments used to evaluate a system's response to test signals make up the second major category of television test and measurement equipment. Although some measurements can be performed with a general purpose oscilloscope, a waveform monitor is generally preferred in television facilities. Waveform monitors provide TV triggering capabilities and video filters that allow evaluation the chrominance and luminance portions of the signal independently. Most models also have a line selector for looking at signals on individual lines.

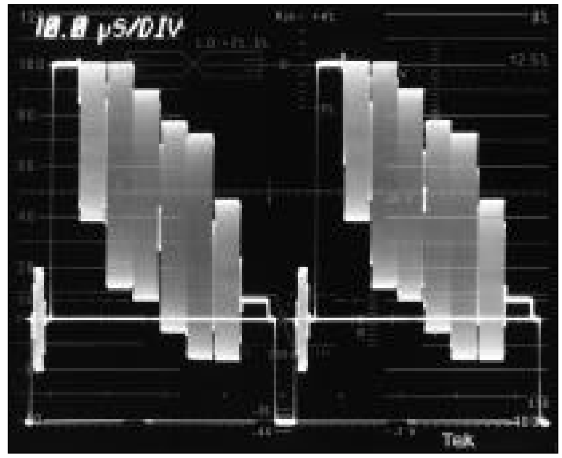
A vectorscope, which demodulates the signal and displays R-Y versus B-Y, is another important test and measurement tool. With a vectorscope, the chrominance portion of the signal can be accurately evaluated.

When selecting a waveform monitor and vectorscope, carefully evaluate the feature sets and specifications to make sure they will meet present and future needs. This is particularly true if making accurate measurements of all signal parameters and distortions described in this booklet. Many varieties of waveform monitors and vectorscopes are available today but the majority of them are not intended for precision measurement applications. Most vectorscopes, for example, do not have precision differential phase and gain measurement capabilities.

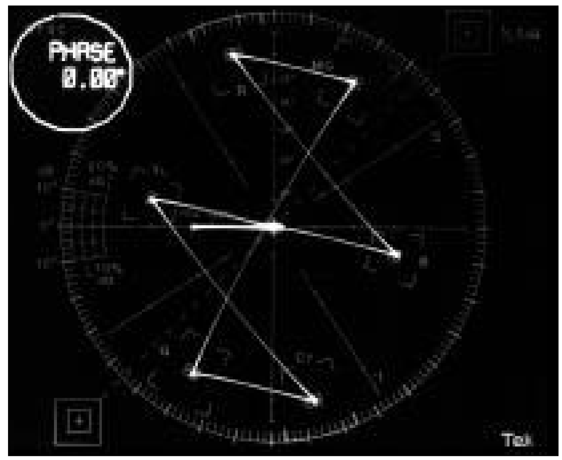
The recommended products for precision measurement applications are the Tektronix 1780R and the VM700T. Most of the measurement procedures in this booklet are based on these instruments.

The 1780R provides waveform monitor and vectorscope functions as well as many specialized measurement features and modes that simplify complex measurements.

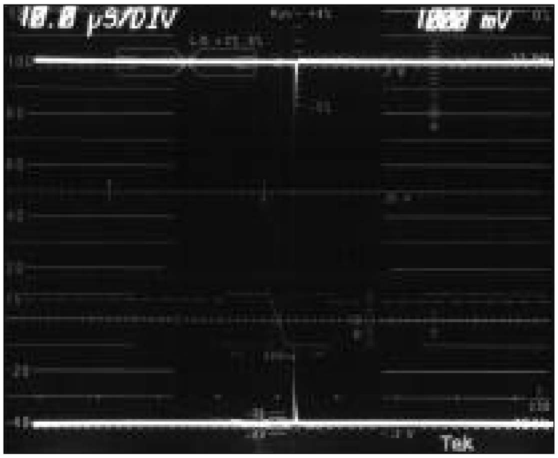
The VM700T is an automated measurement set with results available in numeric and graphic form. Waveform and vector displays, similar to those of traditional waveform monitors and vectorscopes operating in line select mode, are also provided. The VM700T Measure mode provides unique displays of measurement results, many of which are presented in this book.



A waveform monitor display of color bars.



A vectorscope display of color bars.



The 1780R waveform calibrator.

The 1780R vectorscope calibration oscillator.

CALIBRATION

Most instruments are quite stable over time, however, it is good practice to verify equipment calibration prior to every measurement session. Many instruments have internally generated calibration signals that facilitate this process. In the absence of a calibrator, or as an additional check, a test signal directly out of a high quality generator makes a good substitute. Calibration procedures vary from instrument to instrument and the manuals contain detailed instructions.

Analog CRT-based instruments such as the 1780R have a specified warm up time, typically 20 or 30 minutes. Turn the instrument on and allow it to operate for at least that long before checking the calibration and performing measurements. This ensures that the measurement instrumentation will have little or no effect on the measurement results.

Computer-based instruments such as the VM700T also specify a warm up time but the operator does not need to verify or adjust the calibration settings. The VM700T will automatically calibrate itself when it is turned on and will continue to do so periodically during operation. For best results, wait 20 or 30 minutes after initial turn-on before making any measurements.

INSTRUMENT CONFIGURATION

Most of the functions on analog waveform monitor and vectorscope front panels are fairly straightforward and have obvious applications in measurement procedures. A few controls, however, might need a bit more explanation.

DC Restorer. The basic function of the DC restorer in a waveform monitor is to clamp one point of the video waveform to a fixed DC level. This ensures that the display will not move vertically with changes in signal amplitude or APL (Average Picture Level).

Some instruments offer a choice of slow and fast DC restorer speeds. The slow setting is used to measure hum or other low frequency distortions. The fast setting removes hum from the display so it will not interfere with other measurements. Back porch is the most commonly used clamp point, but sync tip clamping has some applications at the transmitter.

AFC/Direct. This control provides selection of the method of triggering the waveform monitor horizontal sweep. The ramp that produces the horizontal sweep is always synchronous with the H or V pulses of the reference video and is started either by the pulses themselves (Direct) or by their average (AFC).

In the direct mode, the video sync pulses directly trigger the waveform monitor's horizontal sweep. The direct setting should be used to remove the effects of time base jitter from the display in order to evaluate other parameters. Since a new trigger point is established for each sweep, line-to-line jitter is not visible in this mode.

In the AFC (Automatic Frequency Control) mode, a phase-locked loop generates pulses that represent the average timing of the sync pulses. These averaged pulses are used to trigger the sweep. The AFC mode is useful for making measurements in the presence of noise as the effects of noise-induced horizontal jitter are removed from the display.

The AFC mode is also useful for evaluating the amount of time base jitter in a signal. The leading edge of sync will appear wide (blurred) if much time base jitter is present. This method is very useful for comparing signals or for indicating the presence of jitter but be cautious about actually trying to measure it. The bandwidth of the AFC phase-locked loop also affects the display.

75%/100% Bars. Some vectorscopes have a 75%/100% selection on the front panel. This setting changes the calibration of the vectorscope chrominance gain to accommodate two different types of color bars. The 75%/100% distinction refers to amplitude, not to saturation or white bar level. These issues are discussed in detail in Appendix A.

75% bars are most frequently used in NTSC systems as the large chrominance peaks in 100% bars may overload the transmitter. However, some test signal generators produce both. It is important to know what amplitude color bar is being used and to select the corresponding gain setting on the vectorscope. Otherwise chrominance gain can easily be misadjusted.

DEMODULATED RF SIGNALS

All of the baseband measurements discussed in this booklet may also be made on demodulated RF signals. It is important, however, to eliminate the demodulator itself as a possible source of distortion. Measurement-quality instruments such as the Tektronix TV1350 and 1450 Television Demodulators will eliminate the likelihood that the demodulator is introducing distortion.

TERMINATION

Improper termination is a very common source of operator error and frustration. Always make sure the signal under measurement is terminated with a 75 Ohm terminator in one location. It is generally best to terminate at the final piece of equipment in the signal path.

The quality of the terminator is also important, particularly when measuring very small distortions. Select a terminator with the tightest practical tolerance as incorrect termination impedance can cause amplitude errors, frequency response problems, and pulse distortions. Terminators in the 1/2% to 1/4% tolerance range are widely available and are generally adequate for routine testing.

STANDARDS AND PERFORMANCE GOALS

No one standard defines all amplitude and timing relationships for the NTSC signal. There are a number of reference documents produced by different organizations, several of which are in common use today. RS-170A and FCC 73.699 Figure 6, two of the most frequently used, are reproduced in Appendices C and D of this booklet. Both documents define blanking and synchronizing signal parameters. RS-170A includes references to SCH phase and is generally used in studio environments. The FCC diagram is used to verify the quality of transmitted signals. Use them as a reference but exercise caution in assuming that compliance with these standards is mandatory or that compliance is sufficient to ensure signal quality.

Acceptable levels of distortion are usually determined subjectively but a number of organizations publish documents that provide recommended limits. These standards, which include EIA-250-C, are frequently edited and revised. Each facility ultimately needs to determine its own performance goals, however, these documents can provide some good guidelines.

While there is usually agreement about the nature of each distortion, definitions for expressing the magnitude of the distortion vary considerably from standard to standard. A number of questions should be kept in mind. Is the measurement absolute or relative? If it is relative, what is the reference? Under what conditions is the reference established? Is the peak-to-peak variation or the largest single deviation to be quoted as the distortion?

A misunderstanding of any one of these issues can seriously affect measurement results so it is important to become familiar with the definitions in whatever standards are used. Make sure those involved in measuring system performance agree on how to express the amount of distortion. It is good practice to record this information along with the measurement results.

I. VIDEO AMPLITUDE AND TIME MEASUREMENTS

This section deals with two fundamental properties of the signal, amplitude and time. In these two dimensions, problems are more frequently caused by operator error than by malfunctioning equipment. Correction of amplitude and pulse width problems often simply involves proper adjustment of the equipment the signal passes through.

Two kinds of amplitude measurements are important in television systems. Absolute levels, such as peak-to-peak amplitude, need to be properly adjusted. The relationships between the parts of the signal are also important. The ratio of sync to the rest of the signal, for example, must be accurately maintained.

Composite NTSC video signals are nominally 1 volt peak-to-peak. Amplitudes are also sometimes described in terms of the IRE scale, which divides the video signal into 140 equal parts. Strictly speaking the IRE scale is a relative one and can be used to compare parts of the signal regardless of overall amplitude. In practice, however, the IRE scale is sometimes treated as an absolute scale with a direct relationship to volts. In the 1780R, 1 IRE is defined as an absolute unit equal to 1/140 of 1 volt. With the VM700T, the user can define IRE to be relative to zero carrier or the white bar or to be an absolute unit (100 IRE = 714 mV).

When setting video amplitudes, it is not sufficient to simply adjust the output level of the final piece of equipment in the signal path. Every piece of equipment should be adjusted to appropriately transfer the signal from input to output. Television equipment is generally not designed to handle signals that deviate much from the nominal amplitude. Signals that are too large may be clipped or distorted and signals that are too small will suffer from degraded signal-to-noise performance.

In most television facilities, video amplitudes are monitored and adjusted on a daily basis. Signal timing parameters are usually checked less frequently, however, it is still important to understand the measurement methods. A periodic verification that all timing parameters are within limits is recommended.

This booklet does not address system timing issues which deal with relative time relationships between the many signals in a television facility. Although system timing is critical to production quality, it is outside the scope of this publication. Only those timing measurements that relate to a single signal are addressed.

DEFINITION

Video amplitudes are most frequently measured in order to verify that they conform to nominal values. The gain must be adjusted if signals are too large or too small. Similar methods of evaluating the waveform are used for both measurement and adjustment of signal levels.

Measurements of the peak-to-peak amplitude of video signals are sometimes known as insertion gain measurements. For NTSC systems, the nominal peak-to-peak amplitude is 1 volt (140 IRE).

PICTURE EFFECTS

Insertion gain errors cause the picture to appear too light or too dark. Because of the effects of ambient light, apparent color saturation is also affected.

TEST SIGNALS

Insertion gain is most easily measured with a test signal that contains a 100 IRE white level. Color bars and pulse and bar signals are most frequently used (see Figures 1 and 2).

MEASUREMENT METHODS

Waveform Monitor Graticule. Signal amplitude can be measured with a waveform monitor by comparing the waveform to the vertical scale on the graticule. With the waveform monitor vertical gain in the calibrated setting (1 volt full scale), the signal should be 1 volt (140 IRE) from sync tip to peak white (see Figure 3). The graticule in the VM700T WAVEFORM mode can be used in a similar manner.

Added Calibrator Method. Some waveform monitors have a feature that allows the internal calibrator signal to be used as a reference for amplitude measurements. This feature is known as WFM + CAL in the 1780R. In the 1480 it is accessed by depressing both the CAL and OPER buttons.

The WFM + CAL display consists of two video traces vertically offset by the calibrator amplitude. This display is obtained by adding the incoming signal to a calibrated square wave of known amplitude. Signal amplitude is equal to the calibrator amplitude when the bottom of the upper trace and the top of the lower trace coincide.

The WFM + CAL mode is most commonly used to set insertion gain which requires a 1-volt calibrator signal. If using a 1780R, select a calibrator amplitude of 1000 mV (140 IRE). In the 1480, the DC RESTORER setting determines which of two calibrator amplitudes is currently selected. The calibrator amplitude is 1 volt when SYNC TIP is selected and 714 millivolts when BACK PORCH is selected.

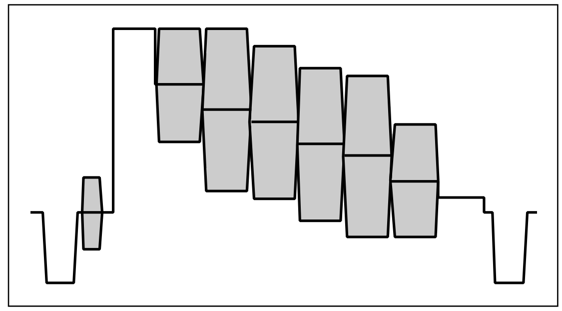


Figure 1. A 75% amplitude color bar signal with a 100% white reference bar.

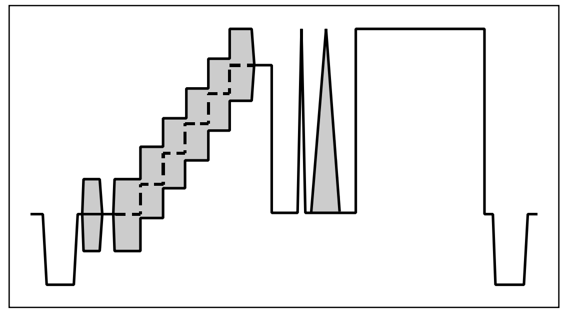


Figure 2. A composite signal (also known as FCC Composite) that includes a 100 IRE white bar.

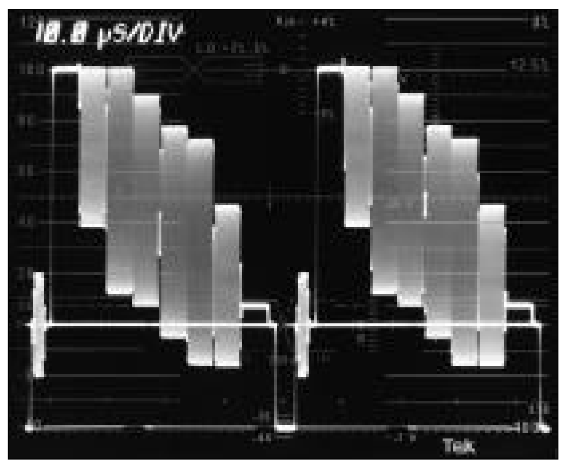


Figure 3. A 1-volt signal properly positioned with respect to the 1780R graticule.

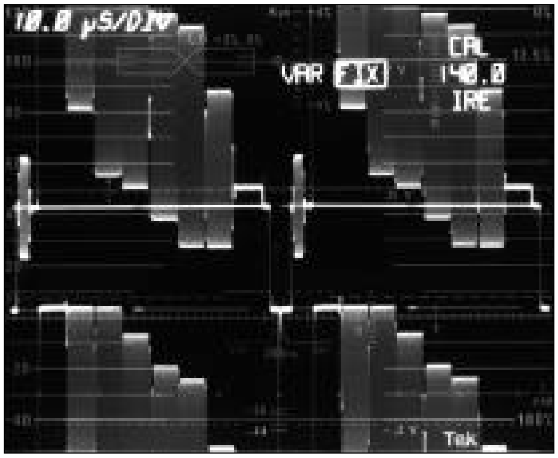


Figure 4. The WFM + CAL mode in the 1780R indicating that insertion gain is properly adjusted.

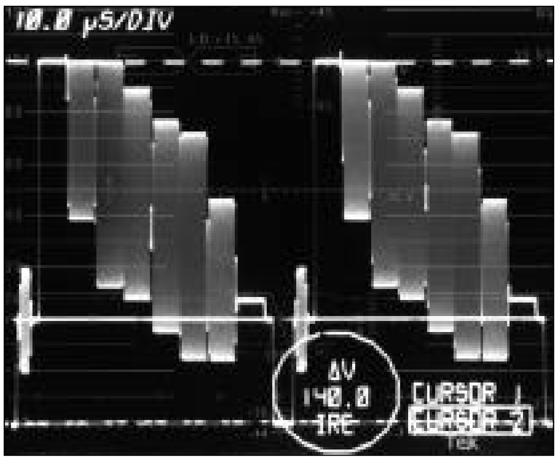


Figure 5. 1780R voltage cursors positioned to measure peak-to-peak amplitude.

Insertion gain is set by externally adjusting the signal amplitude until sync tip of the upper trace and peak white of the lower trace coincide. Figure 4 shows a properly adjusted signal. Since the waveform monitor vertical gain need not be calibrated in this mode, the gain may be increased for greater resolution.

The 1780R has a variable calibrator so the WFM + CAL mode can be used to measure signal amplitudes. Measurements are made by adjusting the calibrator amplitude (with the large knob on the 1780R front panel) until the traces meet. At this point the calibrator amplitude equals the signal amplitude and can be read from the screen.

Voltage Cursors (1780R). Some waveform monitors, such as the 1780R, are equipped with on-screen voltage cursors for making accurate amplitude measurements. Peak-to-peak amplitude can be measured by positioning one cursor on sync tip and the other on peak white (see Figure 5). The 1780R vertical gain control affects the cursors and the waveform in the same manner so vertical gain can be increased to allow for more accurate positioning of the cursors.

When setting insertion gain, it may be convenient to first set the cursor separation for 1000 mV (140 IRE). The video signal amplitude should then be adjusted to match the cursor amplitude.

Cursors (VM700T). Manual amplitude measurements can be made with the VM700T by selecting CURSORS in the WAVEFORM mode. The horizontal baseline in the middle of the screen is used as a reference. To measure insertion gain, first position sync tip on the baseline. Touch the RESET DIFFS selection on the screen to reset the voltage difference to zero. Now move the waveform down until the white bar is on the baseline and read the voltage difference from the screen.

VM700T Automatic Measurement. The VM700T provides amplitude measurements in the AUTO mode.

NOTES

1. Sync to Picture Ratio. When the signal amplitude is wrong, it is important to verify that the problem is really a simple gain error rather than a distortion. This can be accomplished by verifying that the ratio of sync to the picture signal (the part of the signal above blanking) is 40:100. If the ratio is correct, proceed with the gain adjustment. If the ratio is incorrect, there is a problem and further investigation is needed. The signal may be suffering from distortion or equipment that reinserts sync and burst could be malfunctioning.

2. Sync and Burst Measurements. Sync and burst should each be 40/140 of the composite video signal (286 millivolts for a 1-volt signal). Most of the methods discussed in this section can be used to measure sync and burst amplitudes. When using the 1780R voltage cursors, the TRACK mode is a convenient tool for comparing sync and burst amplitudes. In this mode, the separation between the two cursors remains fixed and they can be moved together with respect to the waveform.

3. Measurement Accuracy. In general, the added calibrator and voltage cursor methods are more accurate than the graticule technique. However, some cursor implementations have far more resolution than accuracy creating an impression of measurements more precise than they really are. Familiarity with the specifications of the waveform monitor and an understanding of the accuracy and resolution available in the various monitoring modes will help make an appropriate choice.

4. Using the Luminance Filter. When setting insertion gain with a live signal rather than a test signal, it may be useful to enable the waveform monitor luminance filter (also called lowpass or IRE). This filter removes the chrominance information so that peak white luminance levels can be used for setting gain.

5. White Levels. When setting insertion gain, make sure a 100 IRE bar is used as the reference peak white level. As noted in Appendix A, some color bar signals have a 77 IRE white bar rather than 100 IRE.

6. Setup. Most NTSC signals use "black level setup" which is often simply referred to as "setup". In a signal with setup, video black is 7.5 IRE above the blanking level. The peak-to-peak amplitude and sync amplitude do not change. The peak white level therefore remains at 100 IRE so the 7.5 IRE pedestal reduces the amplitude range available for picture information. Both luminance and chrominance levels of the entire signal are scaled down in order to fit into the 92.5 IRE range which remains above the pedestal.

Virtually all NTSC program material has setup but many test signals do not. When measuring amplitudes, it is necessary to know whether or not the signal has setup and to understand the differences associated with it. When working with signals that have setup, do not to confuse the black level (7.5 IRE) with the blanking level.

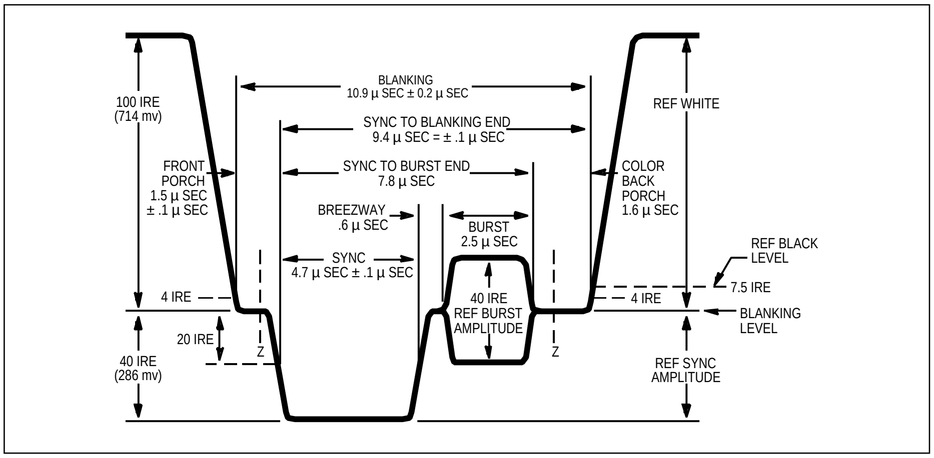


Figure 6. RS-170A pulse width requirements.

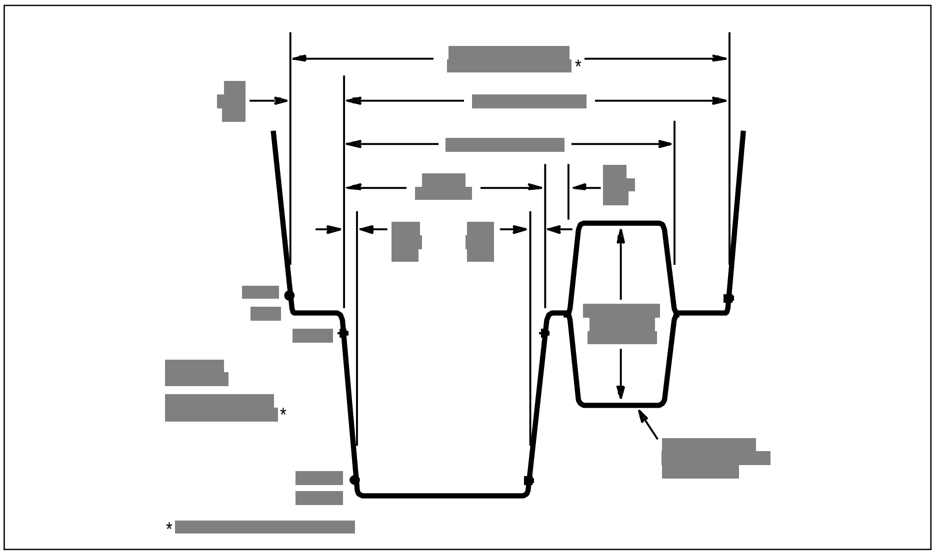


Figure 7. FCC pulse width requirements.

DEFINITION

Horizontal and vertical synchronization pulse widths are measured in order to verify they fall within specified limits. Rise times, fall times, and the position and number of cycles in burst are also specified.

Both RS-170A and the FCC provide recommended limits for these parameters. However, the two standards have different definitions for the various time intervals. For example, the FCC specifies sync width between the 90% (-4 IRE) points of the two transitions while RS-170A specifies sync width between the 50% (-20 IRE) points. The definition for each parameter should be clearly understood before measuring it.

Even when differences in definition are taken into account, RS-170A and the FCC give different recommended limits for the various sync pulse parameters. The RS-170A requirements are generally more stringent. Pulse width requirements for the two standards are given in Figures 6 and 7.

PICTURE EFFECTS

Small errors in pulse widths will not affect picture quality. However, if the errors become so large that the pulses cannot be properly processed (by equipment), picture breakup may occur.

TEST SIGNALS

Timing measurements may be made on any composite signal containing horizontal, vertical and subcarrier (burst) synchronization information.

MEASUREMENT METHODS

Waveform Monitor Graticule. Time intervals can be measured by comparing the waveform to the marks along the horizontal baseline of a waveform monitor graticule. In order to get adequate resolution, it is usually necessary to magnify the waveform display horizontally. Select the setting that provides as much magnification as possible while still keeping the interval of interest entirely on-screen. The scale factor, typically microseconds per major division, changes with horizontal magnification. The 1780R displays the microseconds per division setting on the screen while for the 1480 it is obtained from the switch setting.

To make measurements between the 90% (-4 IRE) points, it is generally most convenient to use the waveform monitor variable gain control to normalize the sync height to 100 IRE. The blanking level may then be positioned at +10 IRE and a reading obtained from the marks on the baseline (see Figure 8).

For measurements specified at the 50% amplitude points, normalizing to 100 IRE is probably not necessary. In this case, place the top of the pulse at +20 IRE and the bottom at -20 IRE. The pulse width can then be read from the horizontal scale (see Figure 9).

Time Cursors (1780R). Some waveform monitors are equipped with cursors to facilitate the measurement of time intervals. The time cursors in the 1780R appear as bright dots on the waveform. To find the 90% points of the sync transitions, it is best to normalize the sync pulse to 100 IRE and use the vertical graticule scale to locate the proper level. Alternatively, the voltage cursors in the RELATIVE mode can be used to locate the 90% points.

Similar procedures can be used to find the 50% points of the transitions (see Figure 10), but in this case it may not be necessary. Since it is easier to visually locate the halfway point of a transition, 50% point measurements can often be made without using an amplitude reference.

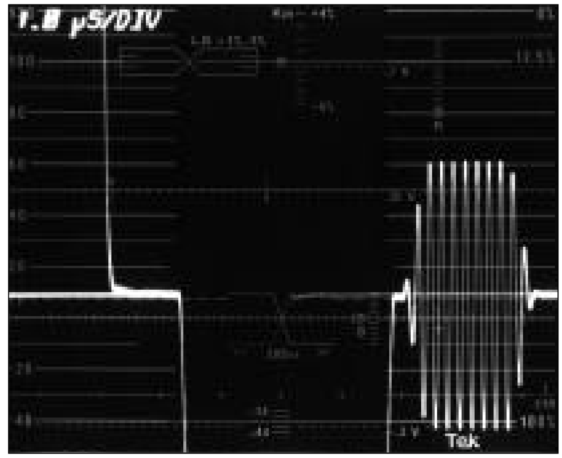


Figure 8. Horizontal sync width measurement at the 90% amplitude (4 IRE) points.

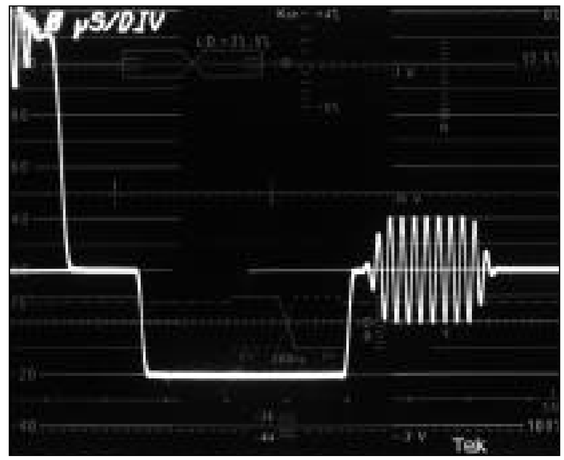


Figure 9. Horizontal sync width measurement at the 50% amplitude points.

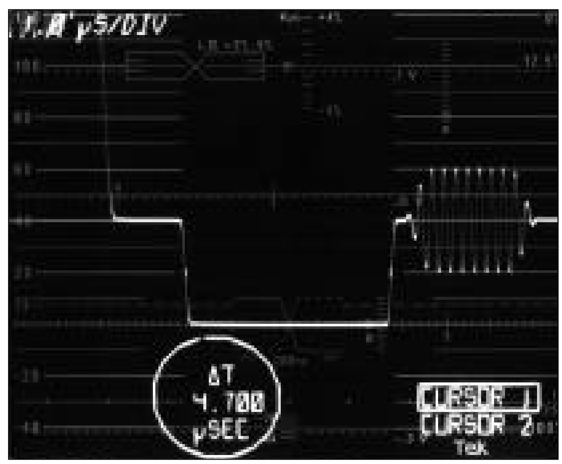


Figure 10. The 1780R time cursors positioned to measure horizontal sync width at the 50% amplitude points.

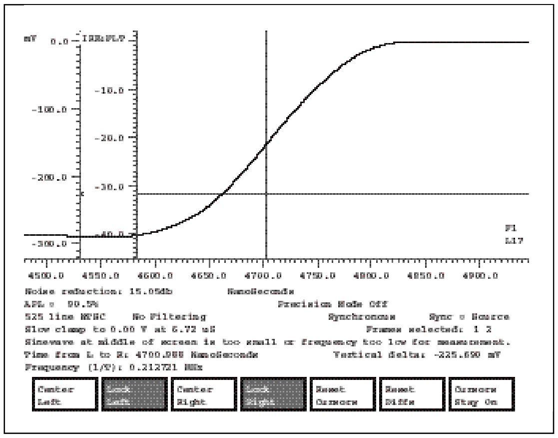


Figure 11. Horizontal sync width measurement at the 50% amplitude points using the VM700T cursors.

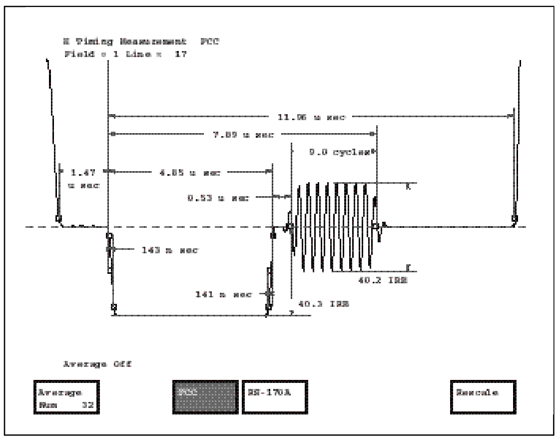


Figure 12. The H Timing Measurement display in the VM700T MEASURE mode.

Cursors (VM700T). The cursors in the VM700T WAVEFORM mode can be used to make pulse width measurements. After establishing the 100% and 0% points of sync, the cursors can be moved to either the 50% or 90% points to obtain a time measurement (see Figure 11). Consult the manual for detailed instructions on how to use the cursors.

VM700T Automatic Measurement. The H TIMING selection in the VM700T MEASURE mode displays all horizontal blanking interval timing measurements (see Figure 12). Note that either FCC or RS-170A measurements can be selected. Timing measurements are also available in the AUTO mode.

NOTES

7. Rise and Fall Time Measurements. Both the FCC requirements and RS-170A include specifications for the rise time and fall time of the sync pulse. These measurements are indicators of how fast the transitions occur. They are typically made between the 10% and 90% points of the transition. The methods used for measuring pulse widths can generally be applied to rise and fall times.

8. Burst Position and Number of Cycles. The position of burst with respect to sync and the number of subcarrier cycles in burst are specified and it may be desirable to occasionally verify these parameters. RS-170A calls for 9 cycles in burst while the FCC allows 8 to 11 cycles.

RS-170A specifies burst position with respect to sync in terms of subcarrier cycles. There are nominally 19 subcarrier cycles between the 50% point of the leading edge of sync and the start of burst (defined as "the zero crossing that precedes the first half-cycle of subcarrier that is 50% or greater of the burst amplitude"). The 1780R FSC TIME MARKS mode may be used to check this parameter. Refer to the SCH Phase section of this book for the measurement methodology.

9. Checking the Vertical Interval. The number of pulses in the vertical interval, as well as the widths of the equalizing pulses and vertical serrations, are also specified. Recommended limits can be found in Appendices C and D and most of the pulse width measurement methods discussed in this section can be applied.

DEFINITION

SCH (SubCarrier to Horizontal) Phase refers to the timing relationship between the 50% point of the leading edge of sync and the zero crossings of the reference subcarrier. Errors are expressed in degrees of subcarrier phase.

RS-170A specifies that SCH phase must be within ±40 degrees. Practically speaking, much tighter tolerances are generally maintained. Modern facilities often try to ensure that SCH phase errors do not exceed a few degrees.

PICTURE EFFECTS

SCH phase becomes important only when television signals from two or more sources are combined or sequentially switched. In order to prevent color shifts or horizontal jumps from occurring when a switch is made, the sync edges of the two signals must be accurately timed and the phase of color burst matched. Since both sync and subcarrier are continuous signals with a fixed relationship to one another, it is possible to simultaneously achieve both timing conditions only if the two signals have the same SCH phase relationship.

Because of the complex relationship between the sync and subcarrier frequencies, the exact SCH phase relationship for a given line repeats itself only once every four fields. In order to understand why this four-field sequence exists, first consider the fact that there are an odd number of subcarrier half-cycles in a line. This implies that SCH phase must be 180 degrees apart on adjacent lines. Since there are also an odd number of lines in a frame, the exact phase relationship between sync and burst for a given line repeats itself once every four fields (two frames).

In order to achieve the sync and burst timing conditions required for a clean switch between two signals, the four-field sequence of the signals must be properly lined up (i.e., Field 1 of Signal A and Field 1 of Signal B must occur at the same time). When this condition is achieved, the two signals are said to be "color framed." It is important to remember that color framing is inextricably tied to other system timing parameters and is by no means an independent variable. Only if two signals have the same SCH phase relationship and are properly color framed can the sync timing and burst phase matching requirements be achieved.

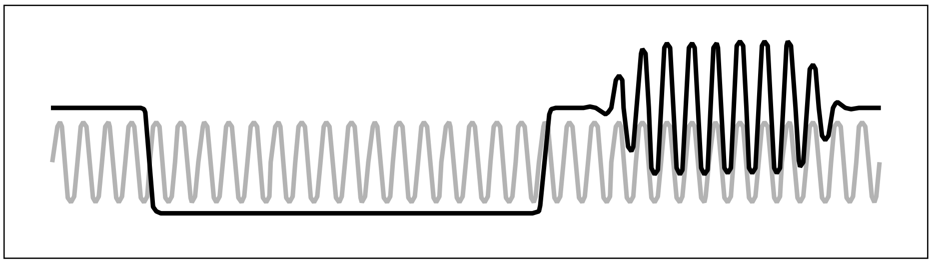


Figure 13. The SCH phase error of this signal is 0 degrees. Note that the 50% point of the leading edge of sync and a zero crossing of the extrapolated subcarrier are time coincident.

Figure 14. The 1780R polar SCH phase display showing an 8 degree error. Internal reference is used for synchronization.

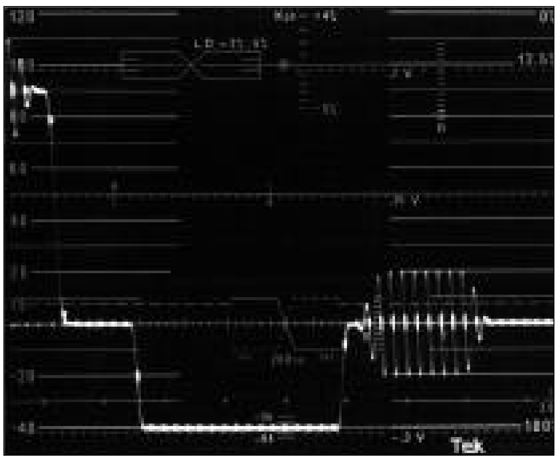


Figure 15. The 1780R FSC TIME MARKS display indicates that this signal has no SCH phase error.

Since signals must have the same SCH phase relationship in order to be cleanly combined, standardization on one value of SCH phase will clearly facilitate transfer of program material. This is the reason for trying to maintain 0 degrees of SCH phase error. Another reason for keeping SCH phase within reasonable limits is that various pieces of equipment need to be able to distinguish between the color frames in order to process the signal properly. This cannot be done accurately if the SCH phase error is allowed to approach 90 degrees.

TEST SIGNALS

SCH phase measurements can be made on any signal with both sync and color burst present.

MEASUREMENT METHODS

Polar Display. Some instruments, such as the 1780R, are equipped with a polar SCH display that consists of the burst vector and a dot representing horizontal sync. The phase relationship between the two can be determined by reading directly from the vector graticule or by using the precision phase shifter (see Figure 14).

The instrument must be internally referenced to measure the SCH phase of a single signal. Sync and burst of the selected signal are compared to each other in this mode. In the 1780R, two sync dots (180 degrees apart) are displayed along with the burst vector when internal reference is selected.

When external reference is selected, both burst and sync of the selected signal are displayed relative to burst of the external reference signal. A single sync dot appears with the burst vector in this mode. This display is used to determine whether or not two signals are color framed. Assuming that both the reference signal and the displayed signal have no SCH phase error, the sync dot will be in phase with the burst vector if the signals are color framed and 180 degrees away if they are not.

FSC Time Marks (1780R). The 1780R has a mode called FSC TIME MARKS which is accessible through the MEASURE menu. In this mode, bright dots appear on the waveform at intervals of precisely one subcarrier cycle. The dots can be advanced or delayed with respect to the waveform with the precision phase shifter.

To make a measurement, use the phase shifter to set one of the dots on the 50% point of the leading edge of sync. If there is no SCH phase error, the dots on the burst should fall on the zero crossings at the blanking level (see Figure 15). If there is an error and a numeric measurement result is desired, press REF SET to zero the phase readout and use the phase shifter to position the burst dots on the zero crossings. At this point the phase readout indicates the amount of SCH phase error.

This method is not as precise as the polar display but has the advantage of allowing verification that there are 19 subcarrier cycles between sync and burst. Since this mode is independent of instrument calibration, it is also useful for checking calibration of the polar display.

VM700T Automatic Measurement. Select SCH PHASE in the VM700T MEASURE menu to obtain a display of SCH phase. Figure 16 shows the VM700T polar SCH phase display which is similar to the SCH phase display of the 1780R. The VM700T full field SCH phase display (see Figure 17) plots the SCH phase of each line in the field and provides an average result. SCH phase measurements are also available in the AUTO mode.

NOTES

10. For More Information. For a comprehensive discussion of SCH phase and color framing issues, see Tektronix Application Note 20W-5613-2, “Measuring and Monitoring SCH Phase with the 1750A Waveform/ Vector Monitor”.

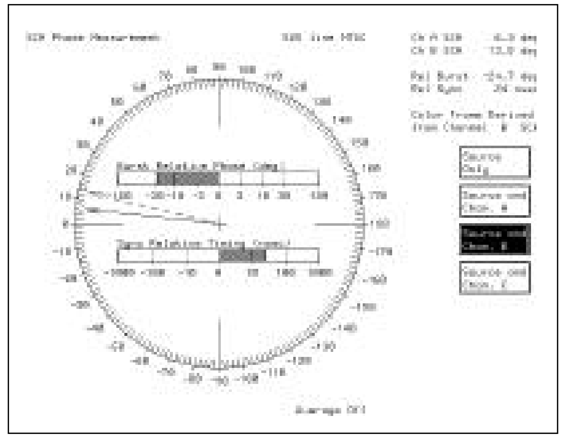


Figure 16. The VM700T polar SCH Phase Measurement display.

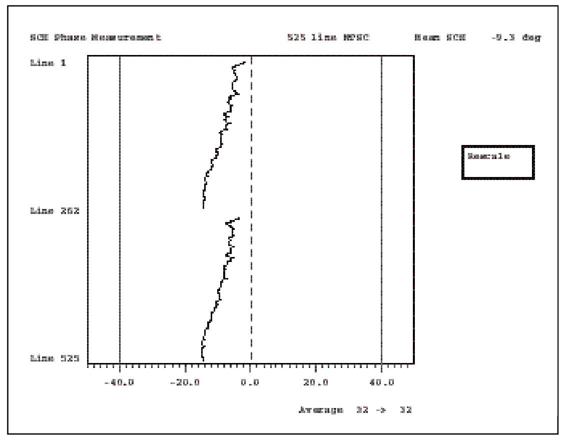


Figure 17. The VM700T full field SCH Phase Measurement display.

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".

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.

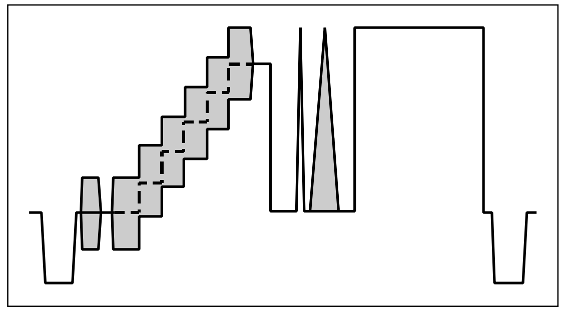


Figure 18. A composite signal (also known as FCC Composite) containing a modulated sine-squared sine pulse.

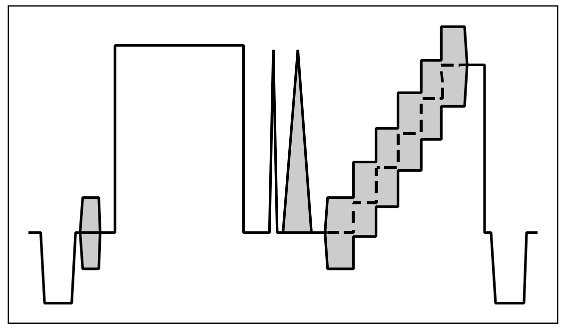


Figure 19. The composite signal specified in the EIA 250-C Standard (also known as NTC-7 Composite).

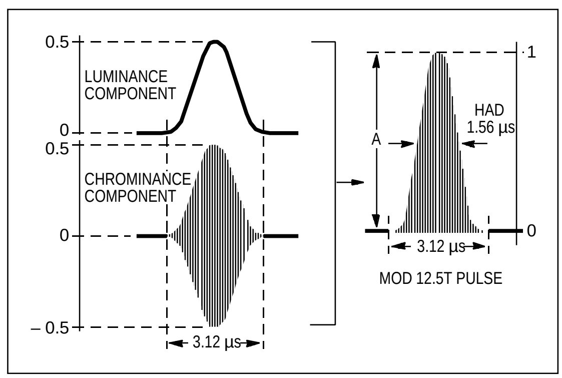


Figure 20. Chrominance and luminance components of the modulated 12.5T pulse.

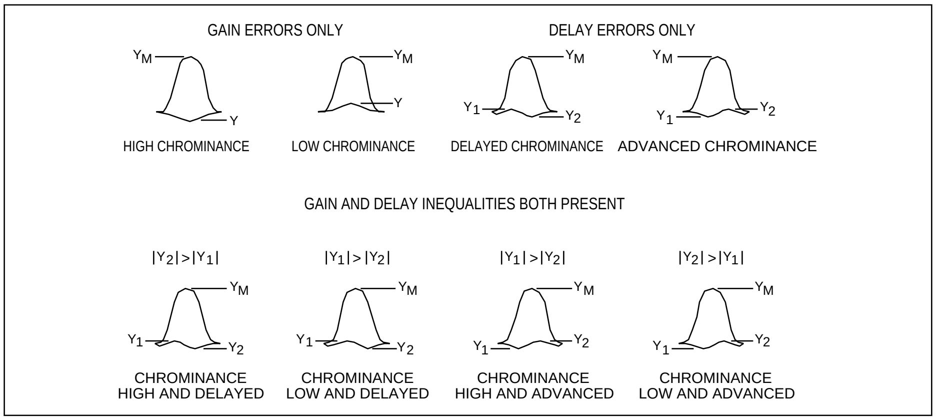


Figure 21. Effects of gain and delay inequalities on the modulated 12.5 T pulse.

The 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.

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.

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.

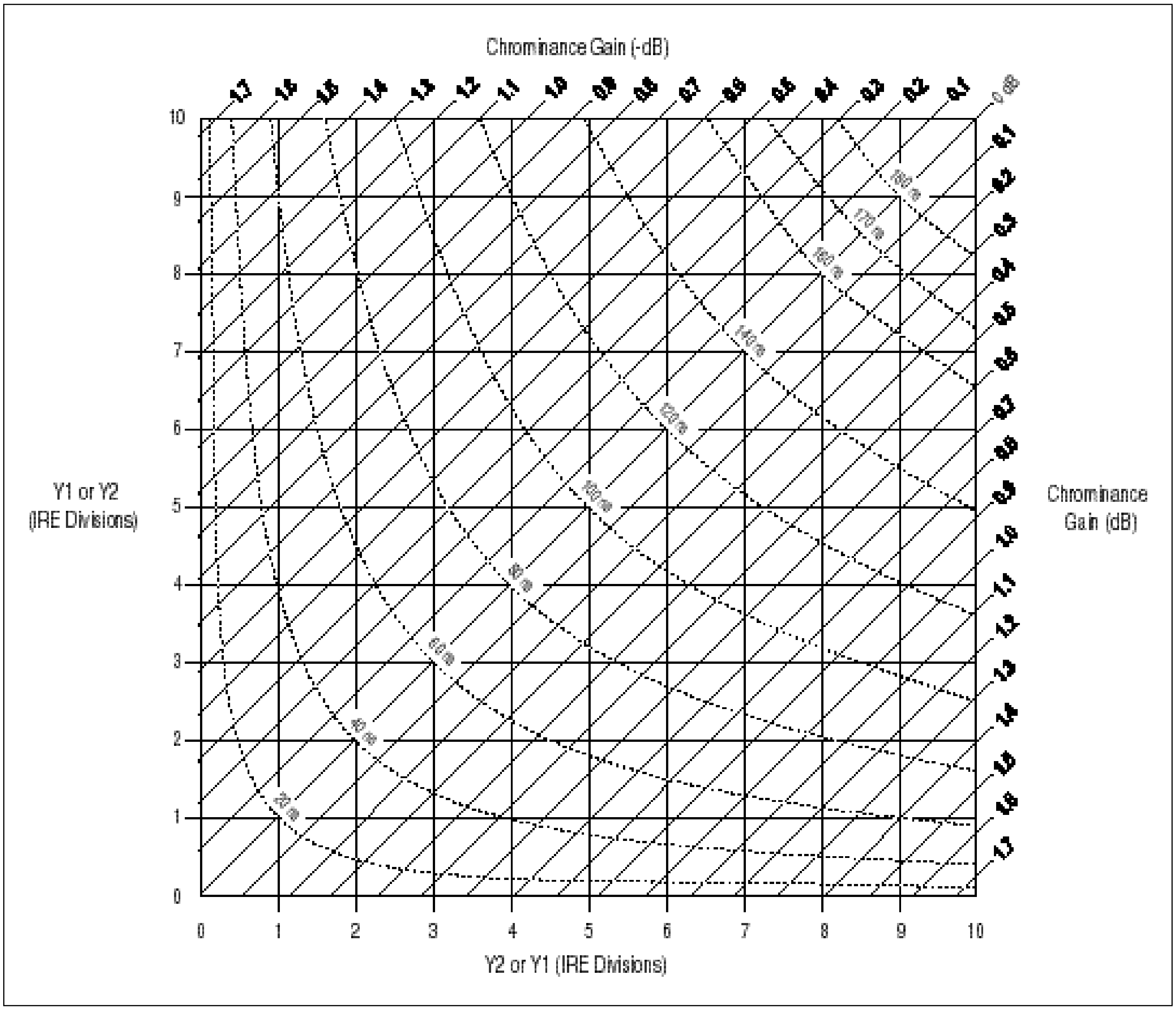


Figure 22. Chrominance-to-luminance gain and delay nomograph.

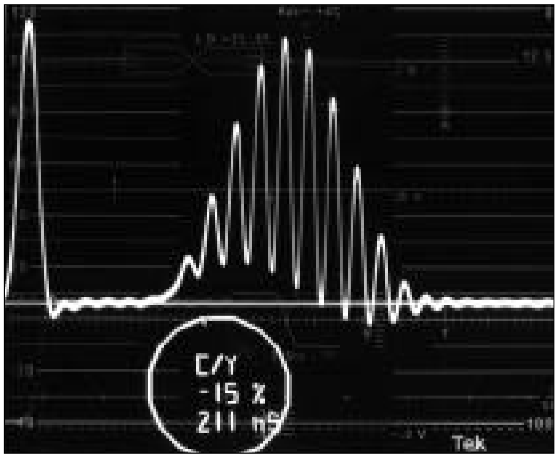


Figure 23. Results obtained with the CHROMA/LUMA selection in the 1780R MEASURE mode.

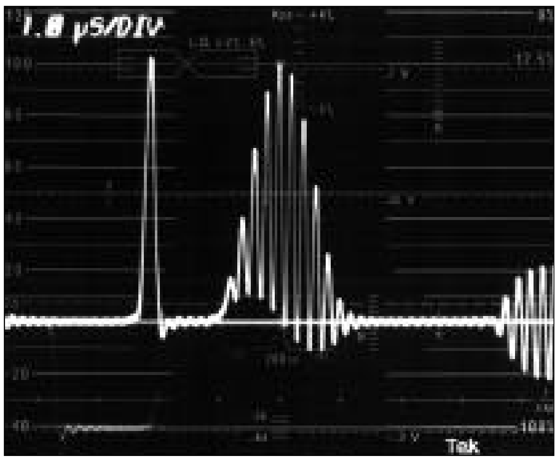


Figure 24. The 1780R graticule indicates that this signal has approximately 200 nanoseconds of chrominance-to-luminance delay.

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.

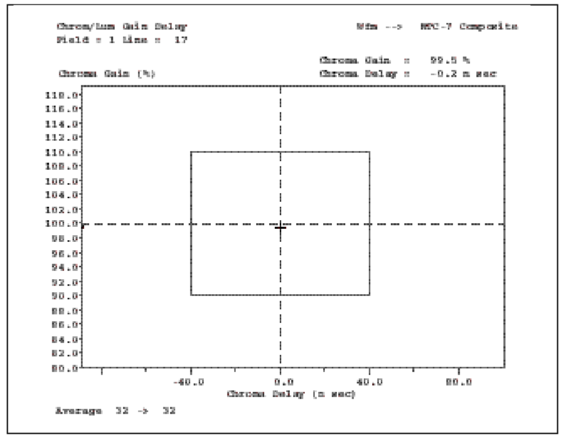


Figure 25. The Chrominance/Luminance Gain Delay display in the VM700T MEASURE mode.

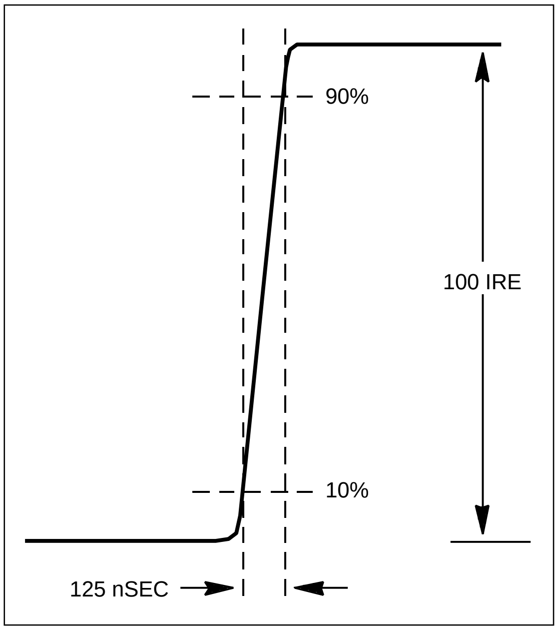


Figure 26. A T rise time bar has a 10% to 90% rise time of 125 nanoseconds.

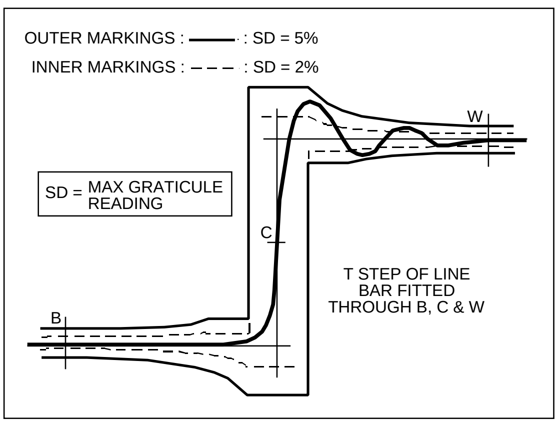


Figure 27. A short time distortion graticule.

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.

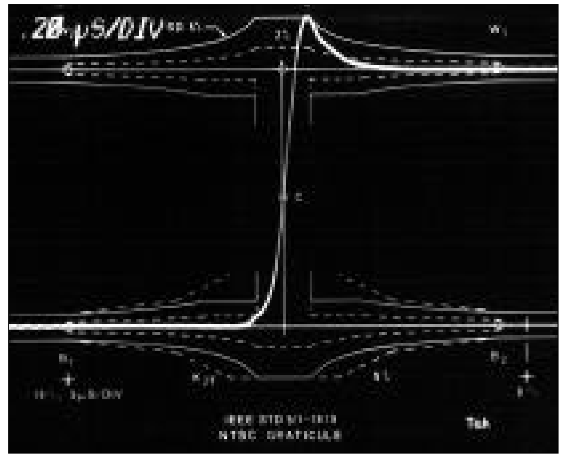


Figure 28. This waveform exhibits short time distortion of 5% SD.

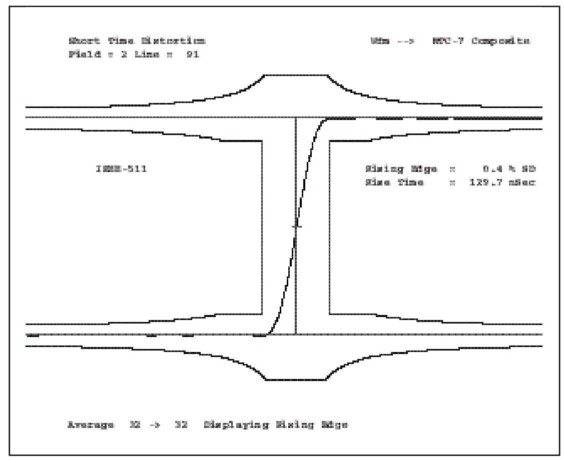


Figure 29. VM700T Short Time Distortion display.

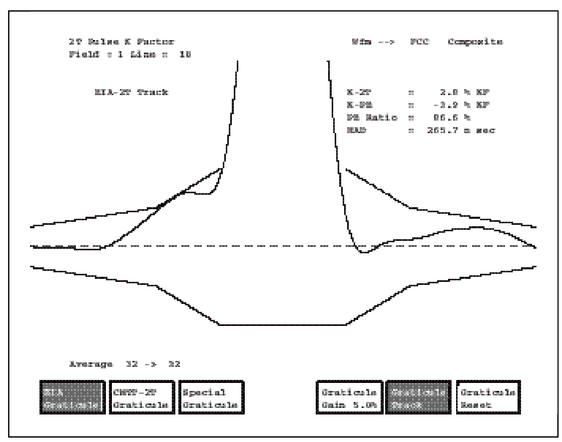


Figure 30. Pulse-to-bar ratio is given in the VM700T MEASURE mode K FACTOR selection.

Line Time Distortion

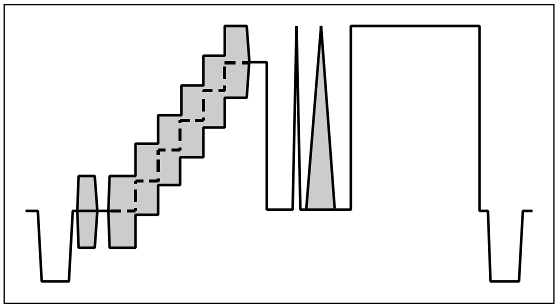


Figure 31. A composite signal (also known as FCC Composite).

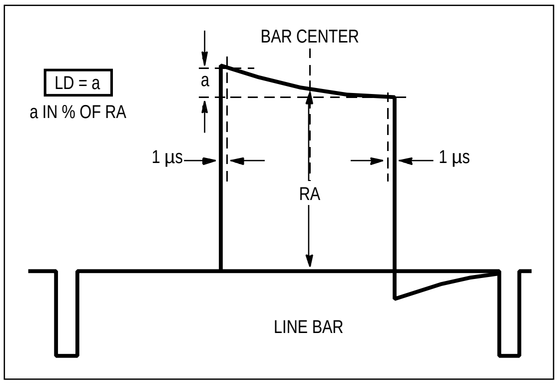


Figure 32. Parameters for measurement of line time distortion.

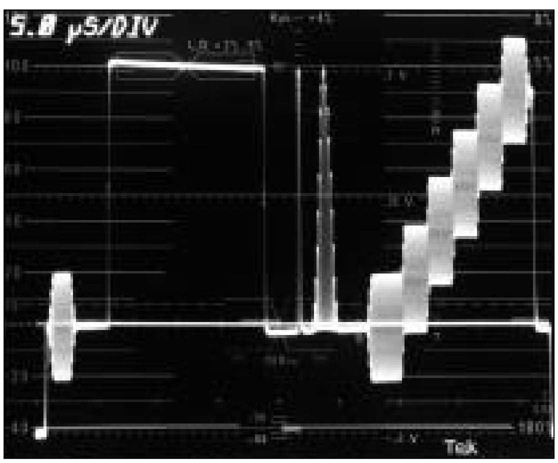


Figure 33. Using the waveform monitor graticule to measure line time distortion. A 3% distortion is shown here.

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.

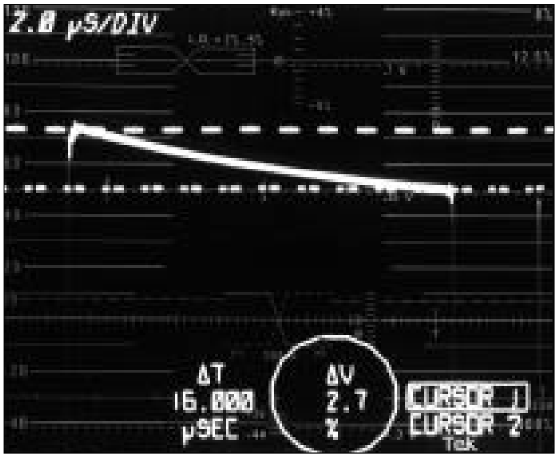


Figure 34. The 1780R voltage and time cursors can facilitate line time distortion measurements.

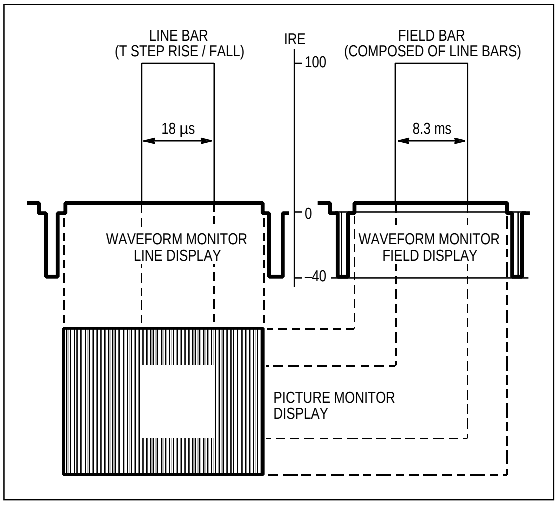


Figure 35. The window signal.

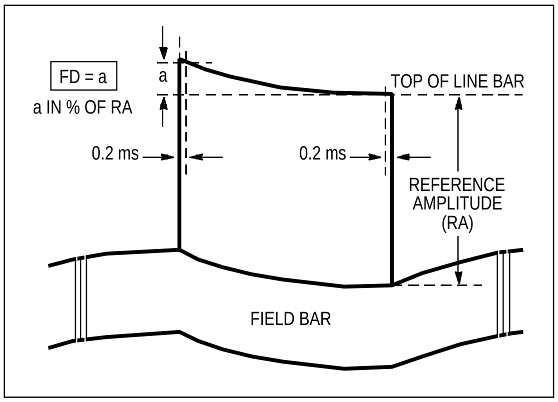


Figure 36. Parameters for measurement of field time distortion.

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.

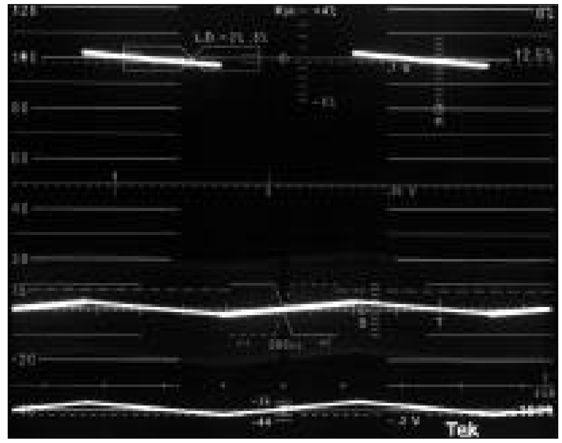


Figure 37. A 2-field waveform monitor display showing about 5% field time distortion.

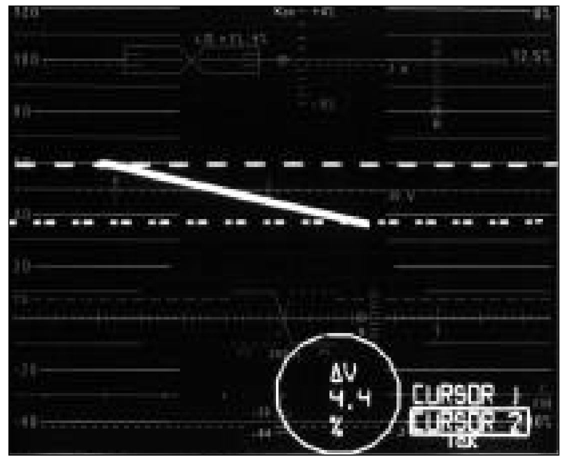


Figure 38. The 1780R voltage cursors can be used to measure field time distortion.

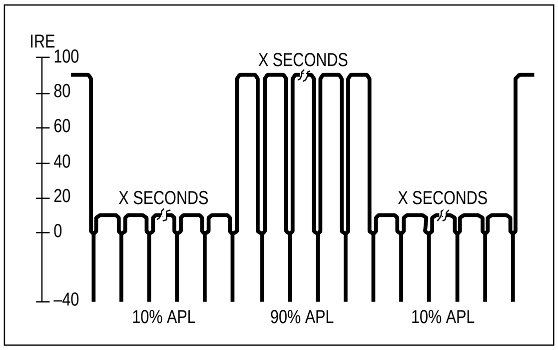


Figure 39. A flat field bounce signal.

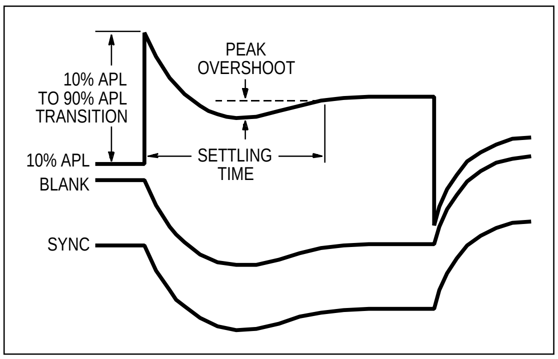


Figure 40. Long time distortion measurement parameters.

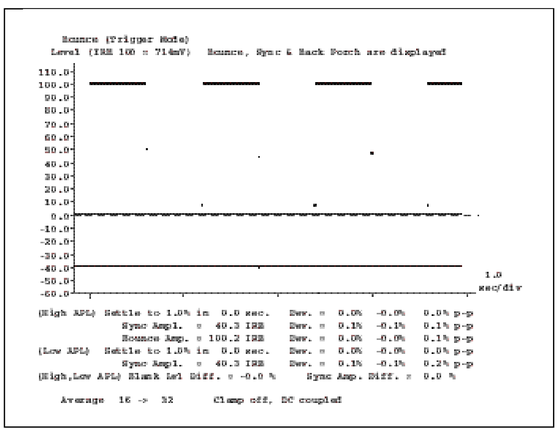


Figure 41. The VM700T Bounce display.

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.

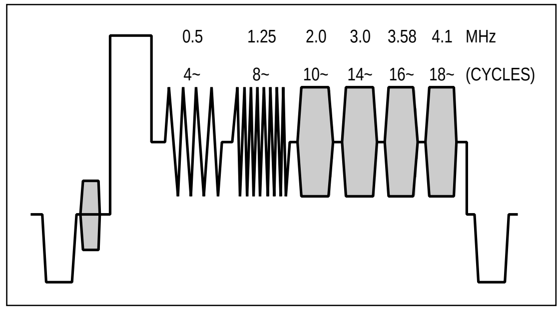


Figure 42. A reduced amplitude multiburst signal (also known as FCC Multiburst).

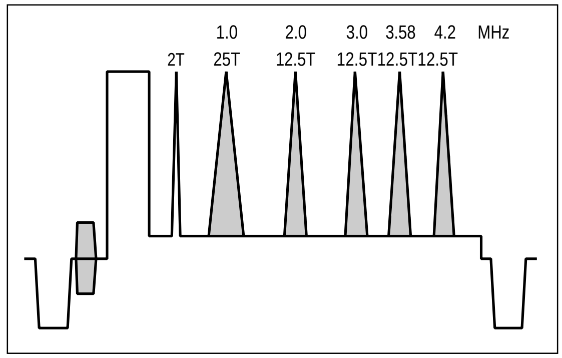


Figure 43. A 70 IRE multipulse signal.

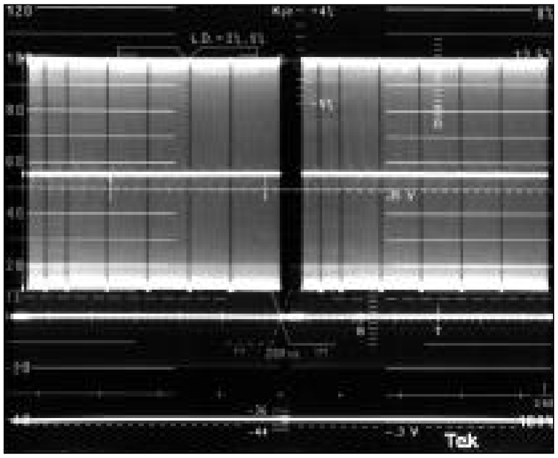


Figure 44. A 6 MHz field rate sweep signal with markers (2-field display).

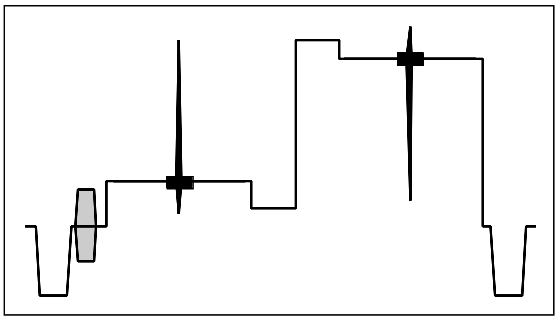


Figure 45. A time domain display of the (sin x)/x signal.

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.

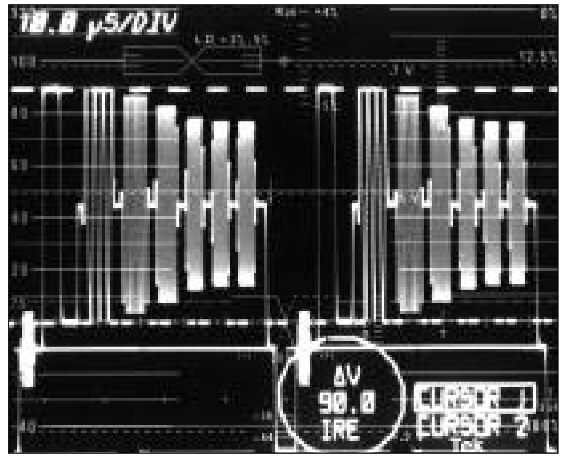


Figure 46. The square wave is measured as a reference.

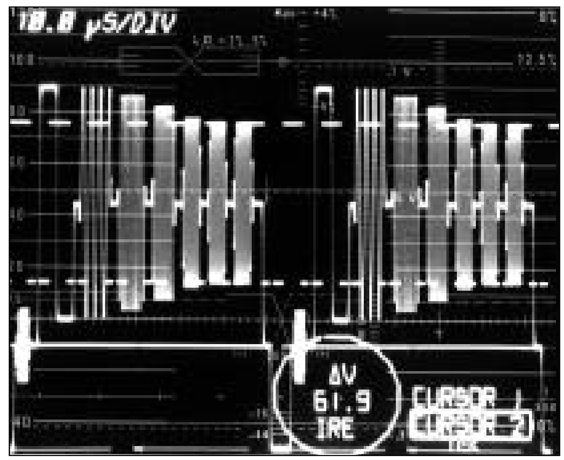


Figure 47. The peak-to-peak amplitude of the smallest packet is then measured.

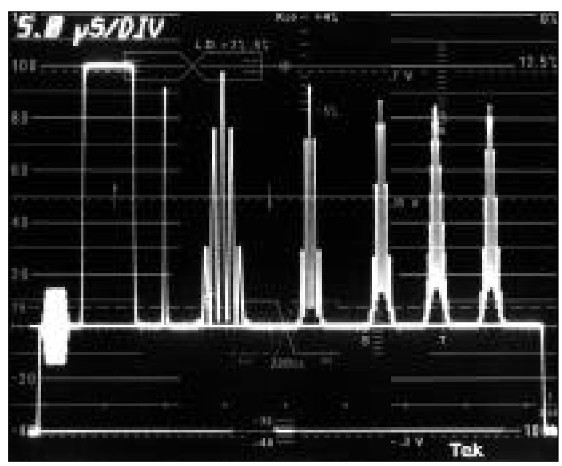


Figure 48. The multipulse signal exhibiting high frequency roll-off.

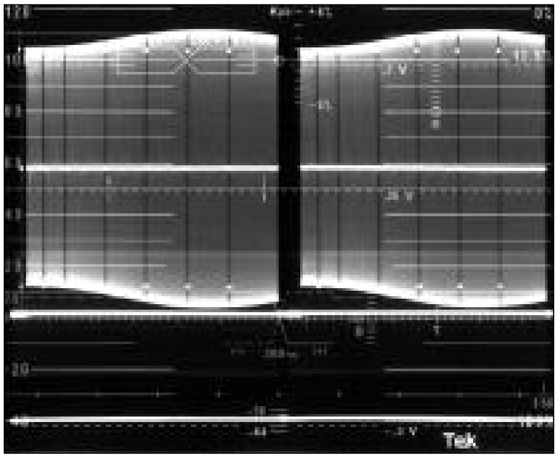


Figure 49. A field rate sweep signal showing frequency response distortion.

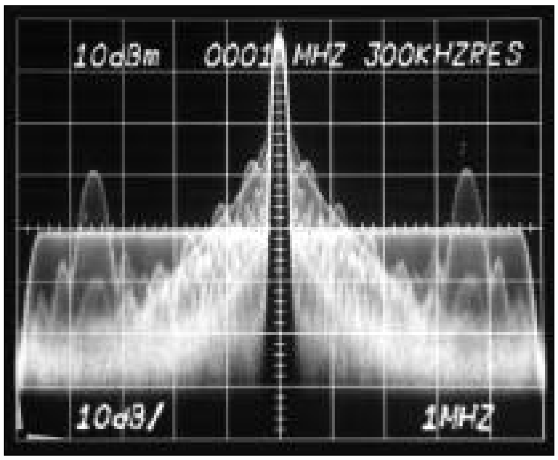


Figure 50. A spectrum analyzer display of a (sin x)/x signal with a cutoff frequency of 4.75 MHz.

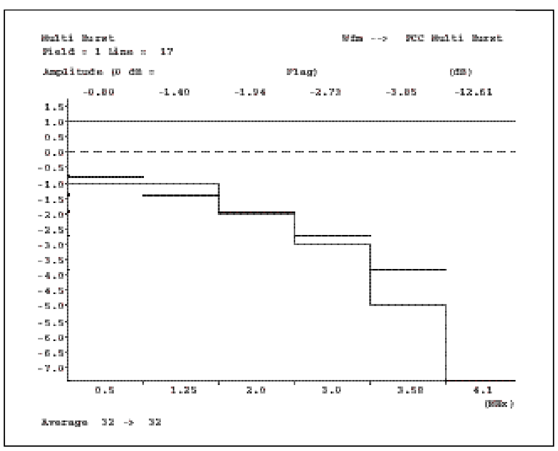


Figure 51. The VM700T Multiburst measurement.

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).

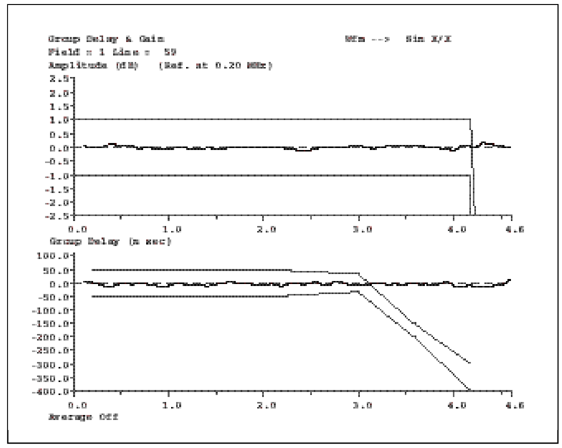


Figure 52. The VM700T Group Delay & Gain measurement also provides frequency response information.

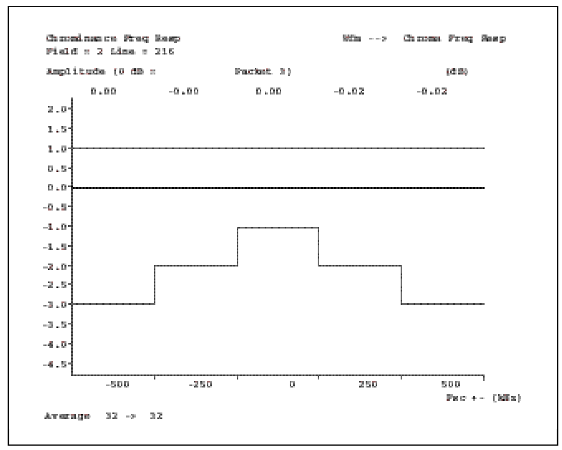


Figure 53. The VM700T Chroma Frequency Response measurement.

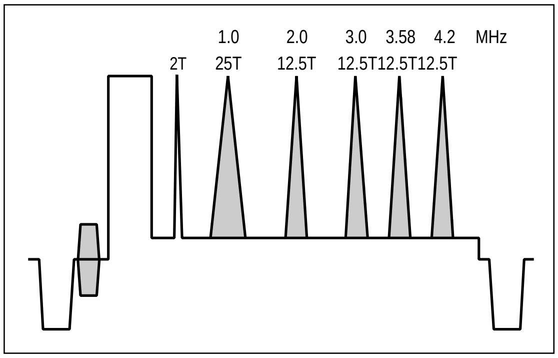


Figure 54. The multipulse signal.

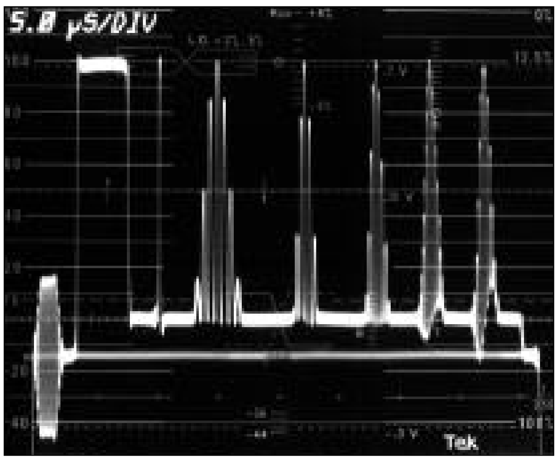


Figure 55. The multipulse signal exhibiting group delay distortion. Group delay differences between the low and high-frequency components of the pulse appear as sinusoidal distortion of the baseline.

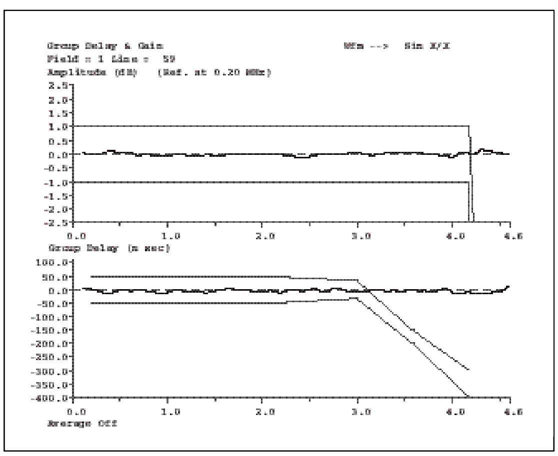


Figure 56. The VM700T Group Delay & Gain display.

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.

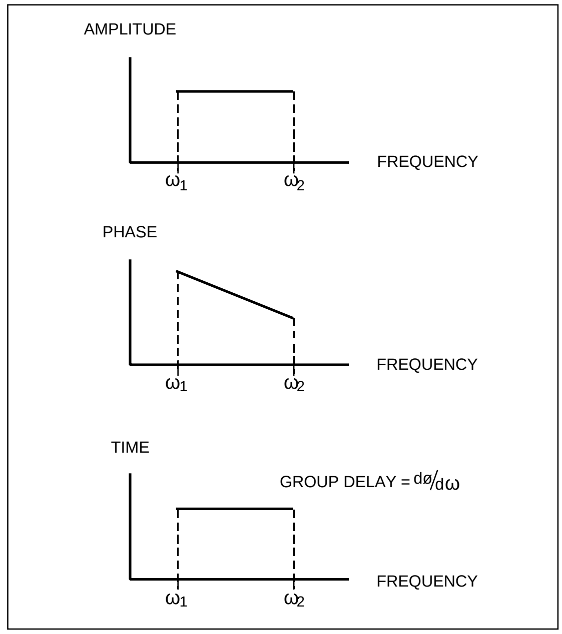


Figure 57. Response of a distortion free system.

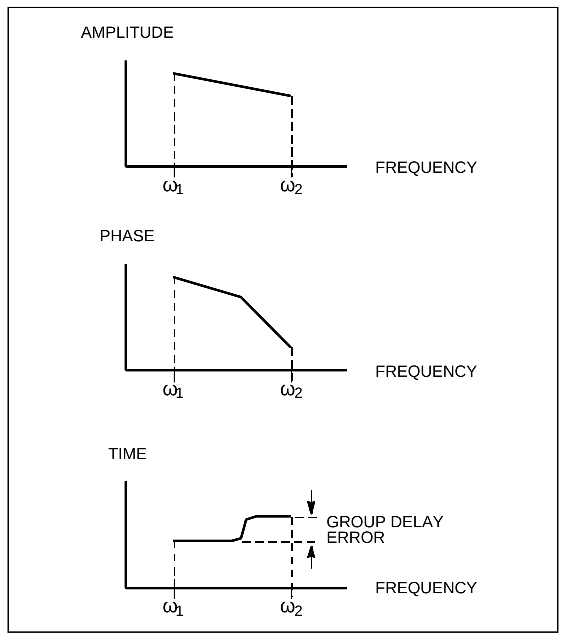


Figure 58. Response of a system with amplitude and phase distortion.

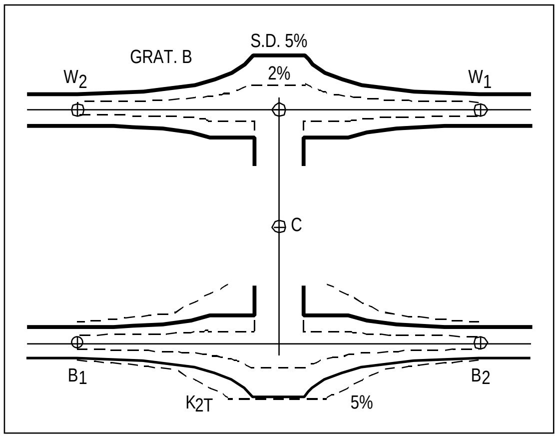


Figure 59. The outer dotted lines at the bottom of the 1780R external graticule indicate 5% K_{2T} limits.

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.

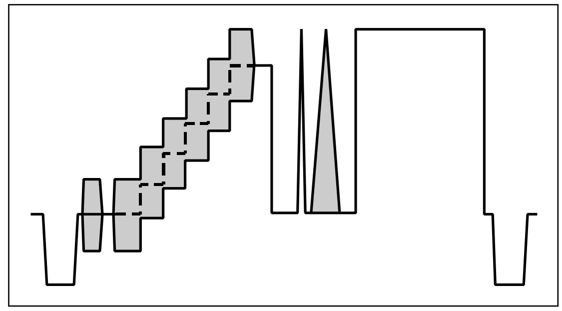


Figure 60. A composite signal (also known as the FCC Composite) with the elements required for K Factor measurements.

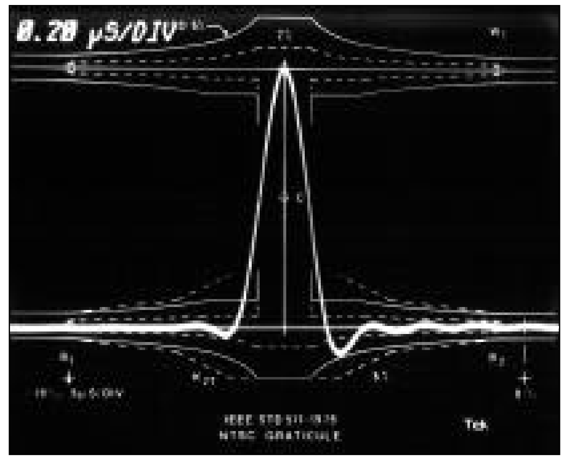


Figure 61. A 2T pulse properly positioned for a K_{2T} measurement with the 1780R external graticule.

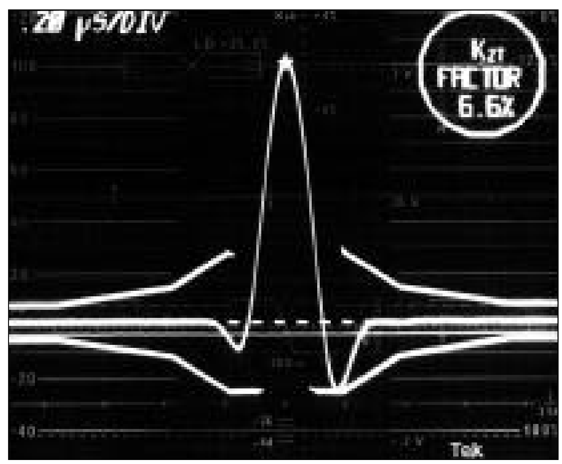


Figure 62. The 1780R electronic K Factor graticule.

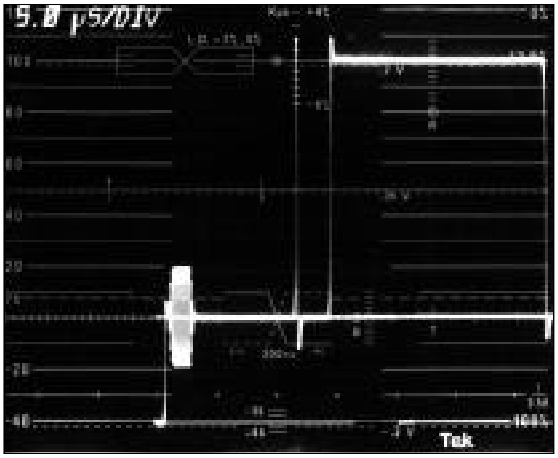


Figure 63. The 1780R graticule indicates 2% $K_{pulse/bar}$.

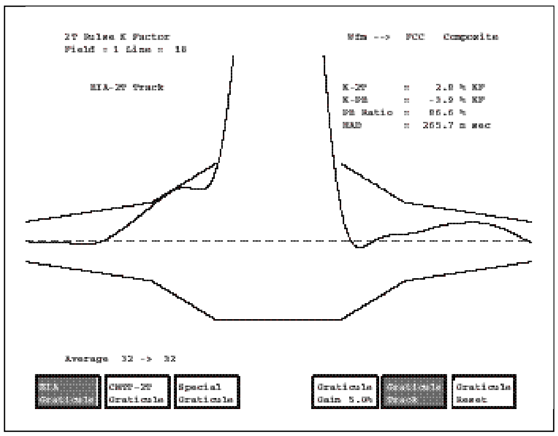


Figure 64. The VM700T 2T Pulse K Factor measurement display.

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%

III. NONLINEAR DISTORTIONS

Amplitude dependent waveform distortions are often referred to as nonlinear distortions. This classification includes distortions that are dependent on APL (Average Picture Level) changes and/or instantaneous signal level changes.

Since amplifiers and other electronic circuits are linear over only a limited range, they tend to compress or clip large signals. The result is nonlinear distortion of one type or another. Nonlinear distortions may also manifest themselves as crosstalk and intermodulation effects between the luminance and chrominance portions of the signal.

The first three distortions discussed in this section are differential phase, differential gain, and luminance nonlinearity. These are by far the most familiar and most frequently measured nonlinear distortions. These parameters are included in the performance specifications of most video equipment and are regularly evaluated in television facilities. The other distortions are generally not measured as frequently, however, they are included in most measurement standards and performance checks.

It is recommended that nonlinear distortions be measured at mid APL and at the APL extremes. Some test signal generators provide signals with different APL by combining the test signal with a variable level pedestal. This is usually accomplished by alternating between one line of the test signal and a group of four lines of the pedestal with the sequence repeated throughout the field. Since in-service measurements cannot be made with full field test signals, measurements requiring control of APL are often excluded from routine testing.

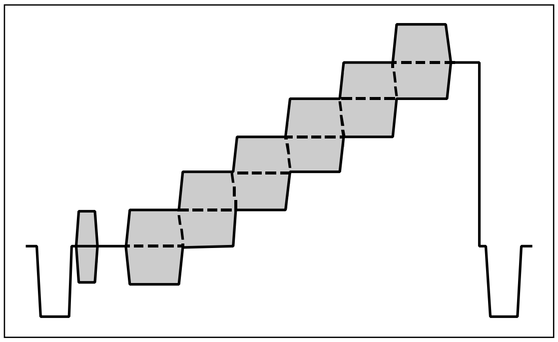


Figure 65. A 5-step modulated staircase signal.

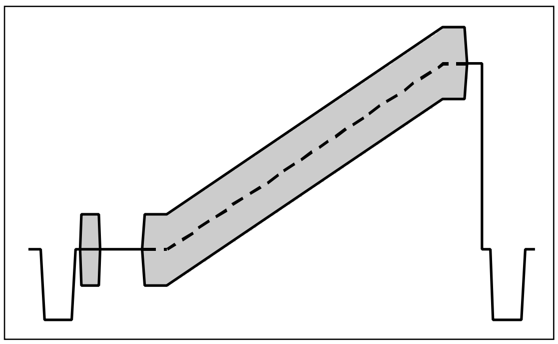


Figure 66. A modulated ramp signal.

DEFINITION

Differential phase distortion, often referred to as "diff phase" or "dP", is present when chrominance phase is affected by luminance level. This distortion occurs when chrominance information is not uniformly processed at all luminance levels.

Differential phase distortion is expressed in degrees of subcarrier phase. Since both positive and negative (lead and lag) phase errors may occur in the same signal, it is important to specify whether the peak-to-peak phase error or maximum deviation from zero is being quoted. In general, NTSC measurement standards (and this booklet) refer to peak-to-peak measurements.

Differential phase should be measured at different average picture levels and the worst error quoted.

PICTURE EFFECTS

When differential phase distortion is present, changes in hue occur when picture brightness changes. Colors may not be properly reproduced, particularly in high brightness areas of the picture.

TEST SIGNALS

Differential phase is measured with a test signal that consists of uniform phase chrominance superimposed on different luminance levels. A modulated staircase (5 or 10 step) or a modulated ramp is typically used (see Figures 65 and 66). A ramp is normally used when performing measurements on devices and systems that convert the signal from analog to digital and back to analog.

MEASUREMENT METHODS

Differential phase can be easily measured after the chrominance has been demodulated and presented on a vector display. Although a standard vector display can indicate the presence of large amounts of distortion, a vectorscope equipped with a special DIFF PHASE mode or an automatic measurement set such as the VM700T is required for precision measurements.

Vectorscope Display. In a vectorscope display, elongation of the dot in the direction of the graticule circumference indicates the presence of differential phase. Measurements are made by using the vectorscope variable gain control to bring the signal vector out to the graticule circle and reading the amount of distortion from the graticule. Vectorscope graticules generally have marks on the left-hand side to help quantify the error (see Figure 67).

R-Y Sweep. Although errors show up in the vectorscope display, there are some advantages to be gained by examining the demodulated R-Y signal in a voltage versus time display. (Recall that the R-Y signal drives the vertical axis of a vectorscope.) First of all, more gain and therefore more measurement resolution is possible in waveform displays. Secondly, the sweep display facilitates correlation of the R-Y signal with the original test signal in the time dimension. This allows determination of exactly how the effects of differential phase vary with luminance level or how they vary over a field.

Precise measurements of differential phase are therefore made by examining a voltage versus time display of the demodulated R-Y information. Distortions manifest themselves as tilt or level changes across the line.

Two different types of R-Y displays, known as "single trace" and "double trace" , can be used to make this measurement. As described below, different measurement techniques are used with the two displays. In the 1780R, these modes are both accessed by selecting DIFF PHASE in the MEASURE menu. The SINGLE/DOUBLE touchscreen selection determines which of the two displays will appear.

R-Y Sweep - Single Trace Method. In the single trace mode, distortions are quantified by comparing the R-Y waveform to a vertical graticule scale.

To make a measurement, first set the signal vector to the reference (9 o'clock) phase position. Use the vectorscope variable gain control to set the signal vector out to the edge of the vectorscope graticule circle. Make sure the 1780R waveform monitor gain is in the calibrated (1 volt full scale) setting.

The R-Y display appears on the waveform (right-hand) screen in the 1780R. Each major division (10 IRE) on the vertical graticule scale corresponds to one degree when the R-Y waveform is being displayed. The amount of differential phase distortion may be determined by measuring the largest vertical deviation between two parts of the signal (see Figure 68).

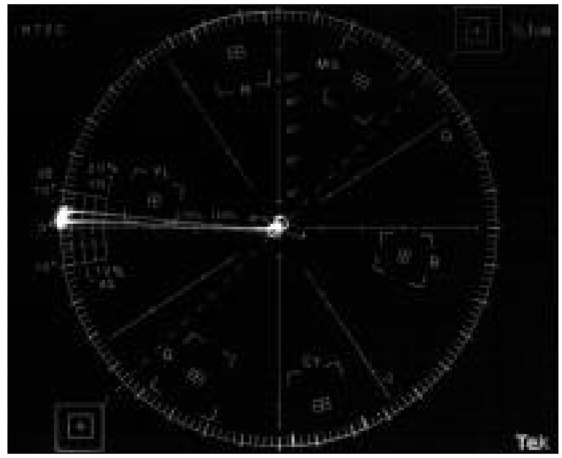


Figure 67. A vectorscope display showing a 5 degree differential phase distortion.

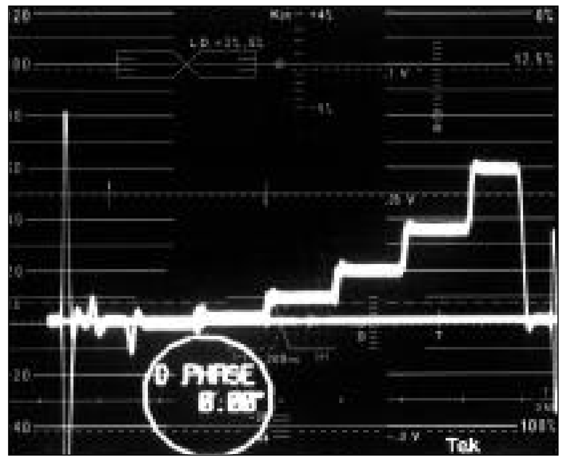


Figure 68. The 1780R single trace DIFF PHASE display indicating 6 degrees of differential phase distortion. The 0.00 D PHASE readout indicates a properly adjusted display, ready for the measurement result to be read from the graticule.

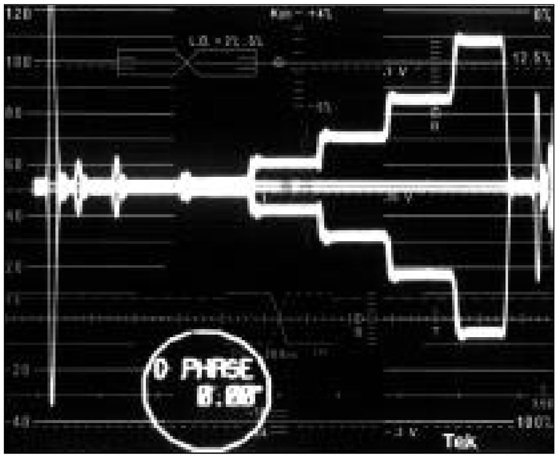


Figure 69. The 1780R double trace DIFF PHASE display with the phase readout zeroed.

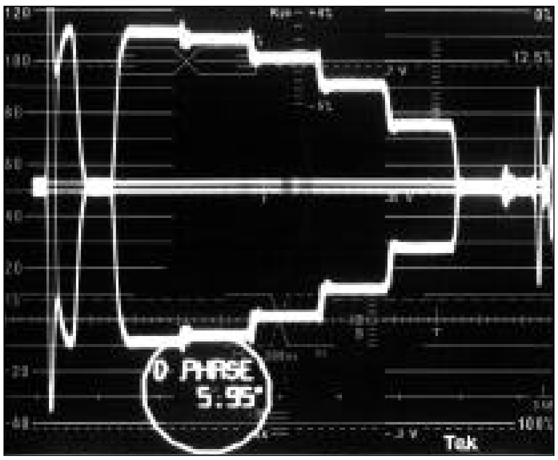


Figure 70. The double trace DIFF PHASE display with the measurement results indicated on the readout.

R-Y Sweep - Double Trace Method. The double trace method provides a more accurate way of measuring the tilt in a one-line sweep of the R-Y information. Instead of comparing the waveform to a graticule, the vectorscope calibrated phase shifter is used to quantify the error.

The double trace display, which appears on the waveform screen in the 1780R, is produced by displaying the single trace R-Y information non-inverted for half the lines and inverted for the other half. As shifting phase moves the two traces vertically with respect to each other, measurements can be made by introducing calibrated amounts of phase shift with the vectorscope phase control. The basic technique involves establishing a reference at one extreme of the tilt by bringing the inverted and non-inverted traces together at that point. The amount of phase shift required to bring the two traces together at the other extreme of the tilt is the differential phase distortion.

Select DOUBLE in the 1780R DIFF PHASE mode to make this measurement. Use the phase shifter to set the signal vector to the reference (9 o'clock) phase position. Neither vectorscope or waveform monitor gain is critical in this mode (see Note 22), however, setting the vector to the graticule circle is a good starting point. Use the phase shifter to bring the largest negative excursion of the upper (non-inverted) waveform to meet its mirror image. When they just touch, press REF SET to set the phase readout to 0.00 degrees (see Figure 69). Now use the phase shifter to bring the largest positive excursion in the upper trace to meet its mirror image. The readout will indicate the amount of differential phase distortion (see Figure 70).

A similar DOUBLE MODE technique is used with the 520A Vectorscope. Start by setting the CALIBRATED PHASE dial to zero. Use the A or B phase control to null the largest negative excursion and then use the calibrated phase shifter to null the largest positive excursion. The number above the calibrated phase dial will indicate the amount of differential phase.

VM700T Automatic Measurement. To make an automatic measurement of differential phase with the VM700T, select DG DP in the MEASURE mode. Both differential phase and differential gain are shown on the same display (see Figure 71). The lower graph is differential phase. These measurements are also available in the AUTO mode.

NOTES

22. 1780R Waveform and Vector Gains. In the single trace mode, the vector gain must be set so the signal vector extends to the graticule circle. The waveform gain must be in the calibrated position. The graticule is calibrated to one degree per division only under these conditions.

With the double mode display, however, more gain may be used for greater resolution. Additional vectorscope gain and/or waveform vertical gain can be selected without affecting the measurement results.

23. Signal Vector. The test signals used for measuring differential phase and gain may have either 20 IRE or 40 IRE chrominance at the same phase as color burst. With 40 IRE chrominance the burst and signal vectors coincide on the vectorscope display. With a 20 IRE signal, the burst and signal vectors will have the same phase but different amplitudes. In this case, be sure to set the 20 IRE signal rather than the 40 IRE burst out to the vector graticule circle. The signal gain is what must be normalized.

24. Noise Reduction Filter. A digital recursive filter is available in the 1780R to facilitate differential phase and gain measurements in the presence of noise. Select the NOISE REDUCTION ON touch-screen selection in the DIFF PHASE or DIFF GAIN menu to enable the filter. The filter removes approximately 15 dB of noise from the signal without any loss of bandwidth or horizontal resolution. This mode is particularly useful for VTR and transmitter measurements.

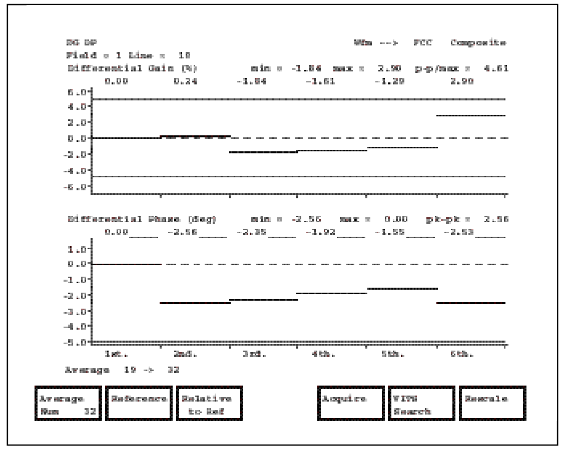


Figure 71. The VM700T DG DP display.

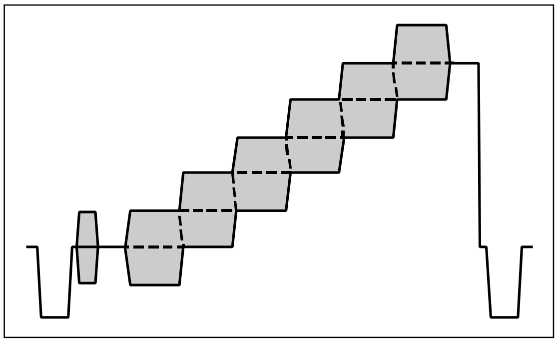


Figure 72. A 5-step modulated staircase signal.

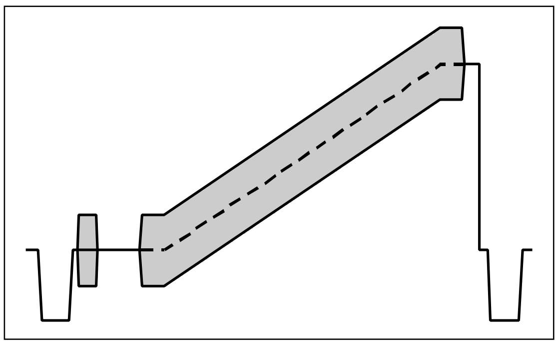


Figure 73. A modulated ramp signal.

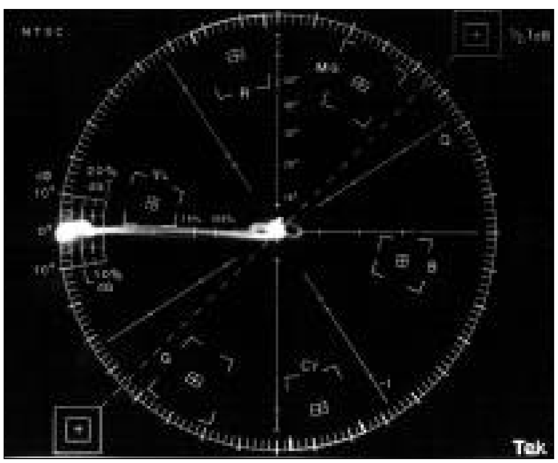


Figure 74. A vectorscope display indicating 15% differential gain.

DEFINITION

Differential gain, often referred to as "diff gain" or "dG", is present when chrominance gain is affected by luminance level. This distortion occurs when chrominance information is not uniformly processed at all luminance levels.

The amount of differential gain distortion is expressed in percent. Since both attenuation and peaking of chrominance can occur in the same signal, it is important to specify whether the maximum overall amplitude difference or the maximum deviation from the blanking level amplitude is being quoted. In general, NTSC measurement standards (and this booklet) specify the largest amplitude deviation between any two levels expressed as percent of the largest chrominance amplitude.

Differential gain should be measured at different average picture levels and the worst error quoted.

PICTURE EFFECTS

When differential gain distortion is present, changes in color saturation occur when picture brightness changes. Colors may not be properly reproduced, particularly in high brightness areas of the picture.

TEST SIGNALS

Differential gain is measured with a test signal that consists of uniform amplitude chrominance superimposed on different luminance levels. A modulated staircase (5 or 10 step) or a modulated ramp is typically used (see Figures 72 and 73).

MEASUREMENT METHODS

Differential gain distortions can be quantified in a number of ways. Chrominance amplitudes can be measured directly with a waveform monitor and large distortions can be seen on a vectorscope display. For precision measurements, however, a vectorscope with a special DIFF GAIN mode or an automatic measurement set such as the VM700T is required.

Vectorscope Display. Elongation of the dot in the radial direction indicates the presence of differential gain in a vectorscope display. Measurements can be made by using the vectorscope variable gain control to bring the signal vector out to the graticule circle and reading the amount of distortion from the graticule. Most vectorscope graticules have special marks on the left side to help quantify the error (see Figure 74).

Waveform Monitor/Chrominance Filter. Differential gain measurements can also be made with a waveform monitor. This process is facilitated by enabling the chrominance filter which passes only the chrominance portion of the signal. Peak-to-peak chrominance amplitude can be easily measured in the resulting display. To make a measurement, first normalize the peak-to-peak amplitude of the highest chrominance level to 100 IRE. Then measure the peak-to-peak amplitude of the lowest chrominance level. The amplitude difference, expressed in percent, is the amount of differential gain distortion (see Figure 75).

This measurement can also be made by using the 1780R voltage cursors in the RELATIVE mode. Define the peak-to-peak amplitude of the highest chrominance level as 100%. Then move the cursors to measure peak-to-peak amplitude of the lowest chrominance level. The amplitude difference, expressed in percent, is the amount of differential gain distortion.

In either case, remember that it is the difference between the highest and lowest chrominance amplitudes that represents the amount of differential gain distortion. If the lowest chrominance level is 90% of the highest, a differential gain error of 10% should be quoted.

B-Y Sweep. Some vectorscopes are equipped with a special mode for making accurate differential gain measurements. A line sweep of demodulated B-Y information is displayed with errors manifested as tilt or level changes across the line. Like the R-Y display used to measure differential phase, this display provides greater resolution and an indication of how distortion varies over a line or field. In the 1780R, both "single trace" and "double trace" versions of this display are available. Both are accessed by selecting DIFF GAIN in the MEASURE menu.

B-Y Sweep - Single Trace Method. The single trace differential gain display is familiar to users of the 520A Vectorscope and is also available in the 1780R by selecting SINGLE in the DIFF GAIN menu. Errors are quantified by comparing the demodulated waveform to a vertical graticule scale.

Use the phase shifter to set the signal vector to the reference (9 o'clock) position prior to making this measurement. Adjust the vectorscope variable gain control so the signal vector extends to the edge of the graticule circle. Make sure the 1780R waveform gain is in the calibrated (1 volt full scale) setting.

In the 1780R, the differential gain display appears on the waveform screen. Compare the waveform to the vertical scale on the graticule and measure the largest deviation between any two parts of the signal. One major graticule division (10 IRE) is equal to one percent (see Figure 76).

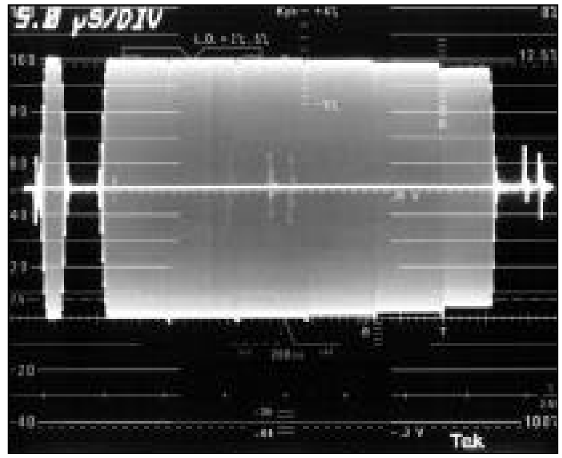


Figure 75. A chrominance filter display indicating about 7% differential gain.

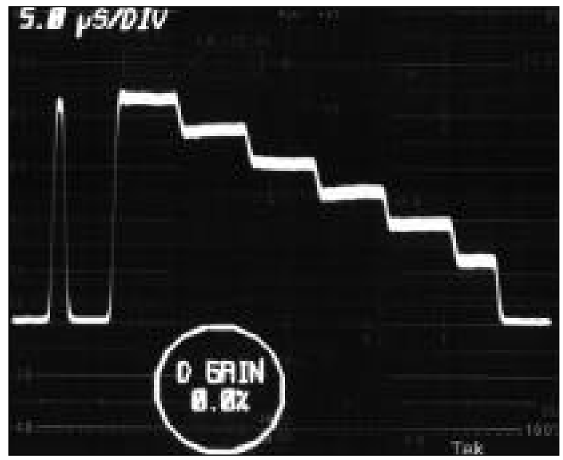


Figure 76. The 1780R single trace DIFF GAIN display indicating a distortion of 6%. As with diff phase, the single trace diff gain measurement result is read off the graticule, not the D GAIN readout.

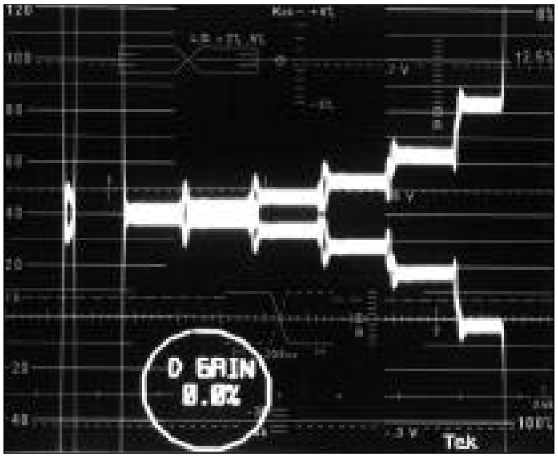


Figure 77. The 1780R double trace DIFF GAIN display with the gain readout zeroed.

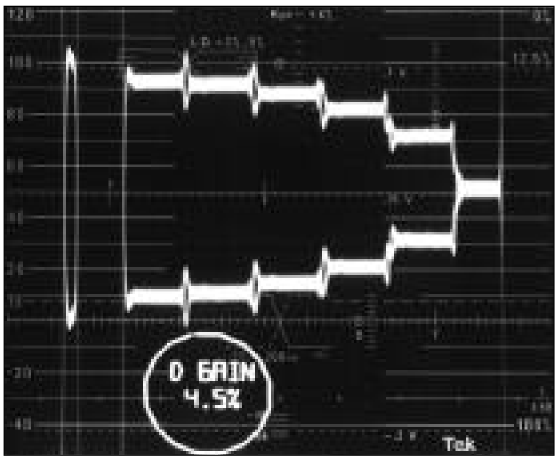


Figure 78. The 1780R double trace DIFF GAIN display with the measurement results indicated on the readout.

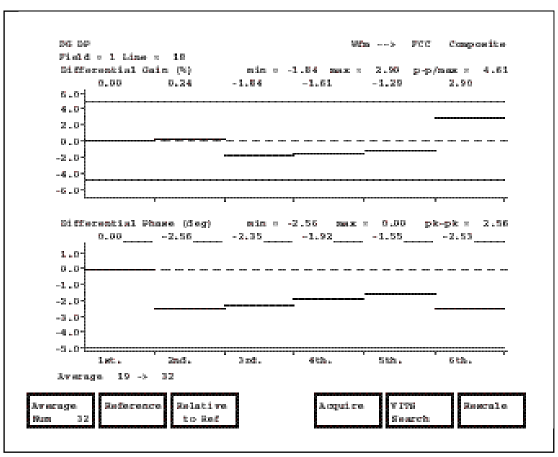


Figure 79. The VM700T DG DP display.

B-Y Sweep - Double Trace Method. The double trace method provides a highly accurate way of measuring the amount of tilt in a one-line sweep of the B-Y information. This method is very similar to the differential phase double trace method, however, a calibrated gain control rather than a calibrated phase control is used to null the traces.

Select DOUBLE in the 1780R DIFF GAIN menu to make this measurement. Use the phase shifter to set the vector phase to the reference (9 o'clock) position. The vectorscope variable gain must be adjusted so the signal vector reaches the graticule circle. The 1780R waveform monitor gain setting is not critical in this mode (see Note 26).

Start the measurement procedure by using the large knob to bring the largest negative excursion of the upper (non-inverted) waveform to meet its mirror image. Press REF SET to set the readout to 0.00 percent (see Figure 77). Use the large knob to bring the largest positive excursion of the upper trace to meet its mirror image. The readout will indicate the amount of differential gain distortion (see Figure 78).

VM700T Automatic Measurement. To make an automatic measurement of differential gain with the VM700T, select DG DP in the MEASURE mode. Both differential phase and differential gain are shown on the same display. The upper graph is differential gain. These measurements are also available in the AUTO mode (see Figure 79).

NOTES

25. Demodulated "B-Y" Signal. It should be noted that in instruments such as the 520A and the 1780R, the displayed signal is not simply the B-Y demodulator output of the vectorscope. Rather, an envelope (square law) detector scheme is used. The demodulated signal is derived by multiplying the signal by itself rather than by a constant-phase CW subcarrier as in a synchronous demodulator. The primary advantage of this method is that in the presence of both differential phase and differential gain, synchronous detection yields a phase-dependent term while square law detection does not. Thus the presence of differential phase does not affect the differential gain result.

26. 1780R Waveform and Vector Gains. When using the single trace mode, the vector gain must be set to the graticule circle and the waveform gain must be in the calibrated position. The graticule is calibrated to one percent per division only under these conditions.

In the double mode display, more gain may be introduced in the waveform vertical (X5 or VAR) for greater resolution. However, it is critical that the vectorscope gain be set to the graticule circle to obtain correct measurement results.

27. Simultaneous Display of DP and DG. It is sometimes useful to have a display that shows both differential phase and differential gain, particularly when adjusting equipment for minimum distortion. A display which shows a one-line sweep of differential phase on the left and a one-line sweep of differential gain on the right can be accessed by selecting DP & DG in the 1780R MEASURE menu (see Figure 80). The VM700T DG DP display also shows both distortions simultaneously.

Figure 80. The 1780R DP & DG display (single trace mode only).

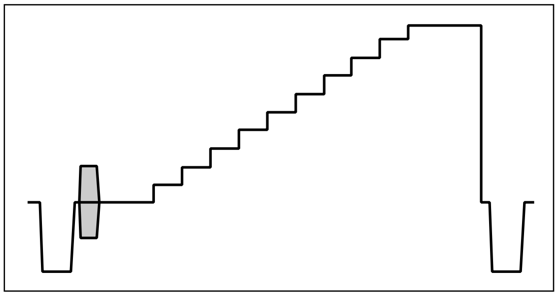


Figure 81. A 10-step staircase test signal.

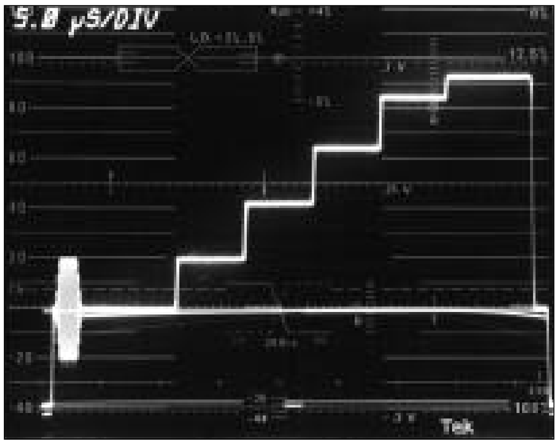


Figure 82. An example of luminance nonlinearity distortion.

DEFINITION

Luminance nonlinearity, or differential luminance, is present when luminance gain is affected by luminance level. In other words, there is a nonlinear relationship between the input and output signals in the luminance channel. This amplitude distortion occurs when luminance information is not uniformly processed over the entire amplitude range.

The amount of luminance nonlinearity distortion is expressed as a percentage. Measurements are made by comparing the amplitudes of the individual steps in a staircase test signal. The result is the difference between the largest and smallest steps expressed as a percentage of the largest step.

Luminance nonlinearity should be measured at different average picture levels and the worst error quoted.

PICTURE EFFECTS

Luminance nonlinearity is not particularly noticeable in black and white pictures. However, if large amounts of distortion are present, loss of detail in the shadows and highlights may be seen. These effects correspond to crushing or clipping of the black and white information.

In color pictures, luminance nonlinearity is often more noticeable. This is because color saturation, to which the eye is more sensitive, is affected.

TEST SIGNALS

Luminance nonlinearity should be measured with a test signal that consists of uniform-amplitude luminance steps. Unmodulated 5 step or 10 step staircase signals are typically used.

If an unmodulated signal is not available, the measurement can also be made with a modulated staircase. This is generally not good practice, however, since both differential gain and luminance nonlinearity can have the same net effect on the signal.

MEASUREMENT METHODS

Luminance nonlinearities are quantified by comparing the step amplitudes of the test signal. Since the steps are generated at uniform height, any differences are a result of this distortion. The waveform in Figure 82 exhibits luminance nonlinearity. Note that the top step is shorter than the others.

Waveform Display. This measurement can be made with a waveform monitor by individually measuring each step in the test signal. It is most convenient to use the variable gain to normalize the largest step to 100 IRE so percentage can be read directly from the graticule. Voltage cursors can also be used to measure the steps. Although this method can yield very accurate results, it is time consuming and not frequently used in practice.

Waveform Monitor - Differentiated Step Filter. Some waveform monitors are equipped with a special filter, usually called a "diff step" filter, for measurement of luminance nonlinearity. When this filter is selected, each step transition appears as a spike on the display. As the amplitude of each spike is proportional to the corresponding step height, the amount of distortion can be determined by comparing the spike amplitudes. Either the waveform monitor graticule or the voltage cursors can be used to measure the spikes. Use the variable gain to normalize the largest spike amplitude to 100 IRE when using the waveform monitor graticule. The difference between the largest and smallest spikes, expressed as a percentage of the largest, is the amount of luminance nonlinearity.

The 1780R voltage cursors should be in the RELATIVE mode for this measurement. Define the largest spike amplitude as 100%. Leave one cursor at the top of the largest spike, and move the other cursor to the top of the smallest spike. The readout will indicate the amount of luminance nonlinearity distortion (see Figure 83).

VM700T Automatic Measurement. Select LUMINANCE NONLINEARITY in the VM700T MEASURE menu to obtain a display of this distortion. The VM700T uses a differentiated step filter in making this measurement (see Figure 84). This measurement is also available in the AUTO mode.

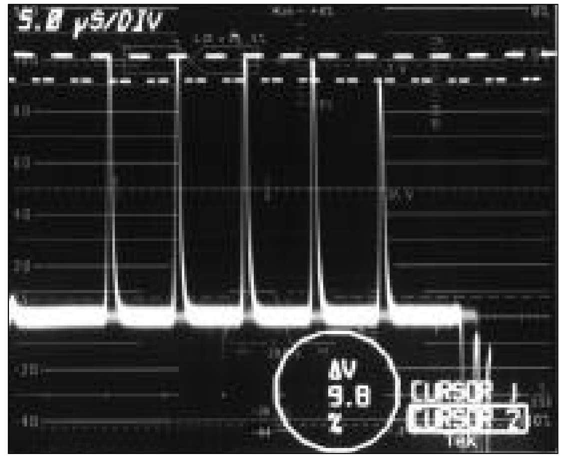


Figure 83. The 1780R voltage cursors indicate 9.8% luminance nonlinearity.

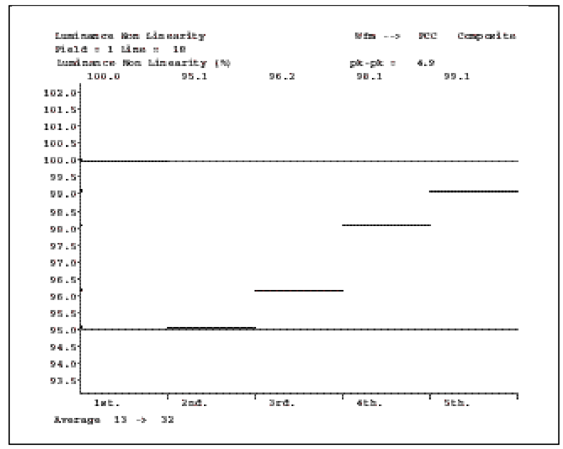


Figure 84. The VM700T Luminance Nonlinearity display.

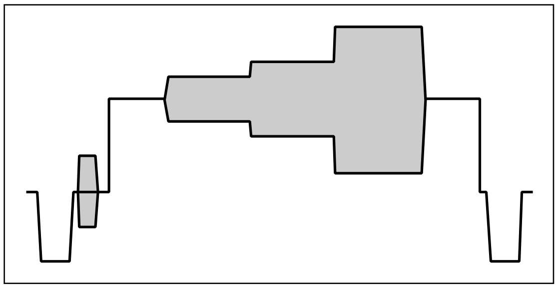


Figure 85. A modulated pedestal test signal.

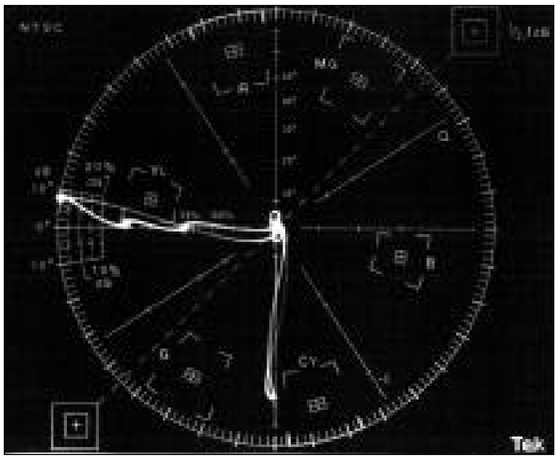


Figure 86. The 1780R vectorscope display indicating a chrominance nonlinear phase distortion of 8 degrees.

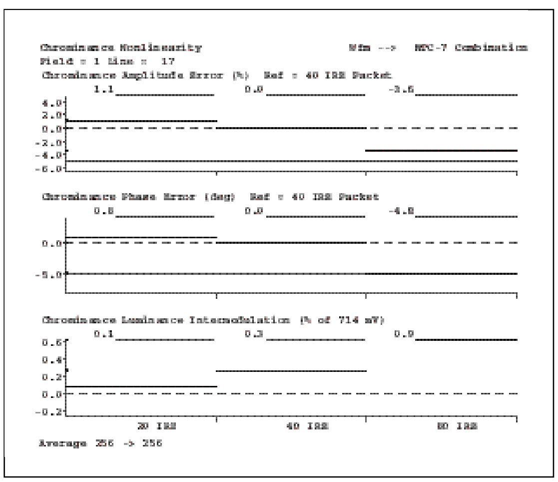


Figure 87. The VM700T Chrominance Nonlinearity display. Chrominance nonlinear phase is shown in the center graph.

DEFINITION

Chrominance nonlinear phase is present when chrominance phase is affected by chrominance amplitude. This distortion occurs when all amplitudes of chrominance information are not uniformly processed.

Chrominance nonlinear phase distortion is expressed in degrees of subcarrier phase. This parameter should be measured at different average picture levels and the worst error quoted.

PICTURE EFFECTS

Chrominance nonlinear phase distortion will cause a shift in hue as color saturation increases. The effect is most noticeable in high amplitude chrominance signals.

TEST SIGNALS

Chrominance nonlinear phase is measured with a modulated pedestal test signal. This signal consists of a single phase, three level chrominance packet superimposed on a constant luminance level (see Figure 85). A typical modulated pedestal signal will have a 50 IRE luminance level and 20, 40, and 80 IRE chrominance levels.

MEASUREMENT METHODS

Chrominance nonlinear phase is quantified by measuring the phase change of the chrominance levels from their nominal phase value. In some cases, this distortion is defined as the peak-to-peak phase change between the three levels.

Vectorscope. Since phase information is required, a vectorscope is used to measure chrominance nonlinear phase. Examine the three dots (which correspond to the three chrominance levels) and measure the maximum phase difference between the three signal vectors. This is easiest when the vectorscope variable gain is adjusted to bring the largest vector out to the graticule circle (see Figure 86). When using a 1780R or a 520A Vectorscope, the calibrated phase shifter can be used to obtain a precise reading.

VM700T Automatic Measurement. Select CHROMA NONLINEARITY in the VM700T MEASURE mode to obtain a display of this distortion. The chrominance nonlinear phase measurement is the middle graph in the display (see Figure 87). These measurements are also available in the AUTO mode.

DEFINITION

Chrominance nonlinear gain is present when chrominance gain is affected by chrominance amplitude. This distortion occurs when all amplitudes of chrominance information are not uniformly processed.

Chrominance nonlinear gain distortion is expressed in IRE or percent. This distortion should be measured at different average picture levels and the worst error quoted.

PICTURE EFFECTS

Chrominance nonlinear gain distortion will cause a change in color saturation as chrominance amplitude increases. The effect is most noticeable in high amplitude chrominance signals.

TEST SIGNALS

Chrominance nonlinear gain is measured with a modulated pedestal test signal. This signal consists of a single phase, three level chrominance packet superimposed on a constant luminance level (see Figure 88). A typical modulated pedestal signal will have a 50 IRE luminance level and 20, 40, and 80 IRE chrominance levels.

MEASUREMENT METHODS

Chrominance nonlinear gain distortion is quantified by measuring the amplitude deviation of the chrominance levels from their nominal values with the 40 IRE level used as the reference.

Waveform Monitor. The waveform monitor graticule should be used for this measurement. First use the waveform monitor variable gain to normalize the middle subcarrier packet to its nominal value of 40 IRE. The chrominance nonlinear gain distortion is the largest deviation from nominal value of the other two levels. The result may be expressed in IRE or as a percentage of the nominal amplitude of the affected packet. The waveform in Figure 89 exhibits 14 IRE of chrominance nonlinear gain distortion.

VM700T Automatic Measurement. Select CHROMA NONLINEARITY in the VM700T MEASURE mode to obtain a display of this distortion. The chrominance nonlinear gain measurement is the top graph in the display (see Figure 90). These measurements are also available in the AUTO mode.

NOTES

28. Chroma Filter. It is sometimes recommended that the chroma filter on the waveform monitor be enabled when measuring chrominance nonlinear gain. While the chroma filter will make the display more symmetrical, the same results should be obtained either way since it is the peak-to-peak amplitudes being measured. A possible exception is a case where chrominance harmonic distortion is present. The chrominance filter can remove the effects of harmonic distortion which are likely to be different for each chrominance level.

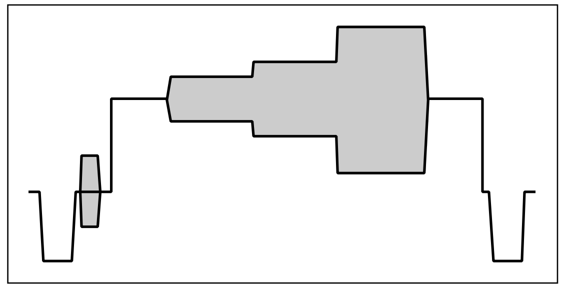


Figure 88. A modulated pedestal test signal.

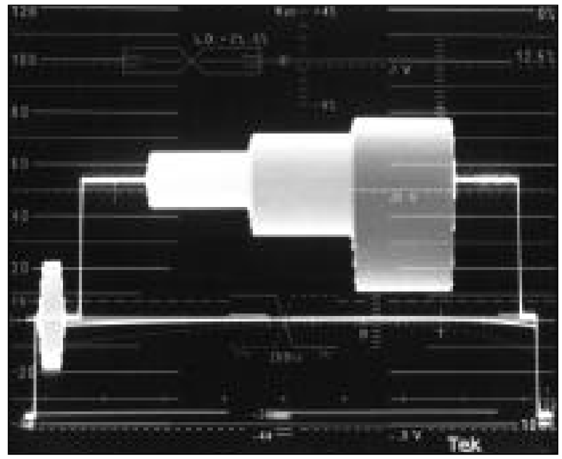


Figure 89. A chrominance nonlinear gain distortion of 14 IRE is shown in this display.

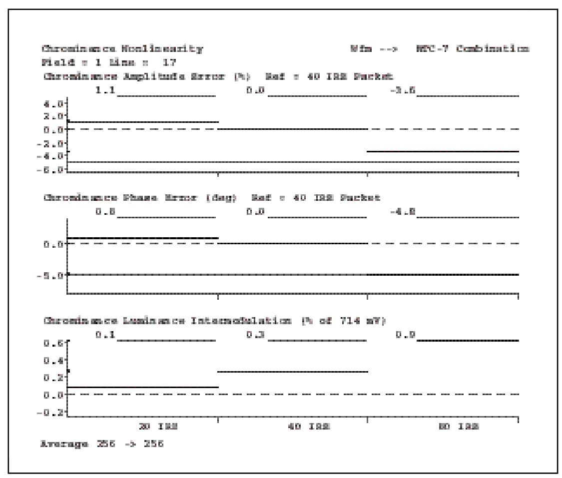


Figure 90. The VM700T Chrominance Nonlinearity display. Chrominance nonlinear gain is shown on the upper graph.

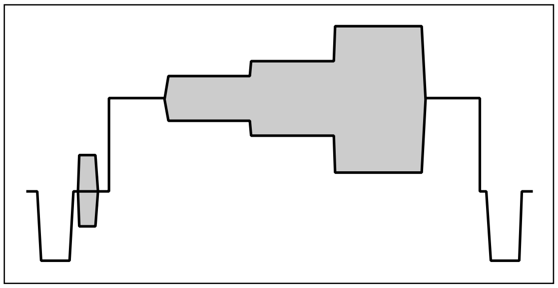


Figure 91. A modulated pedestal test signal.

DEFINITION

Chrominance-to-luminance intermodulation, also known as crosstalk or cross-modulation, is present when luminance amplitude is affected by superimposed chrominance. The luminance change may be caused by clipping of high-amplitude chrominance peaks, quadrature distortion, or crosstalk.

The deviation in the pedestal level may be expressed:

- In IRE with pedestal level normalized to 50 IRE.
- As a percentage of the pedestal level.
- As a percentage of the measured white bar amplitude.
- As a percentage of 714 millivolts.

These definitions will yield different results under some conditions so it is important to standardize on a single method of making intermodulation measurements.

PICTURE EFFECTS

Chrominance-to-luminance intermodulation will cause variations in brightness due to color saturation changes.

TEST SIGNALS

Chrominance-to-luminance intermodulation is measured with a modulated pedestal test signal. This signal consists of a single phase, three level chrominance packet superimposed on a constant luminance level (see Figure 91). A typical modulated pedestal signal will have a 50 IRE luminance level and 20, 40, and 80 IRE chrominance levels.

MEASUREMENT METHODS

Chrominance-to-luminance intermodulation is quantified by measuring the change in luminance level caused by the chrominance information superimposed on it. This process is facilitated by removing the chrominance information from the display with a waveform monitor filter.

Waveform Monitor. The chrominance information can be filtered off with either the luminance or lowpass filter in the 1780R. The lowpass filter should be selected if using the 1480. The IRE filter is not really suitable because some chrominance remains in the display. The Y display of the 520A vectorscope also works well.

Details of the measurement method will depend on how the amount of distortion is expressed. In general, first use the variable gain on the waveform monitor to normalize the portion of the pedestal without superimposed chrominance to the measurement reference level. For an absolute value measurement, this would be the nominal pedestal level. For a percent measurement, this could be 100 IRE (see Figure 92). With the pedestal level normalized, measure the largest level shift at the top of the pedestal.

The 1780R voltage cursors can be used in RELATIVE mode to make this measurement. In Figure 92, the amplitude deviation is 9.2% of the pedestal level.

VM700T Automatic Measurement. Select CHROMA NONLINEARITY in the VM700T MEASURE mode to obtain a display of this distortion. The chrominance-to-luminance intermodulation measurement is the bottom graph in the display (see Figure 93). These measurements are also available in the AUTO mode.

Figure 92. A chrominance-to-luminance intermodulation distortion of 9.2%.

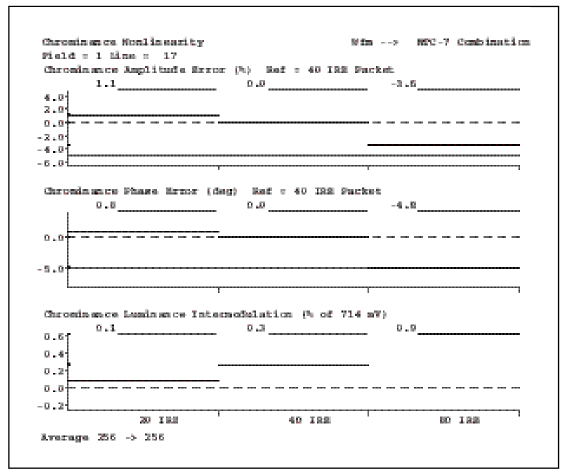


Figure 93. The VM700T Chrominance Nonlinearity display. Chrominance-to-luminance intermodulation is shown in the lower graph.

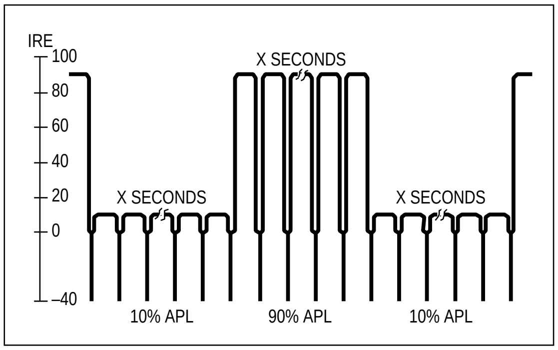


Figure 94. A flat field bounce test signal.

DEFINITION

Transient gain distortion, also referred to as transient nonlinearity, is present when abrupt changes in APL temporarily affect signal amplitude. For the synchronizing signal, the error is defined as the maximum transient departure in the amplitude of sync from the amplitude before the change in APL. It is generally expressed as a percentage of the original amplitude, however, some standards specify a percentage of the largest amplitude. Measurement of this distortion requires an out-of-service test. Both low-to-high and high-to-low APL changes should be evaluated.

PICTURE EFFECTS

If only the sync portion of the signal is affected, this distortion does not generally cause perceptible picture effects. However, the rest of the signal often suffers from the same type of distortion. When this occurs, sudden switches between high APL and low APL pictures can cause transient brightness effects in the picture.

TEST SIGNALS

Transient gain distortion is measured with a flat field test signal (black burst with pedestal). A generator with a "bounce" feature can be used to make the APL transitions if the time interval between transitions is considerably longer than any transient effect (see Figure 94).

MEASUREMENT METHODS

Transient gain changes are measured by abruptly changing APL and observing the transient effects on a waveform monitor.

Waveform Monitor. This distortion is easiest to evaluate with the test signal displayed on a waveform monitor with the differentiated step filter selected. (Recall that this filter produces spikes with amplitudes proportional to signal transitions). The waveform monitor DC restorer must be turned off for this measurement.

Depending on the nature of the distortion, it may be possible to observe it with the waveform monitor operating in the field sweep mode. Otherwise it will be necessary to use the 1780R SLOW SWEEP mode. (Some 1480s are equipped with the SLOW SWEEP option). A waveform photograph may make the measurement easier.

Adjust the waveform monitor variable gain to set the amplitude of the positive spike, which corresponds to the trailing edge of sync, equal to 100 IRE. Switch between extreme APL levels, typically 10% and 90%. The resulting envelope of the sync spikes represents the transient error. Measure the maximum departure from 100 IRE and express that number as a percent to obtain the amount of transient sync nonlinearity.

The 1780R voltage cursors can also be used to make this measurement. In the RELATIVE mode, define the positive sync spike as 100%. Then use the cursors to measure the largest deviation from that amplitude.

DEFINITION

Dynamic gain distortion of the picture signal is present when luminance amplitude is affected by APL. Dynamic gain distortion of the sync signal is present when sync amplitude is affected by APL.

The amount of distortion is usually expressed as a percent of the amplitude at 50% APL, although sometimes the overall variation in IRE units is quoted. This is an out-of-service test.

PICTURE EFFECTS

When luminance levels are APL dependent, picture brightness may seem to be incorrect or inconsistent as scenes change.

TEST SIGNALS

Dynamic gain change is measured with a test signal that extends to 100 IRE and has an APL that can be varied from 10% to 90% (see Figure 95). A staircase signal with variable pedestal is commonly used.

MEASUREMENT METHODS

Waveform Monitor. Dynamic picture gain change is evaluated by measuring amplitude at various APL levels. First select 50% APL and use the waveform monitor variable gain to set the top step of the staircase to 100 IRE. Vary the APL of the signal to 10% and then to 90%. At each APL level, record the level of the staircase top step. The peak-to-peak variation of the top staircase level, expressed in percentage, is typically quoted as the amount of dynamic picture gain change. This measurement can be made with the 1780R voltage cursors in the RELATIVE mode.

A similar procedure is used for dynamic sync gain. Figures 96 and 97 illustrate the measurement procedure.

NOTES

29. Transient vs. Dynamic Gain Changes. The terminology used to describe the two different types of APL dependent nonlinear gain distortions is inconsistent from standard to standard and can be quite confusing. It is necessary to distinguish between the effects of different APL, and effects of changes in APL. Most frequently, the two measurements are referred to as DYNAMIC and TRANSIENT respectively. This booklet adheres to this definition.

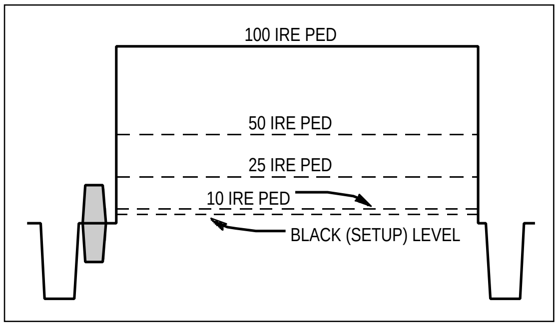


Figure 95. A variable pedestal is multiplexed with a 100 IRE test signal for this measurement.

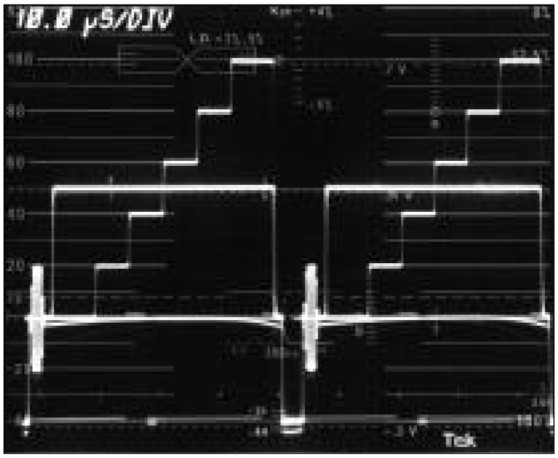


Figure 96. At 50% APL, the sync pulse amplitude is 40 IRE.

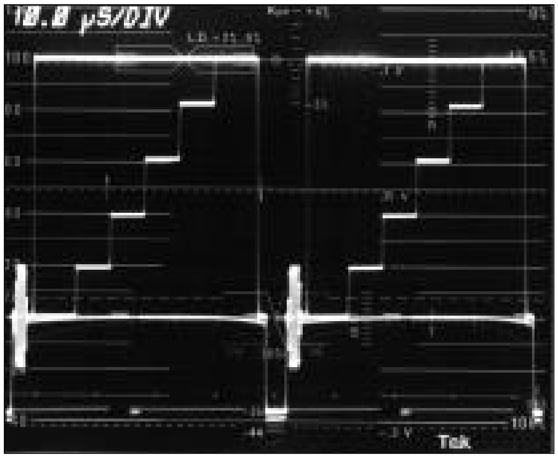


Figure 97. At high APL, the sync pulse amplitude is 36 IRE. This indicates a dynamic sync gain change of 10%.

The electrical fluctuations which we refer to as noise form a very complex signal which does not lend itself to straightforward amplitude measurements. A number of special techniques have therefore been developed for measuring noise. A comprehensive discussion of noise measurement is outside the scope of this publication. However, some of the methods that apply to television systems are presented in this section.

Special filters are generally required for noise measurements. These filters are used to separate the noise into its various frequency components for analysis. Each measurement standard typically calls for three or four measurements made with various combinations of the filters. Note that specifications for the filters vary from standard to standard.

The tangential method of noise measurement, useful for making operational measurements of random noise, is the only method discussed in detail in this publication. While not the most accurate technique, the tangential method can provide a quick way of keeping track of system noise performance over time. Tangential noise measurements are made with a specially equipped waveform monitor. This feature is standard in the 1780R.

Specialized equipment is required to completely characterize the noise performance of a system. Until recently, these capabilities were available only in dedicated noise measurement instruments. The VM700T, however, makes highly accurate noise measurements using filters implemented in software. The noise measurement features of the VM700T are reviewed briefly in this section.

DEFINITION

Noise refers to the fluctuations that are present in any electrical system. Noise can be either random or coherent and comes from a variety of natural and man-made sources. Although there is always some noise present, an excessive amount is undesirable since it tends to degrade or obscure the signal.

Signal amplitudes do not always remain constant as the video signal is processed and transmitted. An absolute measurement of noise is therefore not particularly relevant - a certain amount of noise will have very different effects on signals of different amplitudes.

Since it is the amount of noise relative to the signal amplitude (rather than the absolute amount of noise) that tends to cause problems, measurement of signal-to-noise ratio, expressed in dB, is made.

PICTURE EFFECTS

Noisy pictures often appear grainy or snowy and sparkles of color may be noticeable. Extremely noisy signals may be difficult for equipment to lock to causing horizontal tearing and vertical roll.

TEST SIGNALS

Tangential noise measurement may be made on any portion of the video signal with a constant luminance level without chrominance. The measurement can be made on a line in the vertical interval although full-field measurements are more accurate and somewhat easier to make.

Any line with a constant pedestal level can be used to make VM700T NOISE SPECTRUM measurements. A quiet line in the vertical interval is typically used. The VM700T CHROMA NOISE measurement requires a red field test signal (see Figure 98).

MEASUREMENT METHODS

Tangential Method. Tangential noise measurements may be made with a 1780R with measurement results repeatable to within 1 or 2 dB, down to noise levels of about 60 dB. Filters can be inserted in the AUX OUT/AUX IN path to separate noise components of different frequencies.

Make sure the waveform monitor filter selection is set to FLAT (unless using the auxiliary filter capability) and DC restorer to OFF or FAST. Select NOISE in the 1780R MEASURE menu. In the 1480, use the WAVEFORM COMPARISON mode to split the luminance levels of interest in half and overlay the two parts.

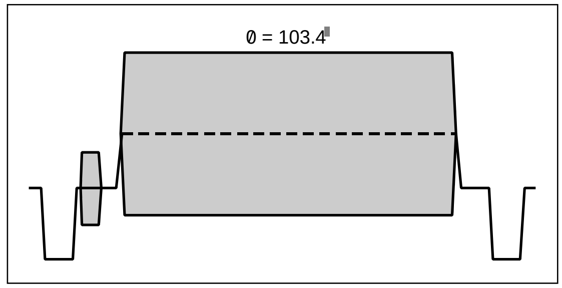


Figure 98. A red field test signal.

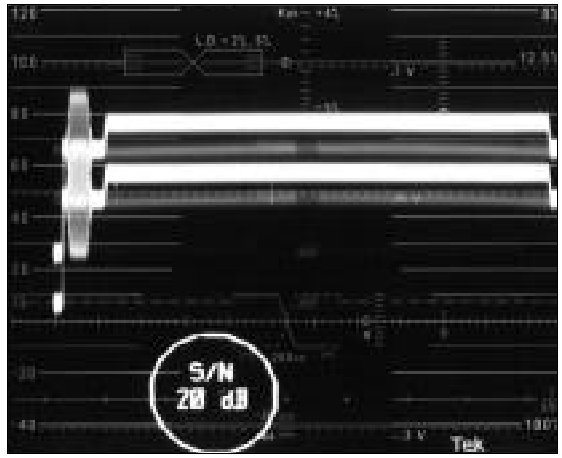


Figure 99. The 1780R tangential noise measurement mode showing excessive trace separation.

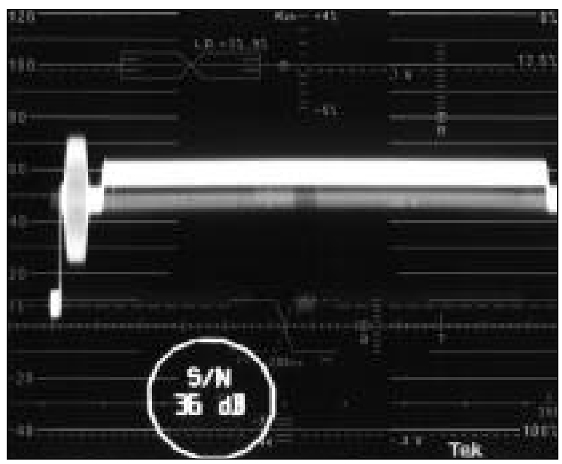


Figure 100. The 1780R tangential noise measurement mode with trace separation properly adjusted. This signal has a signal-to-noise ratio of 36 dB.

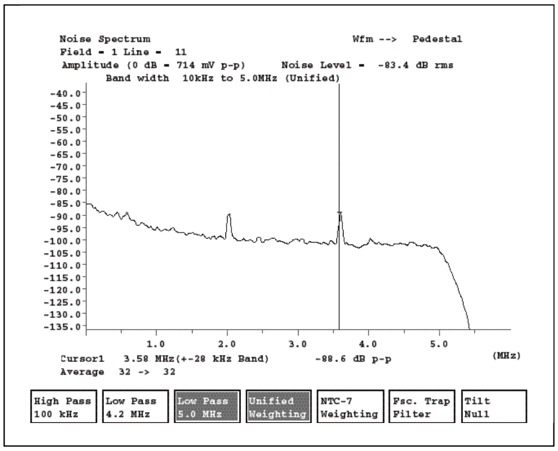


Figure 101. The VM700T Noise Spectrum display.

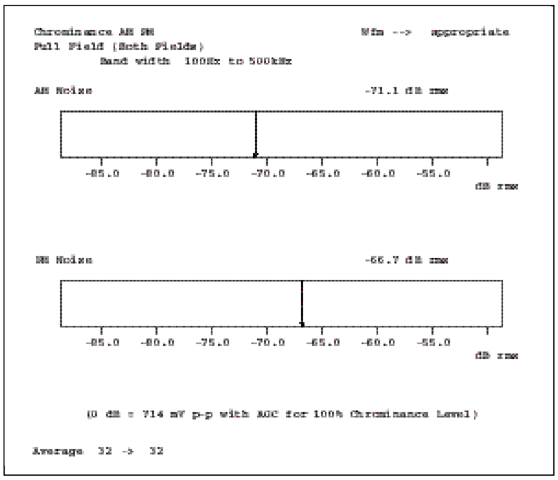


Figure 102. The VM700T Chrominance AM PM Noise display.

The measurement is made by adjusting the separation between the two traces until the dark area between them just disappears. When there is no perceptible dip in brightness between the two traces, the calibrated offset level (in dB) is the amount of noise (see Figures 99 and 100). In the 1780R, the large knob is used to control the offset and the on screen readout provides the dB reading. In the 1480, the offset function is performed by the two dB NOISE controls in the lower right hand corner. The dB reading is obtained from the knob settings.

VM700T Automatic Measurement. Select NOISE SPECTRUM in the VM700T MEASURE menu to make signal-to-noise measurements. A spectral display as well as numeric results is provided in this mode (see Figure 101).

There are four filters available in this mode: 4.2 MHz lowpass, 5 MHz lowpass, a unified weighting filter, and a 3.58 MHz trap. Measurement standards typically require three or four measurements made with various combinations of these filters.

The rms signal-to-noise ratio of the entire spectrum is always displayed in the upper right hand corner of the display.

A cursor can be used to select a certain frequency for a peak-to-peak noise measurement. The cursors can also be used to define a narrow range of frequencies for S/N measurements.

The CHROMINANCE AM PM selection in the VM700T MEASURE menu provides information about the noise that affects the chrominance portion of the signal. Since the chrominance signal is sensitive to both the amplitude (AM) and phase (PM) components of noise, separate measurements are provided. A selection of filters is available in this mode as well. Be sure to use the red field test signal for this measurement (see Figure 102). Noise measurements are also available in the AUTO mode.

NOTES

30. Quiet Lines. "Quiet lines" in the vertical interval are sometimes used to determine the amount of noise introduced in a certain part of the transmission path. A line is reinserted (and is therefore relatively noise free) at one end of the transmission path of interest. This ensures that any noise measured on that line at the other end was introduced in that part of the path.

V. TRANSMITTER MEASUREMENTS

In this section, we discuss two parameters which should be monitored and adjusted at the broadcast television transmitter - depth of modulation and ICPM. These two measurements are commonly made with time domain instruments such as waveform monitors or oscilloscopes. Most of the other tests for characterizing transmitter performance are made with a spectrum analyzer and are not addressed in this publication.

To make these measurements, a high-quality demodulator such as the Tektronix TV1350 or 1450 is required. These instruments provide envelope and synchronous detection demodulation. Unlike envelope detectors, synchronous detectors are not affected by the quadrature distortion inherent in the vestigial sideband transmission system. For measurement purposes, the effects of quadrature distortion should be removed so as not to obscure distortions from other sources.

A quadrature output is available when the instrument is operating in the synchronous detection mode. Envelope detection is most similar to the demodulation used in most home receivers and is also available in the TV1350 and 1450.

The TV1350 and 1450 produce a zero carrier reference pulse which provides the reference level required for depth of modulation measurements. This pulse is created at the demodulator output by briefly reducing the amplitude of the RF signal to the zero carrier level prior to demodulation.

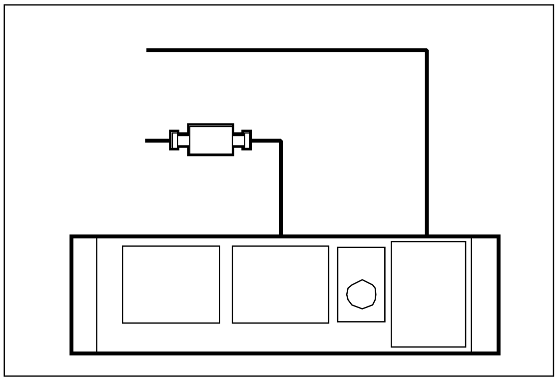


Figure 103. How to set up the 1780R for ICPM measurements.

DEFINITION

ICPM (Incidental Carrier Phase Modulation) is present when picture carrier phase is affected by video signal level. This distortion occurs in the transmitter.

ICPM errors are expressed in degrees using the following definition:

ICPM = arctan (quadrature amplitude/video amplitude).

PICTURE EFFECTS

The effects of ICPM will depend on the type of demodulation used to recover the baseband signal from the transmitted signal. ICPM shows up in synchronously demodulated signals as differential phase and many other types of distortions. With envelope demodulation, the demodulation typically used in home receivers, the baseband signal is generally not as seriously affected and the effects of ICPM are rarely seen in the picture. The sound, however, is another matter.

ICPM may manifest itself as audio buzz in the home receiver. In the intercarrier sound system, the picture carrier is mixed with the FM sound carrier to form a 4.5 MHz sound IF. Audio rate phase modulation in the picture carrier can therefore be transferred into the audio system and heard as a buzzing noise.

TEST SIGNALS

ICPM is measured with an unmodulated linearity signal. A staircase is generally used but a ramp signal may also be used.

MEASUREMENT METHODS

ICPM is measured on an XY plot of VIDEO OUT versus QUADRATURE OUT with the demodulator operating in the synchronous detection mode. A phase error will produce an output from the quadrature detector. If this phase error varies with amplitude, the result is a tilted display. The demodulator zero carrier reference pulse must be turned on and the detection mode set to synchronous. Select the SLOW time constant when using the 1450.

Waveform Monitor. To display ICPM on a waveform monitor, connect the demodulator outputs to the waveform monitor inputs as shown in Figure 103. Select ICPM in the 1780R MEASURE menu or EXT HORIZ on the 1480 front panel.

Although it is not strictly necessary, it is generally recommended that the signals be lowpass filtered to make the display easier to interpret. With either the 1780R or the 1480, this can be accomplished in the vertical channel by selecting the LOWPASS filter. Use an external 250 KHz lowpass filter for the horizontal (see Figure 103).

The display resulting from this configuration, which appears on the right-hand screen in the 1780R, is shown in Figures 104 and 105. The amount of tilt (deviation from the vertical) is an indication of ICPM. There is no ICPM in the signal shown in Figure 104 while distortion is present in Figure 105. When adjusting the transmitter for minimum ICPM, make the line as nearly vertical as possible.

The 1780R has an electronic graticule which can be used to quantify the amount of tilt. The waveform should be positioned so the small dot corresponding to the zero carrier reference pulse is set on the cross at the top of the screen. The horizontal magnification will automatically be set to X25 when this mode is selected. If desired, X50 magnification can be used for greater resolution. Start with the two graticule lines widely separated and use the knob to move them together to the point where a graticule line first contacts one of the dots. Disregard the "loops" in the ICPM display. These correspond to the staircase step transitions and are not indicative of distortion. The amount of ICPM distortion is indicated on the screen (see Figure 105).

An external ICPM graticule is available for the 1480. Position the zero carrier reference pulse, which shows up as a small dot, on the cross at the top of the graticule. The graticule is calibrated for 2 degrees per division when the horizontal magnifier is set to X25 or 1 degree per division with X50 horizontal magnification. Read the amount of ICPM from the graticule at the point of maximum distortion.

VM700T Automatic Measurement. The VM700T provides an ICPM measurement in the AUTO mode. In this case the quadrature signal must be connected to the “C” input.

NOTES

31. Configuring the 1480. 1480-series instruments are shipped with unblanking disabled in the EXTERNAL HORIZONTAL mode to prevent damage to the CRT. ICPM measurements can be made in line select with the instrument in this mode. For full-field ICPM measurements, the unblanking must be enabled. Instructions on how to accomplish this can be found in the OPERATING CHANGES section of the 1480-series manual.

32. Other XY Displays. Any XY display can be used to measure ICPM. Connect QUADRATURE OUT to the horizontal and VIDEO OUT to the vertical and use the formula given on page 62 to calculate the amount of distortion. For small errors, some amount of gain will be needed to improve the measurement resolution. Lowpass filters in both channels are recommended.

33. Phase Noise. Some demodulators have large amounts of phase noise which make it difficult to make ICPM measurements. The Tektronix 1450 has sufficiently low phase noise as do all TV1350 units shipped after July, 1998. Older TV1350 units can be retrofitted to improve phase noise performance. Contact your local Tektronix service department for information on how to update older instruments.

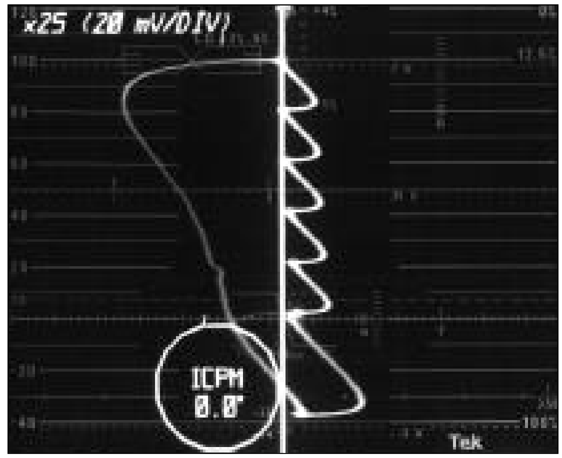


Figure 104. The 1780R ICPM display with no distortion present.

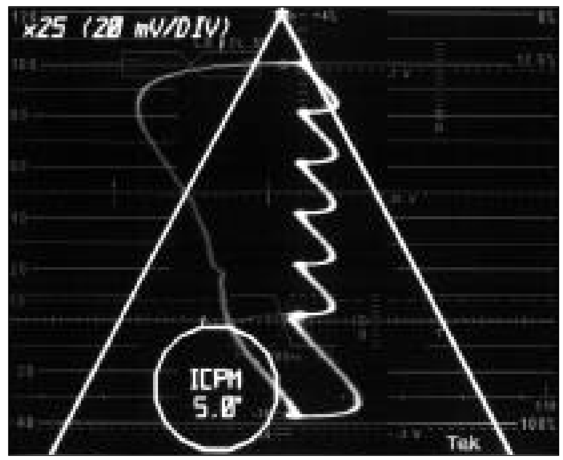


Figure 105. The 1780R electronic graticule indicating an ICPM distortion of 5 degrees.

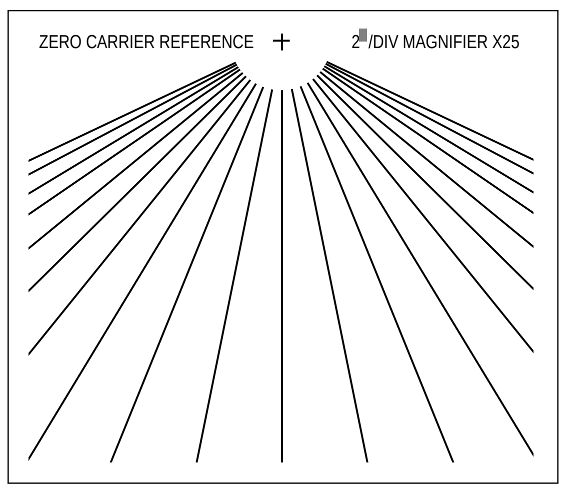


Figure 106. The 1480 ICPM graticule.

Depth of Modulation

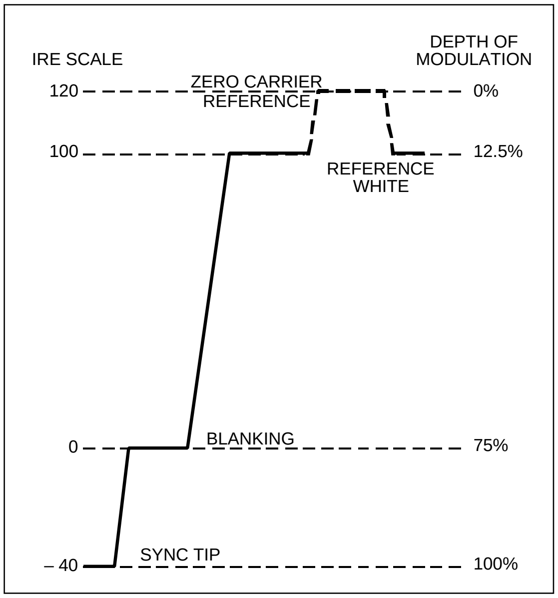


Figure 107. Depth of modulation levels.

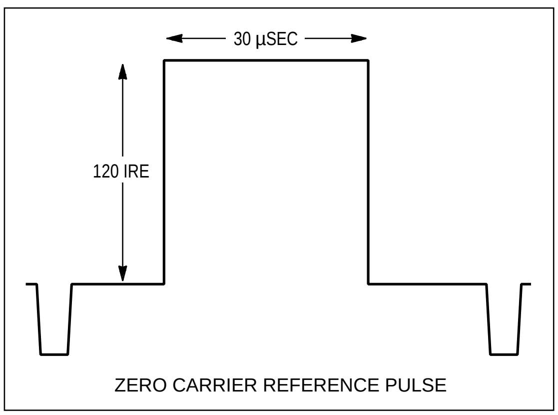


Figure 108. The zero carrier reference pulse typically occurs on line 20 but can be moved to other lines.

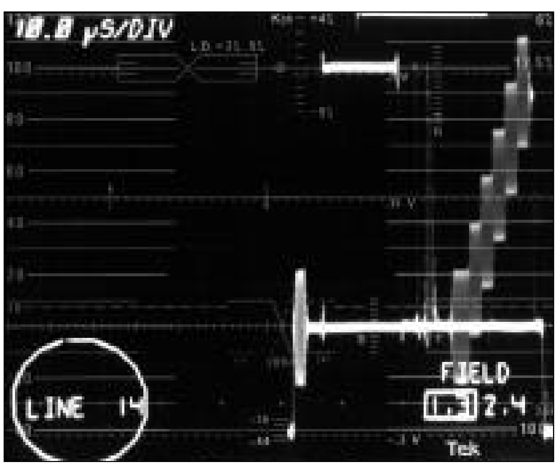


Figure 109. Video levels can be compared to the depth of modulation scale on the right-hand side of the graticule. Note the zero carrier pulse at 120 IRE.

DEFINITION

Depth of modulation (percentage of modulation) measurements indicate how video signal levels are represented in the RF signal.

The NTSC modulation scheme yields an RF signal that reaches its maximum peak-to-peak amplitude at sync tip (100%). In a properly adjusted signal, blanking level corresponds to 75% and peak white to 12.5%. The zero carrier reference level corresponds to 0% (see Figure 107).

PICTURE EFFECTS

Overmodulation often shows up as nonlinear distortions such as differential phase and gain. ICPM or white clipping may also result. Undermodulation often results in degraded signal-to-noise performance. The picture effects of these distortions were discussed earlier.

TEST SIGNALS

Depth of modulation measurements can be made with any signal with peak white (100 IRE) and blanking level (0 IRE) references. This signal is used in conjunction with the zero carrier reference pulse (Figure 108) which typically occurs in the vertical interval on line 20.

MEASUREMENT METHODS

Modulation depth is measured at the output of a precision demodulator by verifying that the video signal modulates the vision carrier as shown in Figure 108. Overall amplitude is not critical, but it should be adjusted in the system to be approximately 160 IRE from sync tip to zero carrier at 100% transmitter power. This will minimize the effects of nonlinearities in the measurement system.

Waveform Monitor. Most waveform monitors, including the 1780R and 1480, provide a depth of modulation scale on the right-hand side of the graticule. Use the variable gain to position the zero carrier reference pulse on the 0% mark at the top of the screen and sync tip on the 100% mark (see Figure 109). Verify that white level and blanking level occur at the prescribed points on the graticule scale. The voltage cursors can also be used for this measurement.

NOTES

33. Envelope Detection. Depth of modulation measurements should be made with the demodulator in the envelope detection mode to minimize effects of ICPM. Quadrature distortion will not affect modulation depth.

AC-COUPLED — A connection which removes the constant voltage (DC component) on which the signal (AC component) is riding. Usually implemented by passing the signal through a capacitor.

AM — Amplitude Modulation (AM) is the process by which the amplitude of a high-frequency carrier is varied in proportion to the signal of interest. In the NTSC television system, AM is used to encode the color information and to transmit the picture.

Several different forms of AM are differentiated by filtering of the sidebands and whether or not the carrier is suppressed. Double sideband suppressed carrier is used to encode the NTSC color information, while the signal is transmitted with a vestigial sideband scheme.

APL — Average Picture Level. The average signal level (with respect to blanking) during active picture time, expressed as a percentage of the difference between the blanking and reference white levels.

BACK PORCH — The portion of the video signal which lies between the trailing edge of the horizontal sync pulse and the start of the active picture time. Burst is located on back porch.

BANDWIDTH — The range of frequencies over which signal amplitude remains constant (within some limit) as it is passed through a system.

BASEBAND — Refers to the composite video signal as it exists before modulating the picture carrier. Composite video distributed throughout a studio and used for recording is at baseband.

BLACK BURST — Also called "color black", black burst is a composite video signal consisting of all horizontal and vertical synchronization information, burst, and usually setup. Typically used as the house reference synchronization signal in television facilities.

BLANKING LEVEL — Refers to the 0 IRE level which exists before and after horizontal sync and during the vertical interval.

BREEZEWAY — The portion of the video signal which lies between the trailing edge of the horizontal sync pulse and the start of burst. Breezeway is part of back porch.

BROAD PULSES — Another name for the vertical synchronizing pulses in the center of the vertical interval. These pulses are long enough to be distinguished from all others, and are the part of the signal actually detected by vertical sync separators.

BURST — A small reference packet of the subcarrier sine wave, typically 8 or 9 cycles, which is sent on every line of video. Since the carrier is suppressed, this phase and frequency reference is required for synchronous demodulation of the color information in the receiver.

B-Y — One of the color difference signals used in the NTSC system, obtained by subtracting luminance from the blue camera signal. This is the signal which drives the horizontal axis of a vectorscope.

CHROMINANCE — Chrominance refers to the color information in a television picture. Chrominance can be further broken down into two properties of color: hue and saturation.

CHROMINANCE SIGNAL — The high-frequency portion of the video signal which is obtained by quadrature amplitude modulation of a 3.58 MHz subcarrier by R-Y and B-Y.

COLOR DIFFERENCE SIGNALS — Signals used by color television systems to convey color information in such a way that the signals go to zero when there is no color in the picture. R-Y, B-Y, I and Q are all color difference signals.

COMPONENT VIDEO — Video which exists in the form of three separate signals, all of which are required in order to completely specify the color picture. For example: R, G and B or Y, R-Y, and B-Y.

COMPOSITE VIDEO — A single video signal containing all of the necessary information to reproduce a color picture. Created by adding quadrature amplitude modulated R-Y and B-Y to the luminance signal.

CW — Continuous Wave. Refers to a separate subcarrier sine wave used for synchronization of chrominance information.

dB (DECIBEL) — A decibel is a logarithmic unit used to describe signal ratios. For voltages,

$$dB = 20 \, Log_{10} \left(\frac{V1}{V2}\right)$$

DC-COUPLED — A connection configured so that both the signal (AC component) and the constant voltage on which it is riding (DC component) are passed through.

DC RESTORER — A circuit used in picture monitors and waveform monitors to clamp one point of the waveform to a fixed DC level.

DEMODULATOR — In general, this term refers to any device which recovers the original signal after it has modulated a high frequency carrier. In television, it may refer to:

(1) An instrument, such as a Tektronix TV1350 or 1450, which takes video in its transmitted form (modulated picture carrier) and converts it to baseband.

(2) The circuits which recover R-Y and B-Y from the composite signal.

EQUALIZER — The pulses which occur before and after the broad pulses in the vertical interval.

ENVELOPE DETECTION — A-demodulation process in which the shape of the RF envelope is sensed. This is the process used by a diode detector.

FIELD — In interlaced scan systems, the information for one picture is divided up into two fields. Each field contains one half of the lines required to produce the entire picture. Adjacent lines in the picture are in alternate fields.

FM — Frequency Modulation (FM) is the process by which the frequency of a carrier signal is varied in proportion to the signal of interest. In the NTSC television system, audio information is transmitted using FM.

FRAME — A frame contains all the information required for a complete picture. For interlaced scan systems, there are two fields in a frame.

FRONT PORCH — The portion of the video signal between the end of active picture time and the leading edge of horizontal sync.

GAMMA — Since picture monitors have a nonlinear relationship between the input voltage and brightness, the signal must be correspondingly predistorted. Gamma correction is always done at the source (camera) in television systems: the R, G and B signals are converted to R 1/g , G 1/g and B 1/g. Values of about 2.2 are typically used for gamma.

GENLOCK — The process of locking both sync and burst of one signal to sync and burst of another, making the two signals completely synchronous.

GRATICULE — The scale which is used to quantify the information on a waveform monitor or vectorscope display. Graticules may either be screened onto the faceplate of the CRT itself (internal graticule), or onto a piece of glass or plastic which fits in front of the CRT (external graticule). They can also be electronically generated.

HARMONIC DISTORTION — If a sine wave of a single frequency is put into a system, and harmonic content at multiples of that frequency appears at the output, there is harmonic distortion present in the system. Harmonic distortion is caused by nonlinearities in the system.

HORIZONTAL BLANKING — Horizontal blanking is the entire time between the end of the active picture time of one line and the beginning of active picture time of the next line. It extends from the start of front porch to the end of back porch.

HORIZONTAL SYNC — Horizontal sync is the -40 IRE pulse occurring at the beginning of each line. This pulse signals the picture monitor to go back to the left side of the screen and trace another horizontal line of picture information.

HUE — Hue is the property of color which allows us to distinguish between colors such as red, yellow, purple, etc.

HUM — Undesirable coupling of the 60 Hz power sine wave into other electrical signals.

INTERCARRIER SOUND — A method used to recover audio information in the NTSC system. Sound is separated from video by beating the sound carrier against the video carrier, producing a 4.5 MHz IF which contains the sound information.

IRE — A unit equal to 1/140 of the peak-to-peak amplitude of the video signal, which is typically one volt. The 0 IRE point is at blanking level, with sync tip at -40 IRE and white extending to +100 IRE. IRE stands for Institute of Radio Engineers, the organization which defined the unit.

LINEAR DISTORTION — Refers to distortions which are independent of signal amplitude.

LUMINANCE — The signal which represents brightness, or the amount of light in the picture. This is the only signal required for black and white pictures, and for color systems it is obtained as a weighted sum ($Y = 0.3R + 0.59G + 0.11B$) of the R, G and B signals.

MODULATED — When referring to television test signals, this term implies that chrominance information is present. (For example, a modulated staircase has subcarrier on each step.)

MODULATION — A process which allows signal information to be moved to other frequencies in order to facilitate transmission or frequency-domain multiplexing. See AM and FM for details.

NONLINEAR DISTORTION — Refers to distortions which are amplitude-dependent.

NTSC — National Television System Committee. The organization which developed the television standard currently in use in the United States, Canada and Japan. Now generally used to refer to that standard.

PAL — Phase Alternate Line. Refers to the television system used in Europe and many other parts of the world. The phase of the chrominance signal alternates from line to line to help cancel out phase errors.

QUADRATURE AM — A process which allows two different signals to modulate a single carrier frequency. The two signals of interest Amplitude Modulate carrier signals which are the same frequency but differ in phase by 90 degrees (hence the Quadrature notation). The two resultant signals can be added together, and both signals recovered at the other end, if they are also demodulated 90 degrees apart.

QUADRATURE DISTORTION — Distortion resulting from the asymmetry of sidebands used in vestigial sideband television transmission. Quadrature distortion appears when envelope detection is used, but can be eliminated by using a synchronous demodulator.

RF — Radio Frequency. In television applications, RF generally refers to the television signal after the picture carrier modulation process.

RGB — Red, Green and Blue. The three primary colors used in color television's additive color reproduction system. These are the three color signals generated by the camera and used by the picture monitor to produce a picture.

R-Y — One of the color difference signals used in the NTSC system, obtained by subtracting luminance from the red camera signal. The R-Y signal drives the vertical axis of a vectorscope.

SATURATION — The property of color which relates to the amount of white light in the color. Highly saturated colors are vivid, while less saturated colors appear pastel. For example, red is highly saturated, while pink is the same hue but much less saturated.

SETUP — In NTSC systems, video black is typically 7.5 IRE above the blanking level. This 7.5 IRE level is referred to as the black setup level, or simply as setup.

SUBCARRIER — The modulation sidebands of the color subcarrier contain the R-Y and B-Y information. For NTSC, subcarrier frequency is 3.579545 MHz.

SYNCHRONOUS DETECTION — A demodulation process in which the original signal is recovered by multiplying the modulated signal with the output of a synchronous oscillator locked to the carrier.

TERMINATION — In order to accurately send a signal through a transmission line, there must be an impedance at the end which matches the impedance of the source and of the line itself. Amplitude errors and reflections will otherwise result. Video is a 75 Ohm system, so a 75 Ohm terminator must be put at the end of the signal path.

UNMODULATED — When used to describe television test signals, this term refers to pulses and pedestals which do not have high-frequency chrominance information added to them.

VECTORSCOPE — A specialized oscilloscope which demodulates the video signal and presents a display of R-Y versus B-Y. The angle and magnitude of the displayed vectors are respectively related to hue and saturation.

VERTICAL INTERVAL — The synchronizing information which appears between fields and signals the picture monitor to go back to the top of the screen to begin another vertical scan.

WAVEFORM MONITOR — A specialized oscilloscope for evaluating television signals.

Y — Abbreviation for luminance.

ZERO CARRIER REFERENCE — A 120 IRE pulse in the vertical interval which is produced by the demodulator to provide a reference for evaluating depth of modulation.

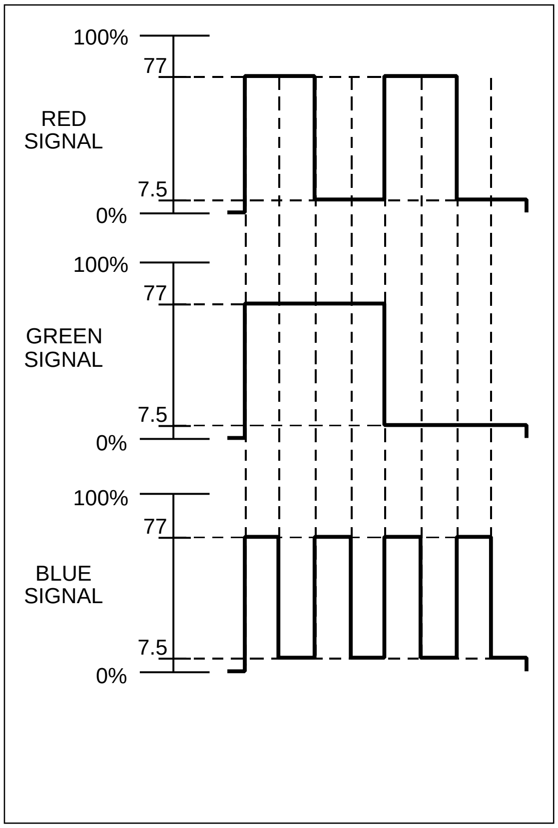


Figure 110. RGB levels decoded from 75% bars with 75% white.

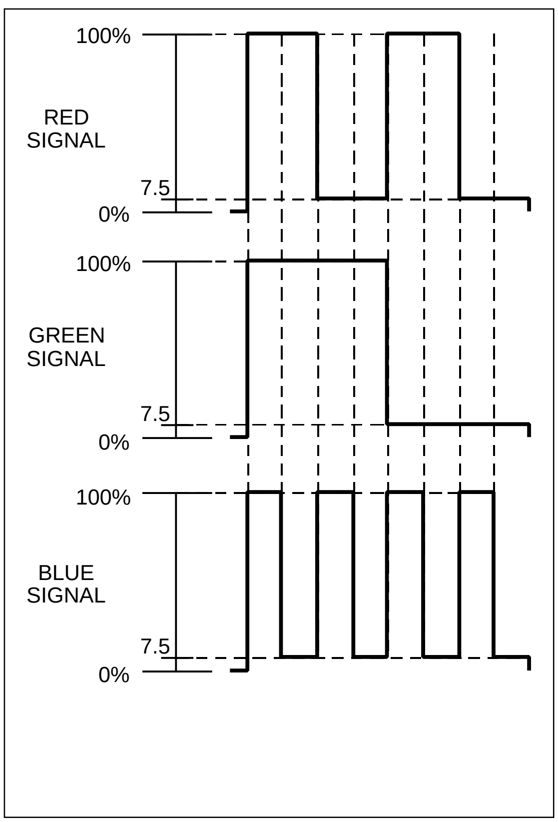


Figure 111. RGB levels decoded from 100% bars with 100% white.

There are two basic types of NTSC color bar signals in common use. The terms "75% bars" and "100% bars" are generally used to distinguish between the two types. While this terminology is widely used, there is often confusion about exactly which parameters the 75% versus 100% notation refers to.

RGB Amplitudes. The 75%/100% nomenclature specifically refers to the maximum amplitudes reached by the Red, Green, and Blue signals when they form the six primary and secondary colors required for color bars. For 75% bars, the maximum amplitude of the RGB signals is 75% of the peak white level. For 100% bars, the RGB signals can extend up to 100% of peak white (see Figures 110 and 111).

Saturation. Both 75% and 100% amplitude color bars are 100% saturated. In the RGB format, colors are saturated if at least one of the primaries is at zero. Note in Figures 110 and 111 that the zero signal level is at setup (7.5 IRE) for NTSC.

The Composite Signal. In the composite signal, both chrominance and luminance amplitudes vary according to the 75%/100% distinction. However, the ratio between chrominance and luminance amplitudes remains constant in order to maintain 100% saturation (see Figures 112 and 113).

White Bar Levels. Color bar signals can also have different white bar levels, typically either 75% or 100%. This parameter is completely independent of the 75%/100% amplitude distinction and either white level may be associated with either type of bars.

Effects of Setup. Because of setup, the 75% signal level for NTSC is at 77 IRE. The maximum available signal amplitude is 100 - 7.5, or 92.5 IRE. 75% of 92.5 IRE is 69.4 IRE, which when added to the 7.5 IRE pedestal, yields a level of approximately 77 IRE.

Note in Figure 110 that the 75% white bar and the 75% RGB signals extend to 77 IRE.

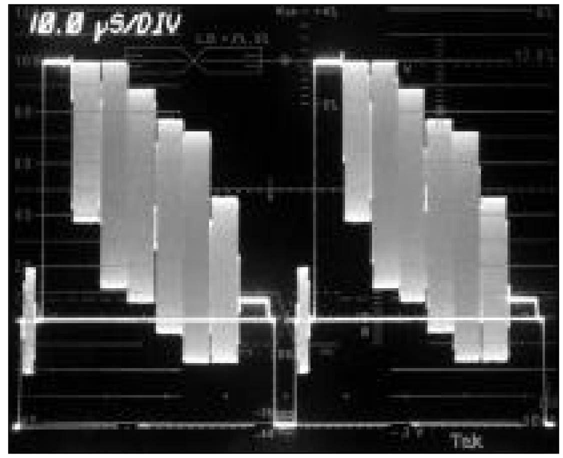


Figure 112. 75% bars with 100% white.

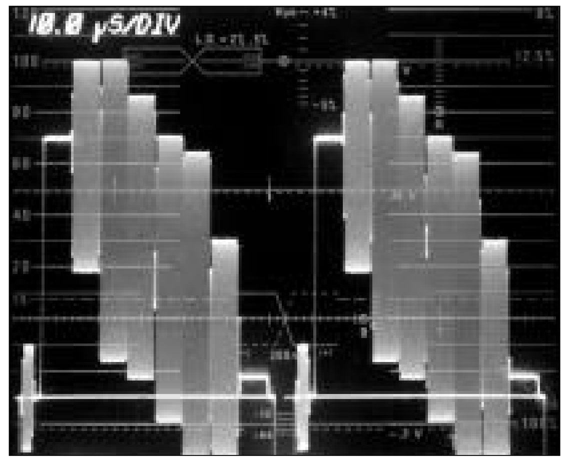


Figure 113. 100% bars with 100% white.

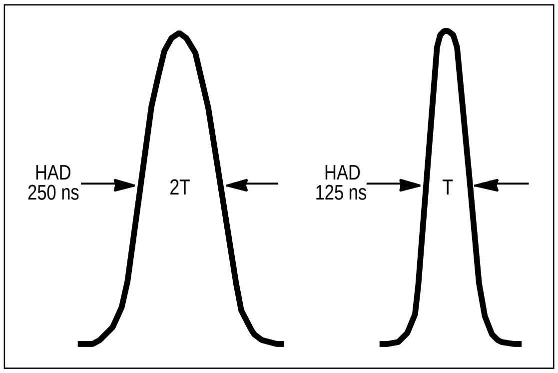


Figure 114. 2T pulse and 1T pulse for NTSC systems.

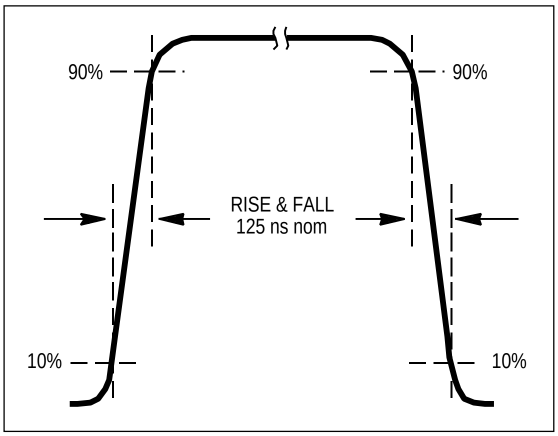


Figure 115. T rise time step.

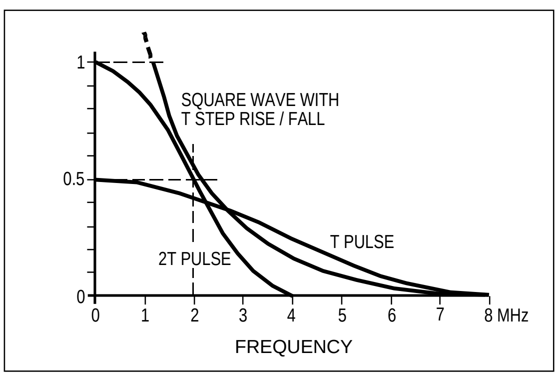


Figure 116. Frequency spectra of T pulse, 2T pulse, and T step.

Testing Bandlimited Systems. Fast rise time square waves cannot be used for testing bandwidth limited systems as attenuation and phase shift of out-of-band components will cause ringing in the output pulse. These out-of-band distortions can obscure the in-band distortions of interest. Sine-squared pulses are themselves bandwidth limited, and are thus useful for testing bandwidth limited television systems.

Description of the Pulse. The sine-squared pulse looks like one cycle of a sine wave (see Figure 114). Mathematically, a sine-squared pulse is obtained by squaring a half-cycle of a sine wave. Physically, the pulse is generated by passing an impulse through a sine-squared shaping filter.

T Intervals. Sine-squared pulses are specified in terms of half amplitude duration (HAD) which is the pulse width measured at 50% of the pulse amplitude.

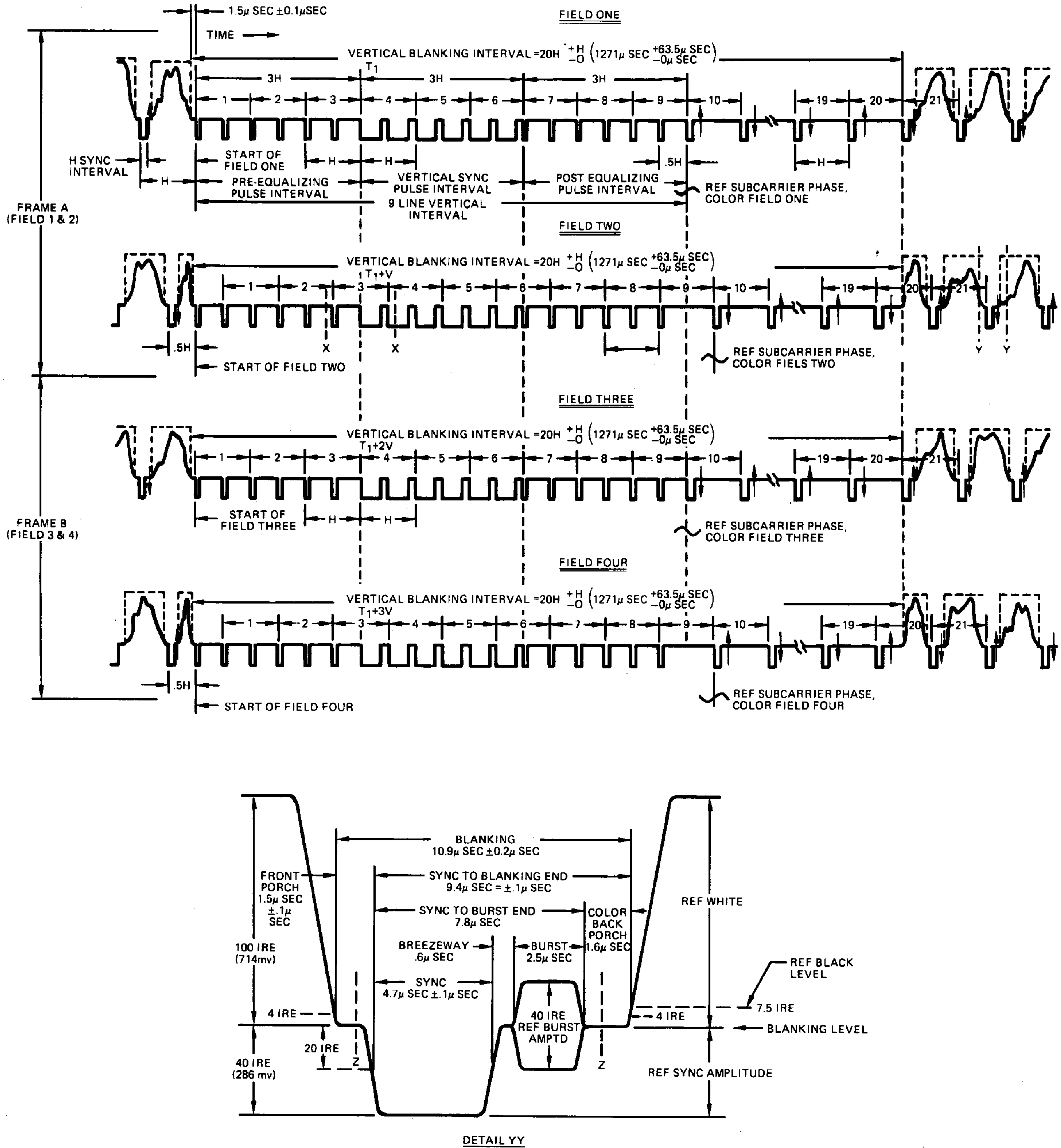
Pulses with a HAD that is a multiple of the time interval T are used to test bandwidth limited systems. T, 2T and 12.5T pulses are common examples. T is the Nyquist interval, or

$$\frac{1}{2f_c}$$

where fc is the cutoff frequency of the system to be measured. For NTSC, fc is taken to be 4 MHz and T is therefore 125 nanoseconds.

T Steps. The rise times of transitions to a constant luminance level (such as a white bar) are also specified in terms of T. A T step has a 10% to 90% rise time of nominally 125 nanoseconds while a 2T step has a rise time of nominally 250 nanoseconds (see Figure 115). Mathematically, a T step is obtained by integrating a sine-squared pulse. Physically, it is produced by passing a step through a sine-squared shaping filter.

Energy Distribution. Sine-squared pulses possess negligible energy at frequencies above f = 1/HAD. The amplitude of the envelope of the frequency spectrum at 1/(2 HAD) is one-half of the amplitude at zero frequency. Energy distributions for a T pulse, 2T pulse, and T step are shown in Figure 116.

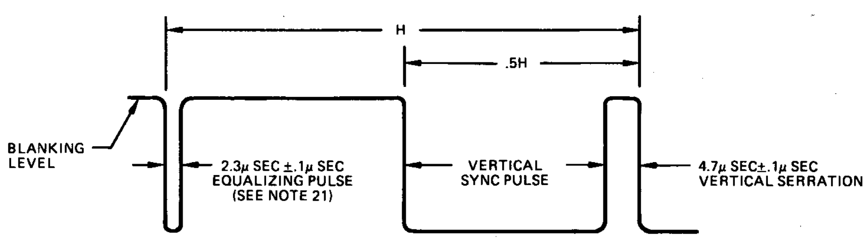

1.5μ SEC ±0.1μSEC
TIME
FIELD ONE
VERTICAL BLANKING INTERVAL =20H +H −O (1271μ SEC +63.5μ SEC −0μ SEC)
3H
T1
H SYNC INTERVAL
START OF FIELD ONE
PRE-EQUALIZING PULSE INTERVAL
VERTICAL SYNC PULSE INTERVAL
POST EQUALIZING PULSE INTERVAL
9 LINE VERTICAL INTERVAL
.5H
REF SUBCARRIER PHASE, COLOR FIELD ONE
FRAME A (FIELD 1 & 2)
FIELD TWO
T1+V
START OF FIELD TWO
REF SUBCARRIER PHASE, COLOR FIELS TWO
FIELD THREE
T1+2V
START OF FIELD THREE
REF SUBCARRIER PHASE, COLOR FIELD THREE
FRAME B (FIELD 3 & 4)
FIELD FOUR
T1+3V
START OF FIELD FOUR
REF SUBCARRIER PHASE, COLOR FIELD FOUR
BLANKING 10.9μ SEC ±0.2μ SEC
FRONT PORCH 1.5μ SEC ±.1μ SEC
SYNC TO BLANKING END 9.4μ SEC = ±.1μ SEC
SYNC TO BURST END 7.8μ SEC
COLOR BACK PORCH 1.6μ SEC
BREEZEWAY .6μ SEC
BURST 2.5μ SEC
SYNC 4.7μ SEC ±.1μ SEC
100 IRE (714mv)
4 IRE
20 IRE
40 IRE (286 mv)
40 IRE REF BURST AMPTD
REF WHITE
REF BLACK LEVEL
7.5 IRE
BLANKING LEVEL
REF SYNC AMPLITUDE
DETAIL YY

NOTES:

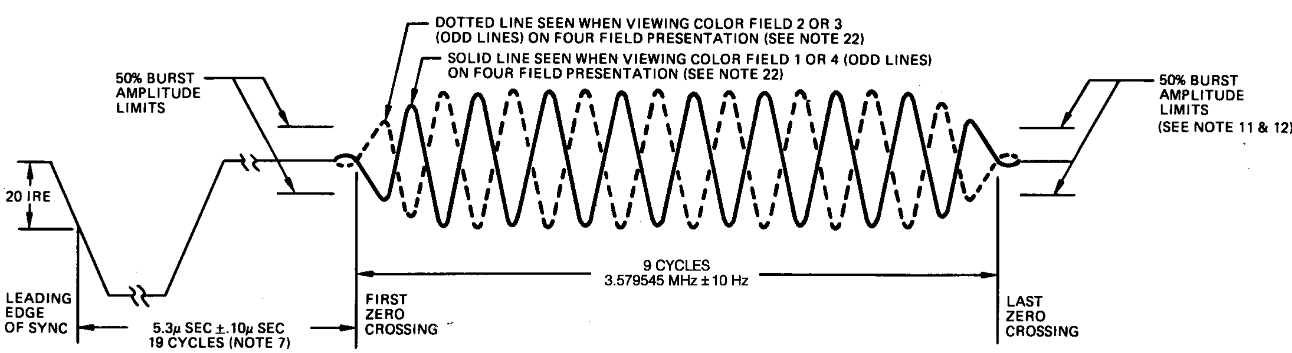
1. SPECIFICATIONS APPLY TO STUDIO FACILITIES. NETWORK AND TRANSMITTER CHARACTERISTICS ARE NOT INCLUDED.
2. ALL TOLERANCES AND LIMITS SHOWN IN THIS DRAWING PERMISSABLE ONLY FOR LONG TIME VARIATIONS.
3. BURST FREQUENCY SHALL BE 3.579545 MHz ±10 Hz.
4. HORIZONTAL SCANNING FREQUENCY SHALL BE 2/455 TIMES THE BURST FREQUENCY.
5. VERTICAL SCANNING FREQUENCY SHALL BE 2/525 TIMES THE HORIZONTAL SCANNING FREQUENCY.
6. START OF COLOR FIELDS ONE AND THREE IS DEFINED BY A WHOLE LINE BETWEEN THE FIRST EQUALIZING PULSE AND THE PRECEDING H SYNC PULSE. START OF COLOR FIELDS TWO AND FOUR DEFINED BY A HALF LINE BETWEEN THE FIRST EQUALIZING PULSE AND THE PRECEDING H PULSE. COLOR FIELD ONE IS THAT FIELD WITH POSITIVE GOING ZERO-CROSSINGS OF REFERENCE SUBCARRIER NOMINALLY COINCIDENT WITH 50% AMPLITUDE POINT OF THE LEADING EDGES OF EVEN NUMBERED HORIZONTAL SYNC PULSES.
7. THE ZERO-CROSSINGS OF REFERENCE SUBCARRIER SHALL BE NOMINALLY COINCIDENT WITH THE 50% POINT OF THE LEADING EDGES OF ALL HORIZONTAL SYNC PULSES. FOR THOSE CASES WHERE THE RELATIONSHIP BETWEEN SYNC AND SUBCARRIER IS CRITICAL FOR PROGRAM INTEGRATION, THE TOLERANCE ON THIS COINCIDENCE IS ±45° OF REFERENCE SUBCARRIER.
8. ALL RISE TIMES AND FALL TIMES UNLESS OTHERWISE SPECIFIED ARE TO BE 0.140 μSEC ±0.02 μSEC MEASURED FROM TEN TO NINETY PER CENT AMPLITUDE POINTS. ALL PULSE WIDTHS EXCEPT BLANKING ARE MEASURED AT FIFTY PER CENT AMPLITUDE POINT.
9. OVERSHOOT ON ALL PULSES DURING SYNC AND BLANKING (VERTICAL AND HORIZONTAL) SHALL NOT EXCEED TWO IRE UNITS. ANY OTHER EXTRANEOUS SIGNALS DURING BLANKING INTERVALS SHALL NOT EXCEED TWO IRE UNITS, MEASURED OVER A BANDWIDTH OF 6 MHz.
10. BURST ENVELOPE RISE TIME IS 0.30 μSEC MEASURED BETWEEN THE TEN AND NINETY PERCENT AMPLITUDE POINTS. IT SHALL HAVE THE GENERAL SHAPE SHOWN.
11. THE START OF BURST IS DEFINED BY THE ZERO-CROSSING (POSITIVE OR NEGATIVE SLOPE) THAT PRECEEDS THE FIRST HALF CYCLE OF SUBCARRIER THAT IS 50% OR GREATER OF THE BURST AMPLITUDE.
12. THE END OF BURST IN DEFINED BY THE ZERO-CROSSING (POSITIVE OR NEGATIVE SLOPE) THAT FOLLOWS THE LAST HALF CYCLE OF SUBCARRIER THAT IS 50% OR GREATER OF THE BURST AMPLITUDE.
13. MONOCHROME SIGNALS SHALL BE IN ACCORDANCE WITH THIS DRAWING EXCEPT THAT BURST IS OMITTED, AND FIELDS THREE AND FOUR ARE IDENTICAL TO FIELDS ONE AND TWO RESPECTIVELY.
14. REFERENCE SUBCARRIER IS A CONTINUOUS SIGNAL WHICH HAS THE SAME INSTANTANEOUS PHASE AS BURST.
15. PROGRAM OPERATING LEVEL WHITE IS 100 IRE, +0, −2 IRE.
16. PROGRAM OPERATING LEVEL BLACK IS 7.5 IRE, ±2.5 IRE.
17. PROGRAM OPERATING LEVEL SYNC IS 40 IRE, ±2 IRE.
18. PROGRAM OPERATING LEVEL BURST IS 40 IRE, ±2 IRE.
19. BURST PEDESTAL NOT TO EXCEED ±2 IRE.
20. BREEZEWAY, BURST, COLOR BACK PORCH, AND SYNC TO BURST END ARE NOMINAL IN DETAIL BETWEEN YY. SEE DETAIL BETWEEN ZZ FOR TOLERANCES.
21. RATIO OF AREA OF VERTICAL EQUALIZING PULSE TO SYNC PULSE SHALL BE WITHIN 45 TO 50 PER CENT.
22. THERE WILL BE A 100 DEGREE REVERSAL OF PHASE WHEN VIEWING EVEN LINES ON A FOUR FIELD PRESENTATION. A FOUR FIELD PRESENTATION MEANS A DISPLAY DEVICE WHICH IS TRIGGERED BY FOUR FIELD (15 Hz) INFORMATION.

THIS DRAWING CORRESPONDS TO PROPOSED RS 170A VIDEO STANDARD.

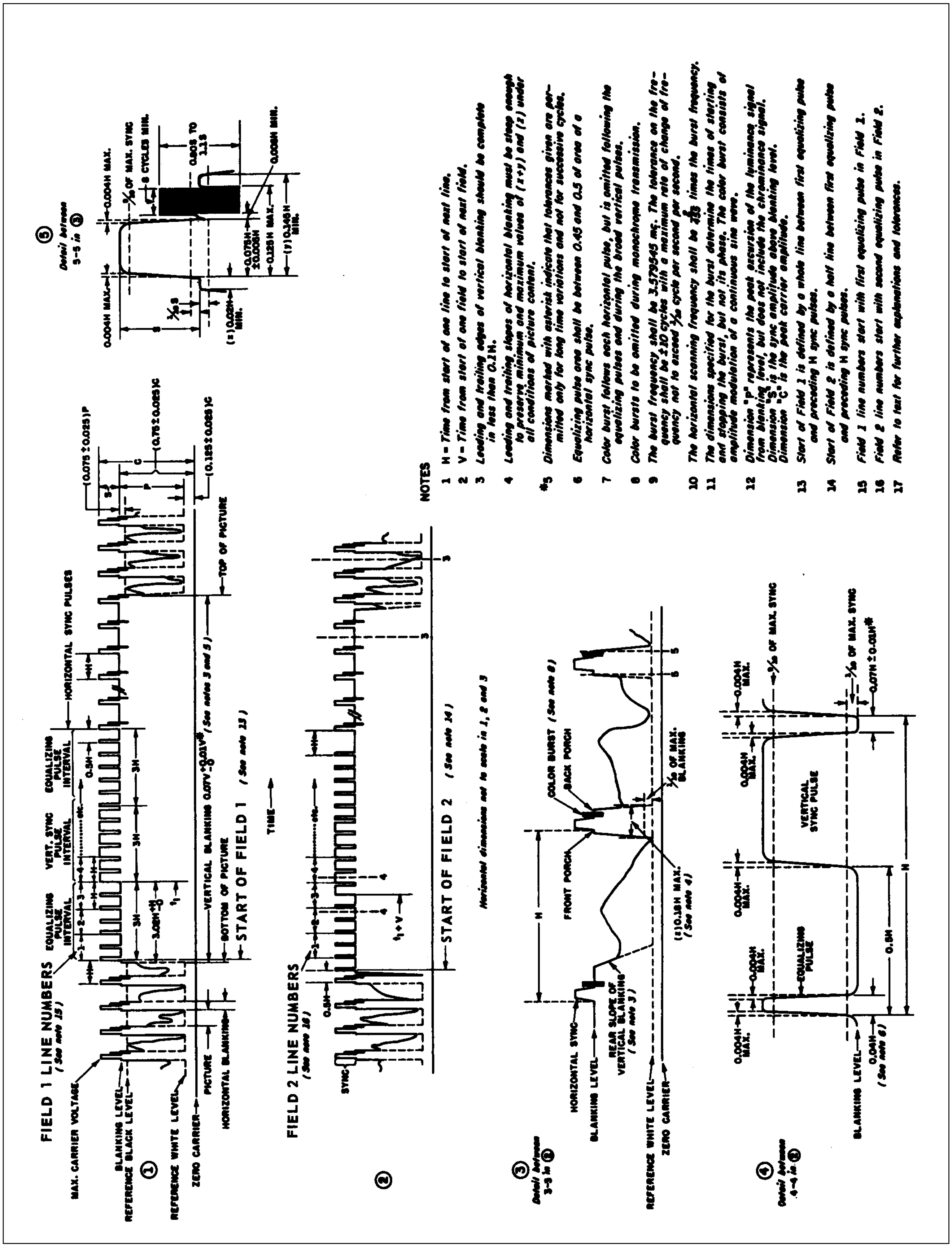
COLOR TIMING DATA:
1° = .776 ns
INS = 1.289°
FOR CABLE WITH 66% PROPAGATION FACTOR,
1° = 6.035″ = .503′
INS = 7.778″ = .648′



DETAIL XX



DETAIL ZZ


FIELD 1 LINE NUMBERS (See note 15)
EQUALIZING PULSE INTERVAL
VERT. SYNC PULSE INTERVAL
EQUALIZING PULSE INTERVAL
HORIZONTAL SYNC PULSES
MAX. CARRIER VOLTAGE
BLANKING LEVEL
REFERENCE BLACK LEVEL
REFERENCE WHITE LEVEL
ZERO CARRIER
PICTURE
HORIZONTAL BLANKING
VERTICAL BLANKING 0.07V +0.01V* -0 (See notes 3 and 5)
BOTTOM OF PICTURE
TOP OF PICTURE
START OF FIELD 1 (See note 13)
(0.075 ± 0.025)P
(0.75 ± 0.025)C
(0.125 ± 0.025)C
TIME
FIELD 2 LINE NUMBERS (See note 16)
SYNC
START OF FIELD 2 (See note 14)
Horizontal dimensions not to scale in 1, 2 and 3
Detail between 3-3 in 2
HORIZONTAL SYNC
BLANKING LEVEL
REAR SLOPE OF VERTICAL BLANKING (See note 3)
REFERENCE WHITE LEVEL
ZERO CARRIER
FRONT PORCH
COLOR BURST (See note 8)
BACK PORCH
(z) 0.18H MAX. (See note 4)
1/10 OF MAX. BLANKING
Detail between 4-4 in 2
EQUALIZING PULSE
VERTICAL SYNC PULSE
0.004H MAX.
9/10 OF MAX. SYNC
1/10 OF MAX. SYNC
BLANKING LEVEL
0.04H (See note 6)
0.5H
0.07H ± 0.01H*
Detail between 3-3 in 3
0.004H MAX.
9/10 OF MAX. SYNC
8 CYCLES MIN.
0.90S TO 1.1S
(x) 0.02H MIN.
0.075H ± 0.005H
0.125H MAX.
0.006H MIN.
(y) 0.145H MIN.
NOTES
1 H = Time from start of one line to start of next line.
2 V = Time from start of one field to start of next field.
3 Leading and trailing edges of vertical blanking should be complete in less than 0.1H.
4 Leading and trailing slopes of horizontal blanking must be steep enough to preserve minimum and maximum values of (x+y) and (z) under all conditions of picture content.
*5 Dimensions marked with asterisk indicate that tolerances given are permitted only for long time variations and not for successive cycles.
6 Equalizing pulse area shall be between 0.45 and 0.5 of area of a horizontal sync pulse.
7 Color burst follows each horizontal pulse, but is omitted following the equalizing pulses and during the broad vertical pulses.
8 Color bursts to be omitted during monochrome transmission.
9 The burst frequency shall be 3.579545 mc. The tolerance on the frequency shall be ±10 cycles with a maximum rate of change of frequency not to exceed 1/10 cycle per second per second.
10 The horizontal scanning frequency shall be 2/455 times the burst frequency.
11 The dimensions specified for the burst determine the times of starting and stopping the burst, but not its phase. The color burst consists of amplitude modulation of a continuous sine wave.
12 Dimension "P" represents the peak excursion of the luminance signal from blanking level, but does not include the chrominance signal. Dimension "S" is the sync amplitude above blanking level. Dimension "C" is the peak carrier amplitude.
13 Start of Field 1 is defined by a whole line between first equalizing pulse and preceding H sync pulses.
14 Start of Field 2 is defined by a half line between first equalizing pulse and preceding H sync pulses.
15 Field 1 line numbers start with first equalizing pulse in Field 1.
16 Field 2 line numbers start with second equalizing pulse in Field 2.
17 Refer to text for further explanations and tolerances.

For further information, contact Tektronix:

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