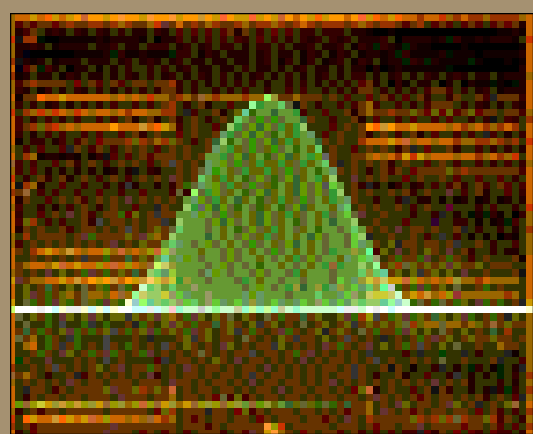
PAL Systems

Television Measurements



Tektronix

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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.

New instruments, test signals, and measurement procedures continue to be 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. Amplitude and Timing Measurements

II. Linear Distortions

III. Nonlinear Distortions

IV. Noise Measurements

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 newer concepts. The basics of waveform monitor and vectorscope operation are also assumed. Consult the instrument manuals for specific operating instructions.

This publication deals with PAL composite analogue signals. Analogue component, digital composite and component, and HDTV measurements are outside its scope.

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 are used to evaluate 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 Analogue 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 analogue 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 Analogue Genlock module provides the interface needed to lock the TG2000 to an external black burst reference signal.

For in-service measurements, the Tektronix VITS201 Generator and Inserter is the recommended product. The VITS201 provides a full complement of PAL 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 VITS201 fully support the measurement capabilities of the 1781R and VM700T 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 automatically trigger on the television synchronizing pulses and provide a voltage versus time display of the video signal. These instruments are equipped with specialized video clamps and filters that facilitate separate evaluation of the chrominance and luminance portions of the signal. Most models also have a line selector for looking at signals in the vertical interval.

A vectorscope is designed for accurate evaluation of the chrominance portion of the signal. This instrument demodulates the PAL signal and displays the V (R-Y) colour difference component on the vertical axis and the U (B-Y) colour difference component on the horizontal axis.

When selecting waveform monitors and vectorscopes, carefully evaluate the feature sets and specifications to make sure they will meet the measurement needs. This is particularly true if making accurate measurements of all the signal parameters and distortions described in this booklet. Many varieties of waveform monitors and vectorscopes are on the market 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 measurements are the Tektronix 1781R and VM700T and most of the measurement procedures in this booklet are based on these instruments.

The 1781R 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.

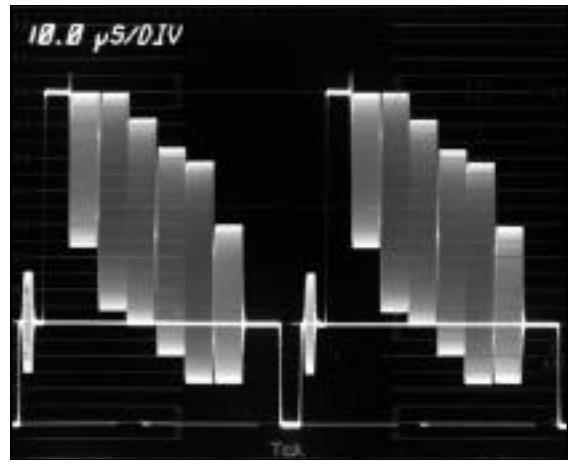

Figure 1. A waveform monitor display of colour bars.

Figure 2. A vectorscope display of colour bars.

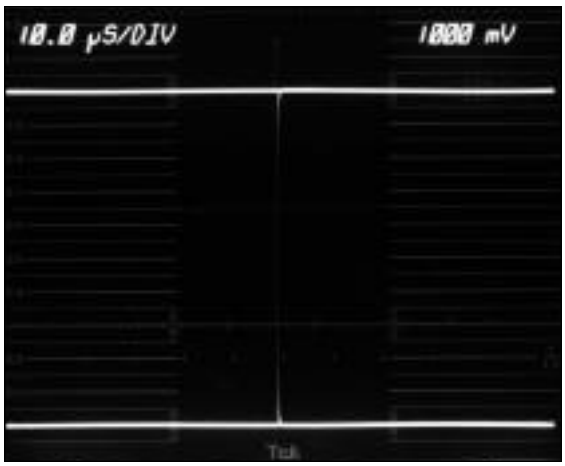

Figure 3. The 1781R waveform calibrator.

Figure 4. The 1781R 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.

Analogue CRT-based instruments such as the 1781R 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 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 in the video waveform to a fixed DC level. This ensures that the display will not move vertically with changes in signal amplitude or Average Picture Level (APL).

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.

Automatic Frequency Control (AFC) versus Direct Triggering. The AFC/DIRECT selection in the 1781R CONFIGURE menu provides a choice between two methods of triggering the waveform monitor's horizontal sweep. The ramp that produces the horizontal sweep is always synchronous with the H (line) or V (field) pulses of the reference video and can be 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 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.

Vectorscope Gain: 75%/100% Bars. Several different kinds of colour bars are used in PAL systems and many generators produce at least two types. In order to accommodate the various types of colour bars, some vectorscopes have a 75%/100% selection on the front panel which changes the calibration of the vectorscope chrominance gain. The 75% setting corresponds to 100.0.75.0 colour bars, often referred to as EBU Bars. The 100% setting corresponds to 100.0.100.0 colour bars. The 75%/100% distinction refers to chrominance amplitude, not to saturation or white bar level. Colour bar parameters and nomenclature are discussed in detail in Appendix A.

It is important to know which colour bar signal is in use and to select the corresponding setting on the vectorscope. Otherwise chrominance gain can easily be misadjusted.

DEMODULATED RF SIGNALS

All of the baseband measurements discussed in this booklet can 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. Double terminated or unterminated signal paths will seriously affect signal amplitude. It is essential that each video signal in a facility be terminated in one location using a 75 Ohm terminator. If a signal is looped through several pieces of equipment, 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 trying to measure very small distortions. Be sure to select a terminator with the tightest practical tolerance as incorrect termination impedance can cause amplitude errors as well as 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.

DEFINITION OF THE PAL TELEVISION STANDARD

The most widely used definition of the PAL standard is probably Report 624 of the CCIR (International Radio Consultative Committee), which specifies amplitude, timing and colour encoding parameters for all of the major television standards. This report was last reviewed in 1990 making version 624-4 the most current at this time.

There are a number of variations of PAL (M, N, B, G, H, I, D, etc.). With the exception of PAL-M, which is a 525-line system, the differences between the standards are fairly minor at baseband and usually involve only a bandwidth change. The default standard for this publication is PAL-B/G, which has a 5-MHz bandwidth and is used in much of Europe.

Governments of the various countries which use the PAL standard, as well as broadcasting organizations (such as the EBU, BBC, IBA, etc.), also publish standards documents. You may find discrepancies between the various standards. These can be difficult to resolve since there is no absolutely ""correct" answer. In general, documents from the local broadcasting authority should take precedence when there are conflicts.

PERFORMANCE GOALS

Acceptable levels of distortion are usually determined subjectively, however, a number of broadcasting organizations publish documents that specify recommended limits. In some cases government regulations may require that certain published criteria be met. While these documents can be useful as performance guidelines, each facility must ultimately determine its own performance goals. Only experience can reveal what is practical with the equipment and personnel at a given facility.

While there is usually agreement about the nature of each distortion, definitions for expressing the magnitude of the distortion may 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 peak deviation to be quoted as the amount of distortion?

A misunderstanding about 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 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.

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 1-volt peak-to-peak amplitude. Signals which are too large can be clipped or distorted and signals which are too small will suffer from degraded signal-to-noise performance.

Video amplitudes are monitored and adjusted on a daily basis in most television facilities. 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. On the following pages, only those timing measurements that relate to a single signal are addressed.

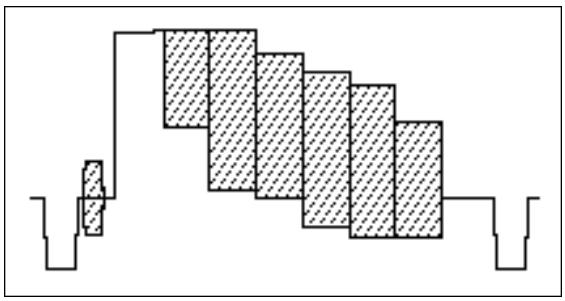

Figure 5. 100.0.75.0 colour bars.

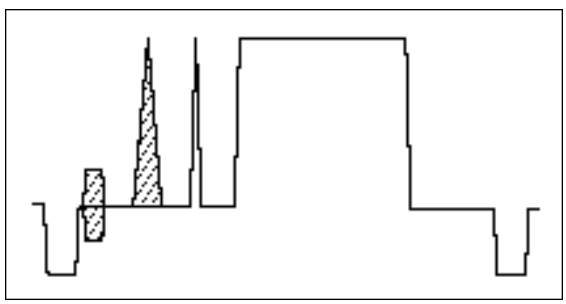

Figure 6. Pulse and bar test signal.

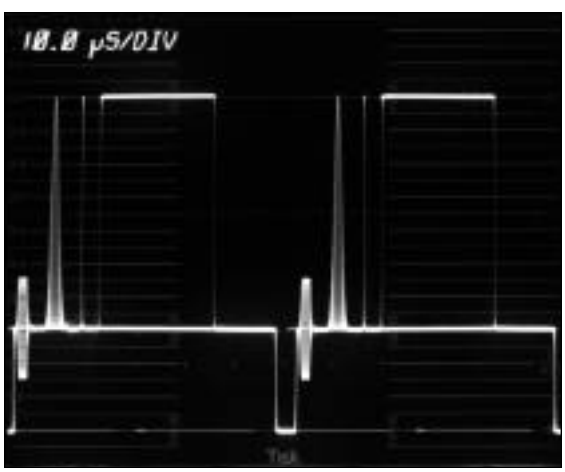

Figure 7. A 1-volt signal properly positioned with respect to the 1781R graticule.

DEFINITION

PAL composite video signals are nominally 1 volt peak-to-peak. Amplitude measurement techniques are used to verify that the signals conform to this nominal value and to make the appropriate gain adjustments when needed. Similar methods of evaluating the waveform are used for both measurement and adjustment of signal levels.

Measurements of the peak-to-peak amplitude of the video signal are sometimes called "insertion gain" measurements.

PICTURE EFFECTS

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

TEST SIGNAL

Insertion gain can be measured with any signal that contains a 700 mV white portion. Colour bars and pulse and bar signals are most frequently used (see Figures 5 and 6). Many of the standard ITS signals also contain a 700 mV bar and can be used to measure or adjust video gain.

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 from sync tip to peak white (see Figure 7). 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 1781R. In the 1481 it is accessed by depressing both the CAL button and the 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. When using a 1781R, select a calibrator amplitude of 1000 mV. In the 1481R, the DC RESTORER setting determines which of two calibrator amplitudes is selected. The calibrator amplitude is 1 volt when SYNC TIP is selected and 700 mV when BACK PORCH is selected.

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 8 shows a properly adjusted signal. Since the waveform monitor vertical gain need not be calibrated in this mode, the gain can be increased for greater resolution.

The 1781R has a variable amplitude calibrator so the WFM + CAL mode can be used to measure signal amplitudes other than 1 volt. Measurements are made by adjusting the calibrator amplitude (with the large front panel knob) until the bottom of the upper trace and the top of the lower trace coincide. At this point the calibrator amplitude equals the signal amplitude and can be read from the screen. The example in Figure 9 shows the WFM + CAL mode being used to measure sync amplitude.

1781R Voltage Cursors. Some waveform monitors, such as the 1781R, 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 10). The 1781R 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. The video signal amplitude should than be adjusted to match the cursor amplitude.

VM700T Cursors. 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 peak-to-peak amplitude, 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.

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 checking the ratio of sync to the picture signal (the part of the signal above blanking), which should be 3:7. 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 could be suffering from distortion, or equipment that re-inserts sync and burst may be malfunctioning.

2. Sync & Burst Measurements. Sync and burst should each be 30% of the composite video amplitude (300 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 1781R 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 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 luminance or lowpass filter on the waveform monitor. This filter removes the chrominance information so that peak white luminance levels can be used for setting gain.

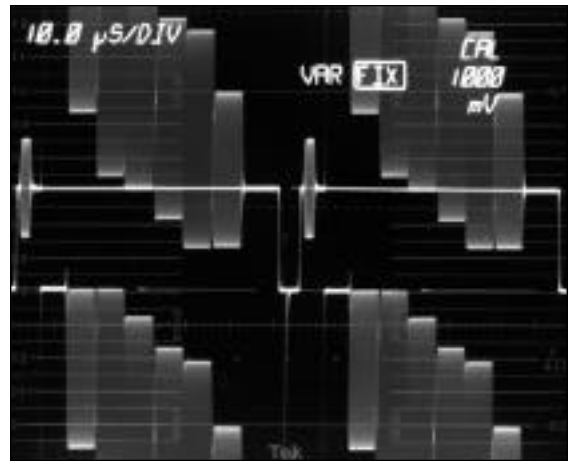

Figure 8. The WFM + CAL mode in the 1781R indicates that insertion gain is properly adjusted.

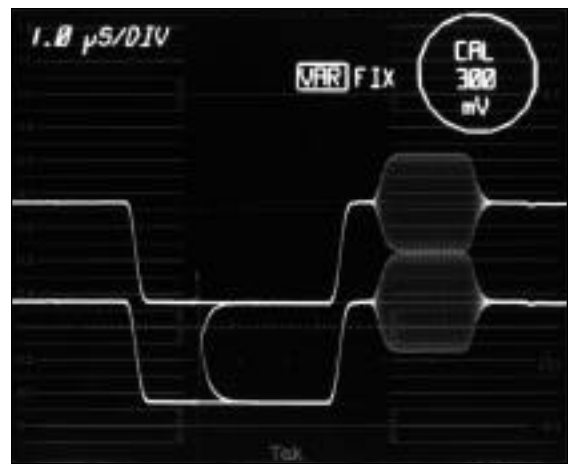

Figure 9. The WFM + CAL mode can also be used to measure sync amplitude.

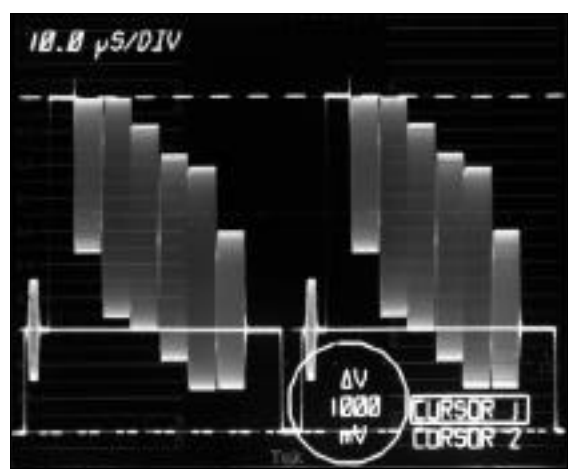

Figure 10. 1781R voltage cursors positioned to measure peak-to-peak amplitude.

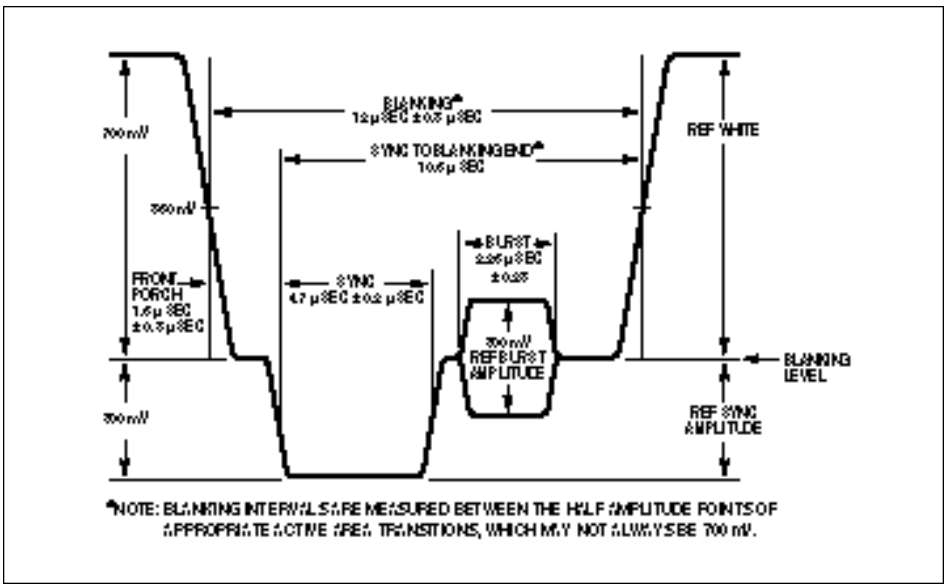

Figure 11. CCIR horizontal pulse width requirements.

DEFINITION

Horizontal and vertical synchronization pulse widths are measured in order to verify that they fall within specified limits. Other synchronization parameters such as rise and fall times and the position and number of cycles in burst are also specified and should occasionally be measured to verify compliance.

CCIR Report 624 is a widely accepted standard for PAL timing values and tolerances. The CCIR horizontal timing information for PAL systems is reproduced in Figure 11.

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 SIGNAL

Timing measurements can be made on any composite signal that contains 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 1781R displays the microseconds per division setting on the screen. For the 1481, time per division is obtained from the switch setting.

Most PAL pulse width measurements are specified between the 50% points of the rising and falling edges. Such measurements can usually be made with the vertical gain in the calibrated position. To measure horizontal sync width, for example, position the waveform so that the sync pulse is centered around the graticule baseline (blanking level at 150 mV above the baseline and sync tip at 150 mV below the baseline). The time scale is now at the 50% level and the pulse width can be read directly from the graticule (see Figure 12).

1781R Time Cursors. Some waveform monitors and oscilloscopes are equipped with cursors to facilitate the measurement of time intervals. The time cursors in the 1781R appear as bright dots on the waveform, an implementation that allows for very accurate positioning on waveform transitions.

To make a pulse width measurement, position the cursors on the 50% points of the transitions and read the cursor separation directly from the screen. An example of a horizontal sync width measurement is shown in Figure 13. If necessary, use the vertical graticule scale to help locate the 50% points. Alternatively, the voltage cursors in the RELATIVE mode can be used to locate the 50% points.

VM700T Cursors. 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 the 50% point to obtain a time measurement (see Figure 14). Consult the manual for detailed instructions on how to use the cursors.

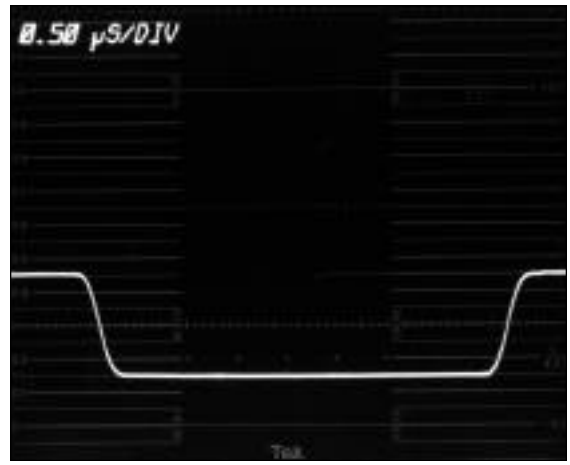

Figure 12. Horizontal sync width measurement at the 50% amplitude points.

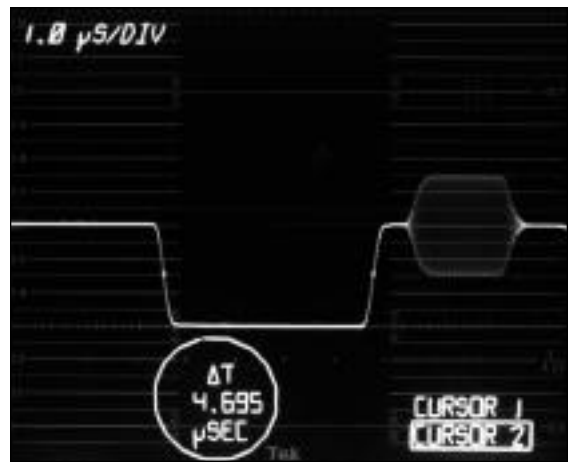

Figure 13. The 1781R time cursors positioned to measure horizontal sync width at the 50% amplitude points.

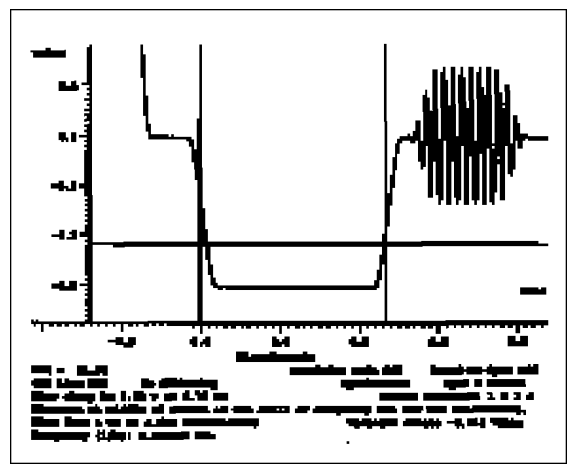

Figure 14. The VM700T cursors can be used to make horizontal sync width measurements.

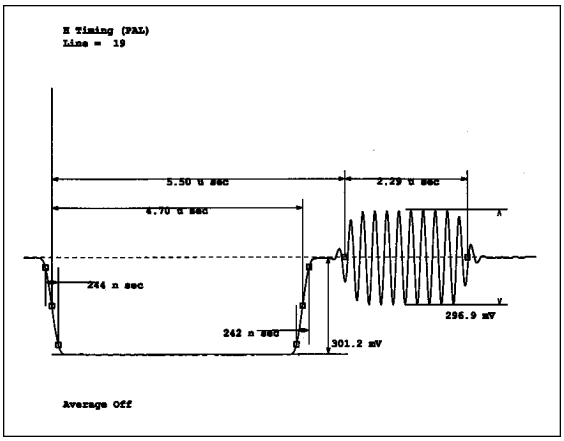

Figure 15. The VM700T H Timing display.

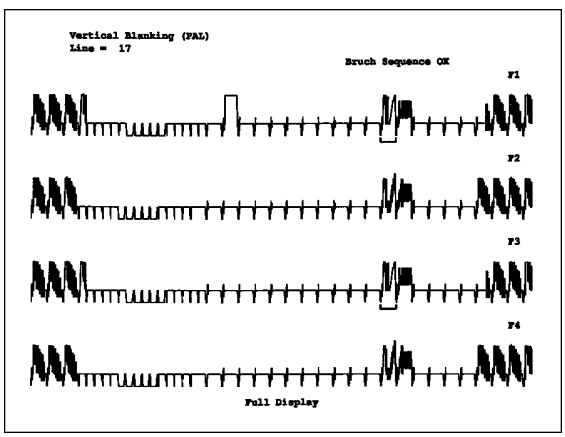

Figure 16 The VM700T Vertical Blanking display.

VM700T Automatic Measurement. The H TIMING selection in the VM700T MEASURE menu displays all horizontal blanking interval timing measurements (see Figure 15). The AUTO mode also provides measurements of the individual parameters.

NOTES

5. Rise and Fall Time Measurements. Many standards include specifications for the rise and fall time of the sync pulse (also referred to as build-up time). These measurements are indicators of how fast the transitions occur and are typically made between the 10% and 90% points of the signal.

The methods used for measuring pulse widths can generally be applied to rise and fall times. However, for 10%-to-90% measurements, it is generally most convenient to use the waveform monitor variable gain control to normalize the pulse height to 500 or 1000 mV. The 10% and 90% points can then easily be located with the graticule. In the 1781R RELATIVE mode, the voltage cursors can be used to locate the appropriate levels.

6. 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. CCIR nominal values and tolerances are shown in Figure 17.

It is good practice to occasionally verify that all of these parameters are correct. The V Blank selection in the VM700T MEASURE mode provides a convenient means of checking the format of the vertical interval and the timing of the individual pulses (see Figure 16).

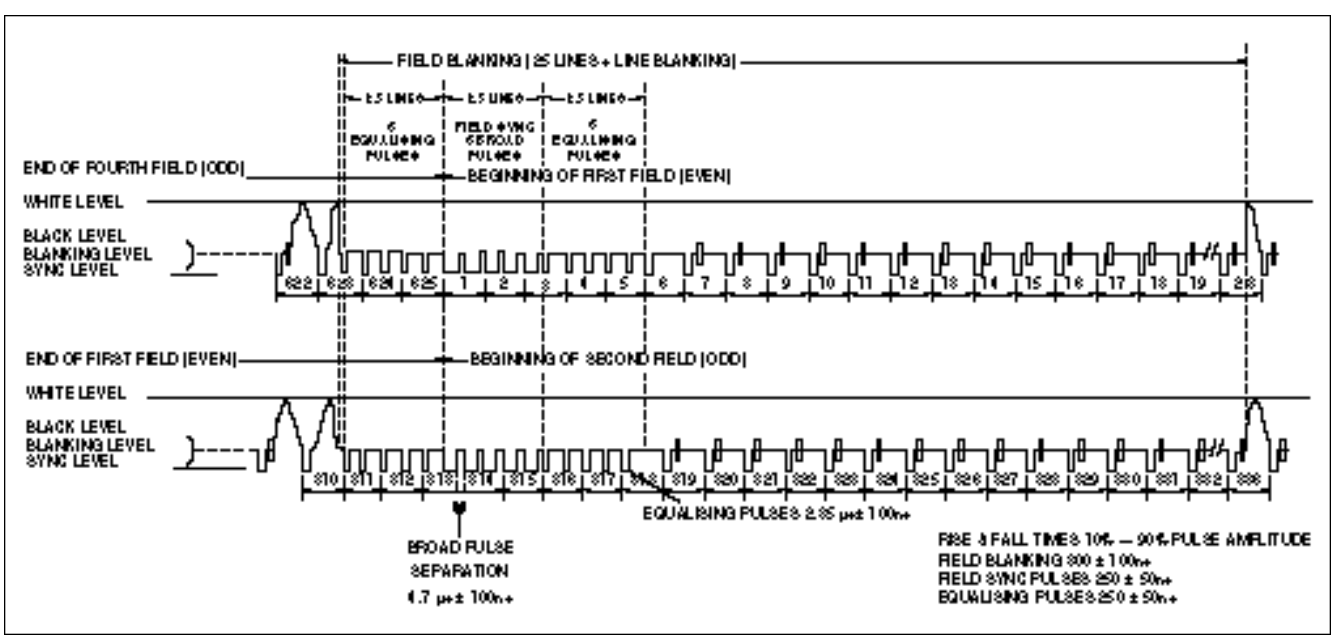

Figure 17. CCIR vertical interval specifications.

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. The official EBU definition, taken from EBU Technical Statement D 23-1984 (E), is as follows: “The subcarrier-to-line sync (Sc-H) phase is defined as the phase of the $+E'_u$ component of the colour burst extrapolated to the half-amplitude point of the leading edge of the synchronizing pulse of line 1 of field 1.”

Since there is no burst on line 1, measurement of SCH phase on line 7 of field 1 has become the generally accepted convention. Target tolerances of ± 20 degrees have been established although, in practice, 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 ensure that horizontal jumps do not occur when a switch is made, the sync edges of the two signals must be accurately timed and the phase of colour 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 eight fields (see Note 7). In order to achieve the sync and burst timing conditions required for a clean switch between two signals, the eight-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 ""colour framed". It is important to remember that colour 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 colour framed can the sync timing and burst phase matching requirements be achieved.

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 the transfer of programme material. This is one reason for trying to maintain 0 degrees of SCH phase error. Another motivation for keeping SCH phase within reasonable limits is that various pieces of equipment need to be able to distinguish between the colour frames in order to process the signal properly. This cannot be done accurately if the SCH phase is allowed to approach 90 degrees.

Figure 18. The 1781R polar SCH phase display showing a 10 degree error.

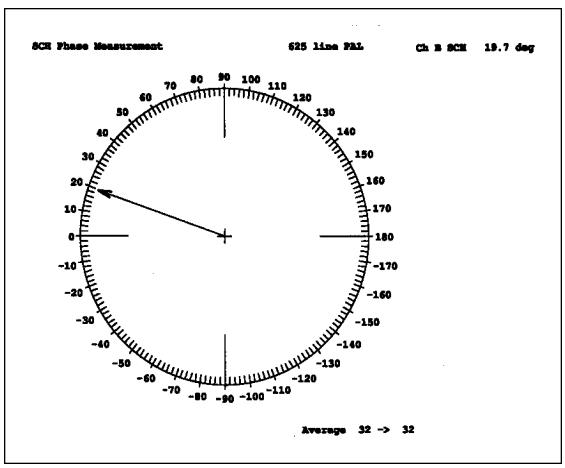

Figure 19. The VM700T SCH Phase Measurement display.

TEST SIGNALS

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

MEASUREMENT METHODS

Polar Display. Some instruments, such as the 1781R, are equipped with a polar SCH display that consists of the two burst vectors and a dot representing the phase of sync. The dot is in the centre of a "window" in the large circle that appears as part of the display (see Figure 18). This circle is a result of the 25 Hertz offset (see Note 7) which changes the SCH phase from line to line. The circle itself contains no relevant information.

The SCH phase is 0 degrees when the dot is at an angle midway between the two bursts. If there is an SCH phase error, its magnitude can be determined by measuring the angle between the sync dot and the midway point of the two bursts. The graticule can be used for this purpose when the bursts are properly positioned on their +135 and -135 degree points. The precision phase shifter in the 1781R can also be used to quantify the error.

The 1781R 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. When external reference is selected, both burst and sync of the selected signal are displayed relative to burst of the external reference signal. This display allows determination of whether or not two signals are colour framed. Assuming that both the reference signal and the selected signal have no SCH phase error, the sync dot will be between the burst vectors if the signals are colour framed and 180 degrees away when they are not.

VM700T Automatic Measurement. Select SCH PHASE in the VM700T MEASURE menu to obtain a polar display of SCH phase (see Figure 19). The vector in this display directly represents SCH phase error (there are not separate vector representations of sync and burst). The dual SCH display provides a simultaneous view of the SCH vectors for two signals. The full field SCH display provides a field-rate display that plots the SCH phase of each line in

the field.

NOTES

7. The PAL Eight-Field Sequence. The eight-field sequence exists in PAL because of the relationships between the line, field and subcarrier frequencies. Remember that subcarrier and H sync can be thought of as two continuous signals with a fixed relationship to one another. This relationship is defined mathematically as:

$F_{sc} = (1135/4 \times F_h) + 25$

which yields a subcarrier frequency (Fsc) of 4,433,618.75 Hz for a line frequency (Fh) of 15,625 Hz. It can be seen from the equation that there are an odd number of subcarrier quarter-cycles in a line. This implies that SCH phase changes by 90 degrees every line.

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 only once every eight fields (four frames).

Due to the 25 Hz offset, which is added to interleave chrominance dot patterns in the picture, the line-to-line change in SCH phase is actually somewhat more than 90 degrees. Keep this in mind when making measurements, as this is why SCH phase is defined on a given line in PAL. It is important to remember, however, that the existence of the eight-field sequence is determined only by the sync-to-subcarrier relationship and is independent of the 25 Hertz offset, the Bruch blanking sequence, and the alternate-line V-axis inversion.

8. For More Information. For a comprehensive discussion of SCH phase and colour framing issues, see Tektronix Application Note (20W-5614-1), “Measuring and Monitoring SCH Phase with the 1751A Waveform/Vector Monitor”.

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-rate or field-rate information, linear distortions are probably present. These distortions are most commonly caused by imperfect transfer characteristics of the equipment 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 familiar television time interval, have been identified. (The range of time intervals for each category may vary somewhat from definition to definition.) These categories are:

SHORT TIME (100 nanoseconds to 1 microsecond)

LINE TIME (1 microsecond to 64 microseconds)

FIELD TIME (64 microseconds to 20 milliseconds)

LONG TIME (greater than 20 milliseconds)

This classification is convenient because it allows 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 useful to have methods of simultaneously evaluating response at all frequencies of interest. Frequency response measurements look at amplitude versus frequency characteristics while group delay measurements examine phase versus frequency characteristics. Unlike the measurements classified by time interval, frequency response and group delay measurements permit separation of amplitude distortions from delay distortions.

In addition to these measurements, there is one specific case that needs to be examined in detail. The phase and amplitude relationships between the chrominance and luminance information in a signal are critical. Chrominance-to-luminance gain and delay are therefore measured in order to 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.

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 change is expressed in percent or dB with the number negative for low chrominance and positive for high chrominance.

Chrominance-to-luminance delay inequality (relative chrominance time) is a change in the time relationship between the chrominance and luminance components of a video signal. The change 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. This shows up in the picture as incorrect colour saturation.

Delay distortion will cause colour 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 inequalities are measured with a 10T or 20T modulated sine-squared pulse. Many combination ITS signals include such a pulse.

The frequency spectrum of a composite pulse includes energy at low frequencies and energy centered on the subcarrier frequency. Selection of an appropriate pulse width is a trade-off between occupying the PAL chrominance bandwidth as fully as possible and obtaining a pulse with sufficient sensitivity to delay errors. The 10T pulse is more sensitive to delay errors than the 20T pulse, but does not occupy as much of the chrominance bandwidth. CCIR specifications generally recommend the use of 20T pulses while 10T pulses are commonly used in the U.K.

A modulated bar is also sometimes used to measure chrominance-to-luminance gain inequalities.

MEASUREMENT METHODS

Conventional chrominance-to-luminance gain and delay measurements are based on analysis of the baseline of a modulated sine-squared pulse. (See Appendix B for a definition of the time interval T.) This pulse is made up of a sine-squared luminance pulse and a chrominance packet with a sine-squared envelope (see Figure 21).

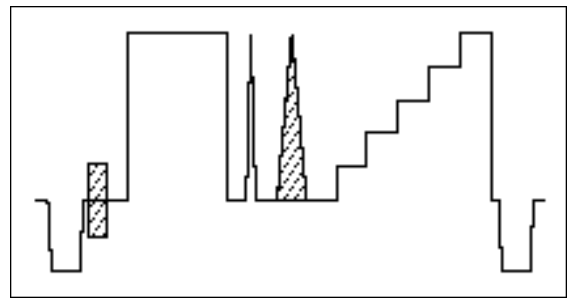

Figure 20. A combination signal that includes a 20T modulated pulse (CCIR Line 17).

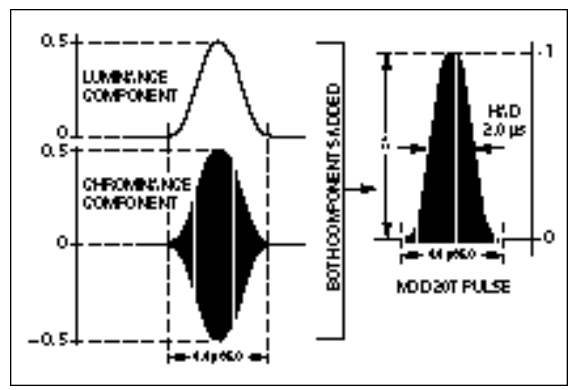

Figure 21. The chrominance and luminance components of a modulated sine-squared pulse.

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.

The baseline of the modulated 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 will not be at the centre of the pulse. Figure 22 shows the effects of various types of distortion.

Waveform Monitor and Nomograph. One method of quantifying chrominance-to-luminance inequalities involves measuring the peaks of the modulated pulse baseline distortion and applying these numbers to a nomograph. The nomograph converts the baseline measurements into gain and delay numbers.

To make a measurement, first normalize the pulse height to 100% (500 mV or 1000 mV is generally most convenient). The baseline distortion can be measured either by comparing the waveform to a graticule or by using voltage cursors. Using a nomograph (see Figure 23), find the locations on the horizontal and vertical axes which correspond to the two measured distortion peaks. At the point where perpendicular lines drawn from these two locations intersect, the gain and delay numbers may be read from the nomograph.

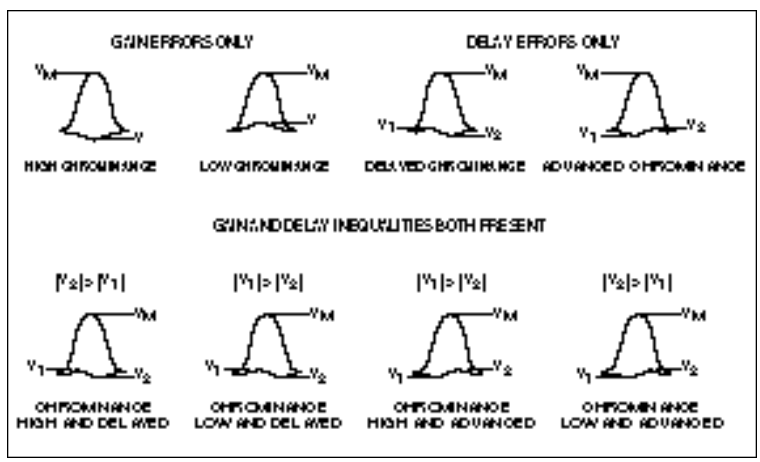

Figure 22. Effects of gain and delay inequalities on the modulated sine-squared pulse.

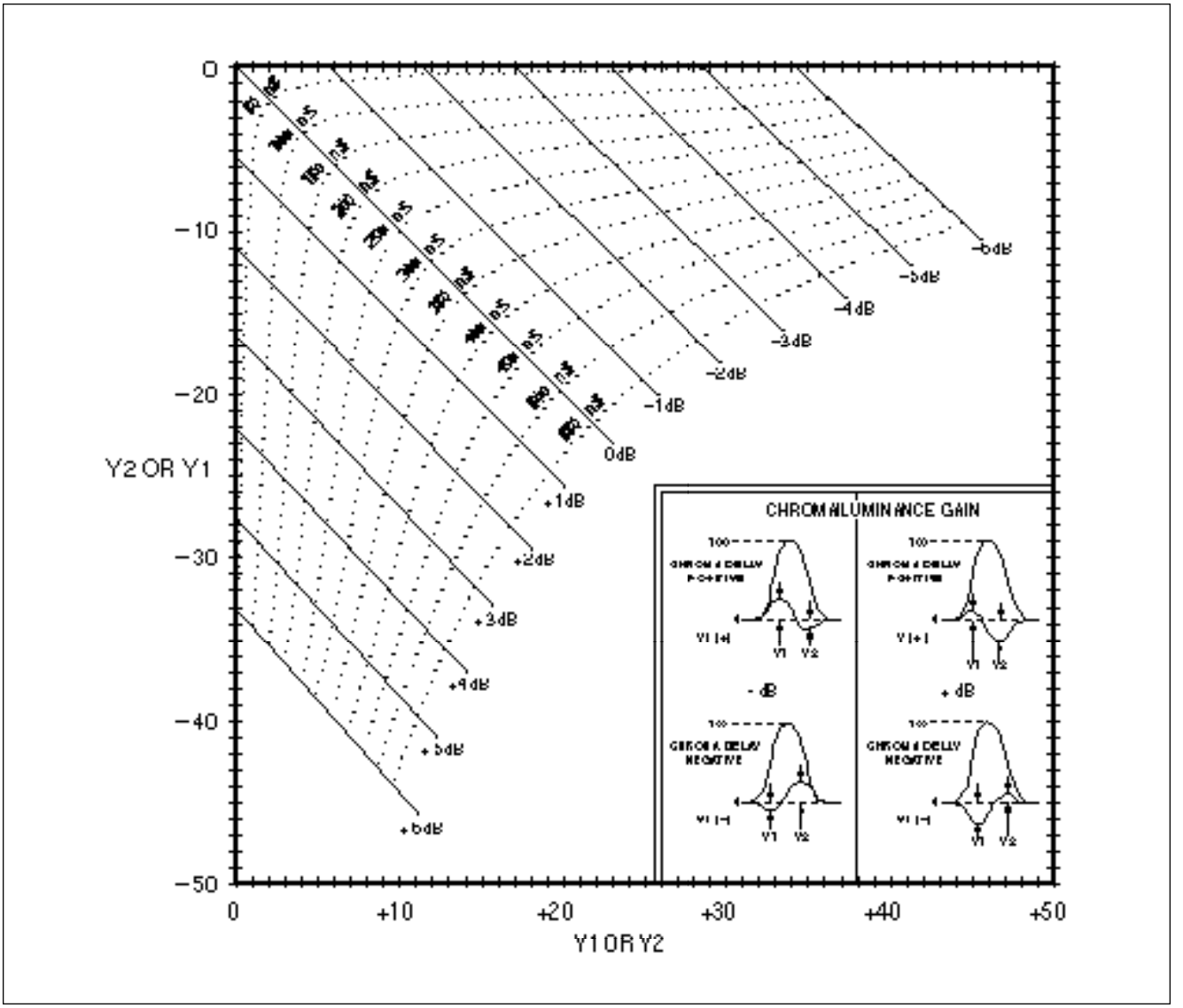

Figure 23. Chrominance-to-luminance gain and delay nomograph for a 20T pulse.

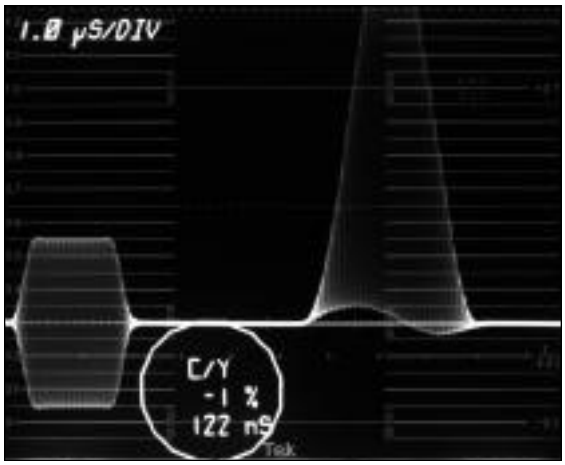

Figure 24. Results obtained with the CHROMA/LUMA selection in the 1781R MEASURE mode.

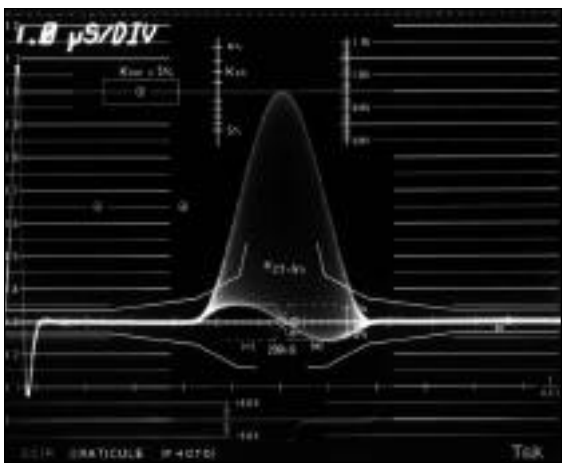

Figure 25. The 1781R graticule indicates that this signal has approximately 200 nanoseconds of chrominance-to-luminance delay.

When making measurements in this manner, it is important to know whether the signal is a 10T or a 20T pulse. The same nomograph can be used for both but a correction factor must be applied. The nomograph in Figure 23 is for a 20T pulse and the result must be divided by two when using a 10T pulse.

1781R Semi-Automatic Procedure. The CHROMA/LUMA selection in the 1781R 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 24). 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 inequalities can be measured directly by comparing the height of the modulated 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 delay distortion in the 100 to 200 nanosecond range and is accurate to within a few percent for signals with several hundred nanoseconds of delay.

This measurement is made by normalizing the white bar amplitude to 100% and then measuring the amplitude difference between the modulated pulse top and the white bar. This difference 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 modulated pulse and the bar is actually twice the difference between their peak values, hence the factor of two.

The lines at the centre of the baseline on the 1781R and 1481 external graticules can be used to estimate chrominance-to-luminance delay errors. This method yields valid results only if gain errors are negligible (the baseline distortion should appear symmetrical). To use these graticule marks, first use the variable gain to normalize the modulated pulse height to 700 mV. Then centre the pulse on the two graticule lines which cross in the centre of the baseline (see Figure 25). The graticule lines indicate 200 nanoseconds of delay for a 20T pulse and 100 nanoseconds for a 10T pulse. With X5 vertical gain selected (in addition to the variable gain required to normalize the pulse), the lines indicate 40 nanoseconds of delay for the 20T pulse and 20 nanoseconds for the 10T pulse.

VM700T Automatic Measurement. Chrominance-to-luminance gain and delay errors can be measured by selecting CHROM/LUM GAIN DELAY in the VM700T MEASURE mode. Numeric results are given in this mode and both parameters are simultaneously plotted on the graph (see Figure 26). Delay is plotted on the X axis and gain inequality on the Y axis. These measurements are also available in the VM700T 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 delay until there is only one peak in the baseline indicating all delay errors have been nulled out. The delay value can then be read from the fixture and gain measured from the graticule. This method can be highly accurate but requires the use of specialized equipment.

NOTES

9. 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. 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.

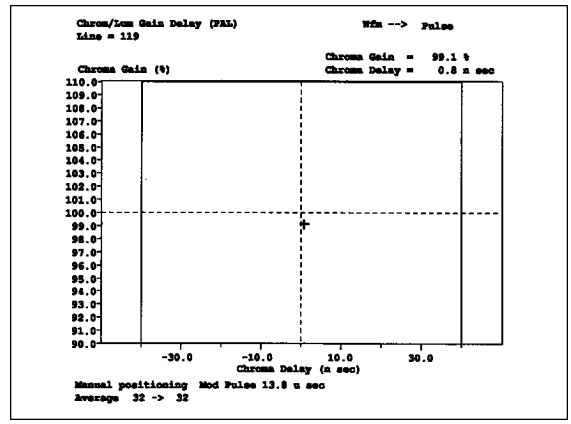

Figure 26. The Chrom/Lum Gain Delay display in the VM700T MEASURE mode.

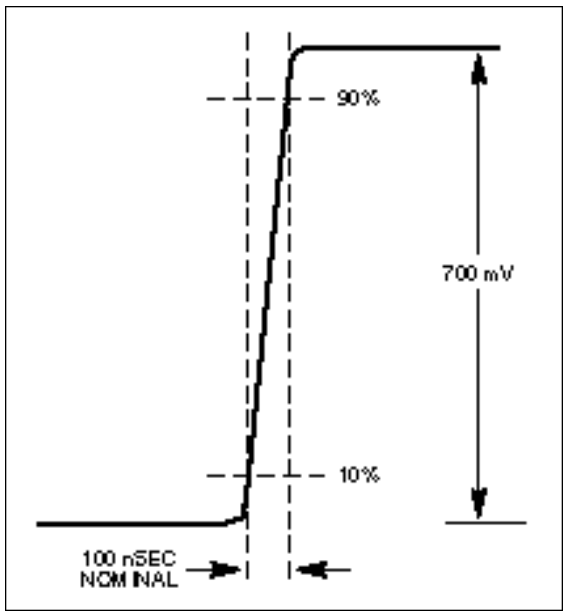

Figure 27. A T rise time bar has a 10% to 90% rise time of nominally 100 nanoseconds.

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 0.100 microsecond to 1.0 microsecond.

For PAL systems, distortions in the short time domain are most often characterized by measuring K_{2T} or $K_{pulse/bar}$. These measurements are described in the K Factor Ratings section of this booklet. Alternatively, the aberrations in a T rise time bar can be described in terms of the "percent SD" method described in this section.

PICTURE EFFECTS

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

TEST SIGNALS

Short time distortion can be measured with any signal that has a T rise time white bar. A T rise time bar has a 10%-to-90% rise time of nominally 100 nanoseconds (see Figure 27). See Appendix B for a discussion of the time interval T.

It is very important a T rise time bar be used with the short time distortion graticule. Many common test signals have 2T rather than T 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 that will be removed by the transmitter 5 or 6 MHz lowpass filter. Short time distortion measurements made on transmitted signals will therefore evaluate only those components in approximately the 200 nanosecond to 1 microsecond range.

MEASUREMENT METHODS

Measurements of the undershoot, overshoot, and ringing at the edge of a T rise bar are not generally quoted directly as a percent of the transition amplitude, but rather in terms of an amplitude weighting system that yields results in ""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. Although results can be calculated from the time and amplitude of the measured ringing lobes, special graticules, conversion tables, or nomographs are used in practice.

Waveform Monitor Graticule. Graticules for measurement of short time distortion are not included in the 1781R. However, some organizations use custom graticules that indicate, for example, 2% and 5% SD limits. The measurement procedure involves normalizing the gain and positioning the rising or falling edge of the bar in the graticule. The largest graticule limit touched by the waveform indicates the amount of distortion. Other values can be interpolated.

VM700 Automatic Measurement. Select SHORT TIME DISTORTION in the VM700T MEASURE mode to obtain a SD result and a tracking graticule (CCIR 421). The user can also define custom graticules in this mode.

NOTES

10. 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.

11. 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%. Now measure the pulse amplitude, in percent, to obtain pulse-to-bar ratio reading. The 1781R's voltage cursors can be used in the RELATIVE mode to make measurements of this type.

A pulse-to-bar measurement can be obtained from the VM700T by selecting K FACTOR in the MEASURE mode. Both pulse-to-bar ratio and $K_{pulse/bar}$ results (see Note 17) are provided in this mode.

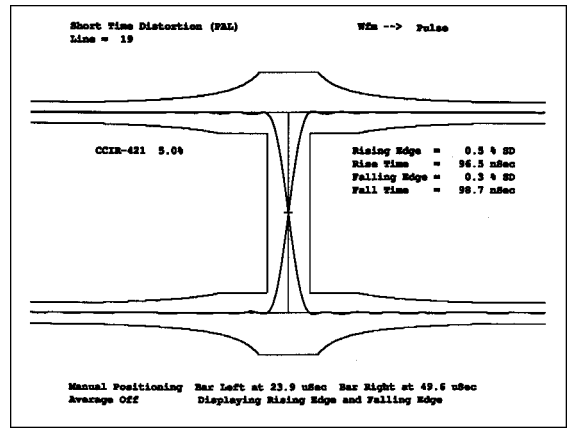

Figure 28. The VM700T Short Time Distortion display.

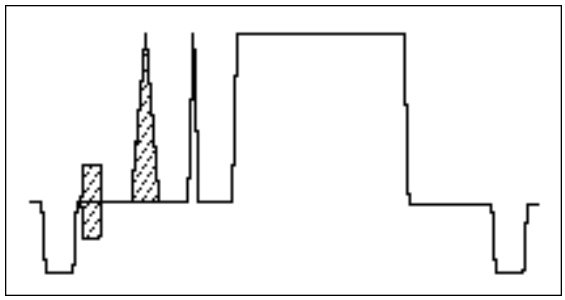

Figure 29. Pulse and bar signal.

DEFINITION

Line time distortion causes tilt in line-rate signal components such as white bars. The affected signal components range in duration from 1.0 microsecond to 64 microseconds. The amount of distortion is expressed as a percentage of the line bar amplitude at the centre of the bar.

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

In large picture detail, this distortion produces brightness variations between the left and right sides of the screen. Horizontal streaking and smearing may also be apparent.

TEST SIGNAL

Line time distortion is measured with a signal that includes a 10 microsecond or 25 microsecond white bar. 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. For PAL systems, the maximum departure of the bar top from the level at the centre of the line bar is most often quoted as the amount of distortion. In some cases the peak-to-peak level variation is given, particularly when a 10 microsecond bar is used. The measurement methods in this section are described in terms of peak results but can readily be adapted for peak-to-peak measurements.

In either case, the tilt is expressed as a percentage of the level at the centre of the bar. The first and last microsecond of the bar should be ignored as errors near the transition are in the short time domain.

Waveform Monitor Graticule. The graticule on a waveform monitor can be used to quantify this distortion. Measure the maximum deviation from the centre of the bar and express that number as a percentage of the level at bar centre. It is generally most convenient to use the variable gain to normalize the centre of the bar to 500 or 1000 mV. Deviations in the top of the bar can then be read directly from the graticule in percent. Remember to ignore the first and last microsecond.

1781R 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 centre as 100%. Leave one cursor at the bar centre and move the other cursor to measure the peak positive and peak negative deviations in the top of the bar. The largest of these numbers (ignore the sign) is the amount of line time distortion.

The 1781R time cursors are convenient for locating the appropriate time interval in the centre of the bar. Set the time separation to the bar time (usually 10 or 25 microseconds) minus 2 micro-seconds. Put the time cursors in the TRACK mode, and move the two cursors together until they are centered on the bar (see Figure 30).

VM700T Automatic Measurement. Select BAR LINE TIME in the VM700T MEASURE menu to obtain a line time distortion result (see Figure 31). Line time distortion can also be measured in the AUTO mode.

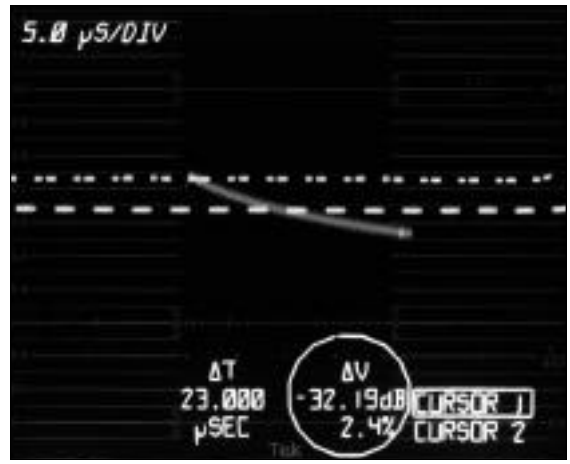

Figure 30. The 1781R voltage and time cursors can facilitate line time distortion measurements.

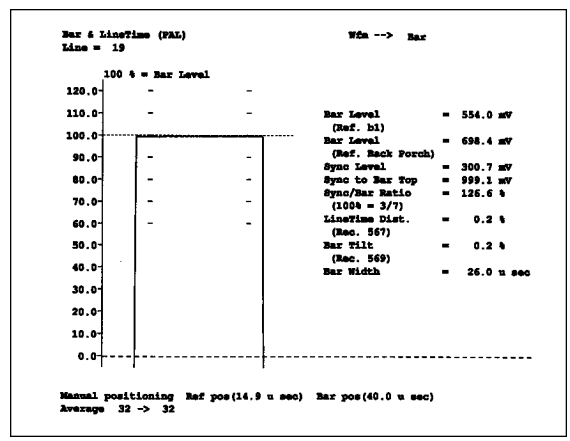

Figure 31. The VM700T Bar Line Time display.

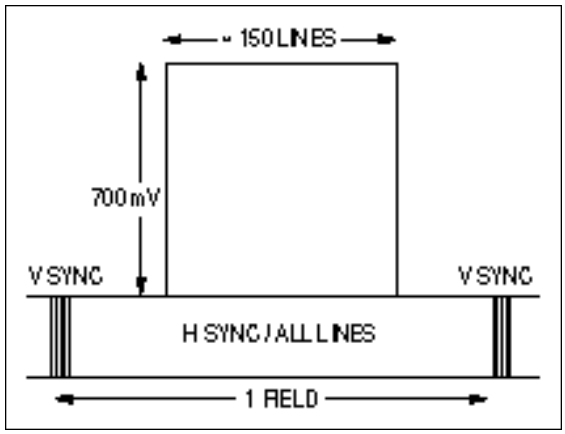

Figure 32. The field square wave test signal.

DEFINITION

Field time distortion causes field-rate tilt in video signals. The affected signal components range in duration from 64 microseconds to 20 milliseconds. The amount of distortion is generally expressed as a percentage of the amplitude at the centre of the line bar.

$K_{50\ Hz}$ measurements, which are discussed in the K FACTOR section of this booklet, provide another method of describing field time distortions.

PICTURE EFFECTS

Field time linear distortion will cause top-to-bottom brightness inaccuracies in large picture details.

TEST SIGNALS

Field time distortion is measured with a field square wave. In this signal, each line in one half of the field is a 0-volt pedestal, while each line in the other half is a 700-millivolt pedestal. The signal usually includes normal horizontal and vertical synchronization information.

MEASUREMENT METHODS

Field time distortions are quantified by measuring the amount of tilt in the top of the field bar (the 700 mV part of the field square wave signal). The maximum departure of the field bar top from the level at the centre of the field bar is generally quoted as the amount of distortion although peak-to-peak results are sometimes given. The measurement methods in this section are described in terms of peak results, but can readily be adapted for peak-to-peak measurements. The centre of the line bar is usually used as the reference amplitude and the first and last 250 microseconds (about 4 lines) of the field bar should be 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 centre of the line bar to 100% (1000 mV or 500 mV). This can be done most accurately with the waveform monitor FAST DC restorer on. The DC restorer will remove the effects of field time distortion from the waveform monitor display and reduce the vertical blurring seen in the line rate display. Now select a field-rate sweep and either the SLOW or OFF setting for the DC restorer. Measure the peak positive and peak negative level change from the centre of the field bar excluding the first and last 4 lines. The larger of these two numbers, expressed as a percentage of the line bar amplitude, is the amount of field time distortion (see Figure 33).

1781R Voltage Cursors. The 1781R voltage cursors can be used in the RELATIVE mode to measure field time distortion. Select a one-line or two-line sweep and define the centre of the line bar (relative to blanking) as 100%. Remember to select the FAST DC restorer setting. Then select a field-rate sweep and set the DC restorer to SLOW or OFF. Place one cursor so that it intersects the top of the field bar in the middle. Use the other cursor to measure the peak positive and peak negative level deviation in the top of the bar ignoring the first and last 4 lines. The larger of the two numbers is the amount of field time distortion in percent.

VM700T Automatic Measurement. Select TWO FIELD in the VM700T MEASURE mode to obtain a field time distortion result (see Figure 35). Field time distortion can also be measured in the AUTO mode.

NOTES

12. Externally Introduced Distortions. 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.

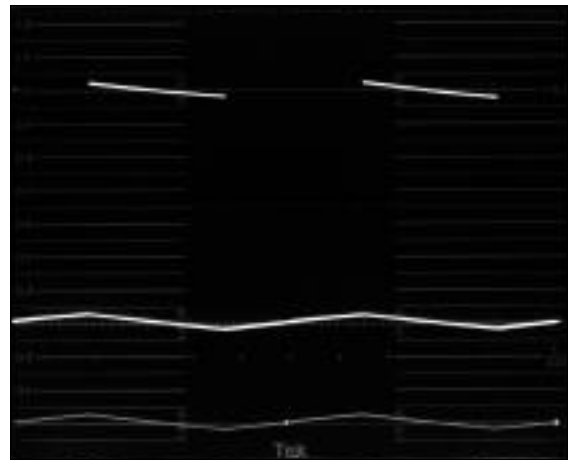

Figure 33. A 2-field waveform monitor display showing field time distortion.

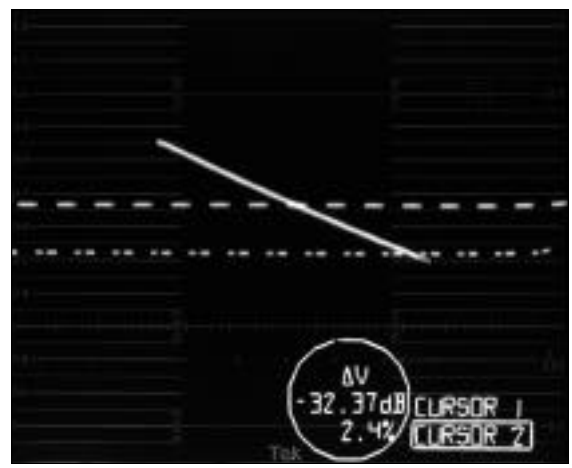

Figure 34. The 1781R voltage cursors can be used to measure field time distortion.

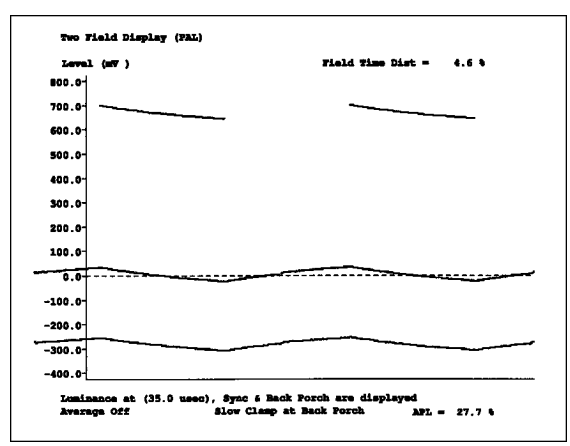

Figure 35. The VM700T Two Field display.

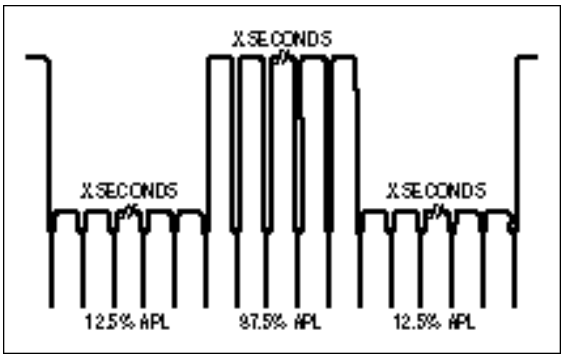

Figure 36. A flat field bounce signal.

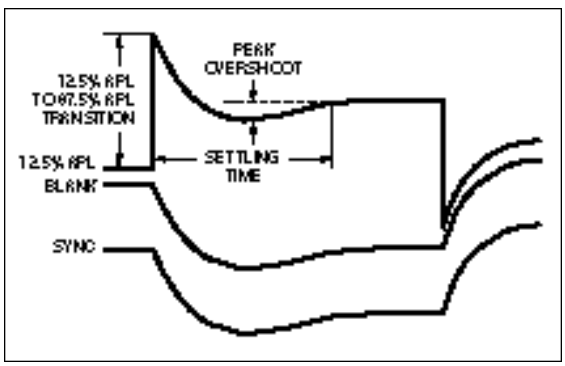

Figure 37. Long time distortion measurement parameters.

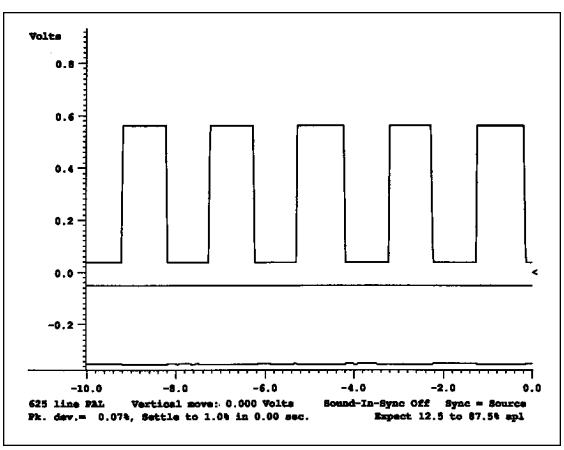

Figure 38. The VM700T Bounce display.

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 (see Figure 37). The affected signal components range in duration from 20 milliseconds to tens of seconds.

The peak overshoot that occurs as a result of an APL change, expressed as a percentage of the nominal luminance amplitude, is generally quoted as the amount of distortion. Settling time and occasionally the slope (in percent per second) at the beginning of the phenomenon are also given.

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 10% and 90% APL, at intervals no shorter than five times the settling time (see Figure 37).

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. Once a stable display is obtained (or a photograph taken), measure overshoot and settling time (see Figure 37).

VM700T Automatic Measurement. Select Bounce in the VM700T MEASURE mode to obtain a display of long time distortion (see Figure 38). 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 amplitudes. 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 or percent. 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 MHz to 5.8 MHz with frequency increasing toward the right side of each line (see Figure 39). This signal is useful for a quick approximation of system frequency response and can be used on an in-service basis as a vertical interval test signal.

Multipulse. The multipulse signal is made up of modulated 20T and 10T sine-squared pulses with high-frequency components at various frequencies of interest, generally from 0.5 MHz to 5.8 MHz (see Figure 40). This signal can also be inserted in the vertical interval.

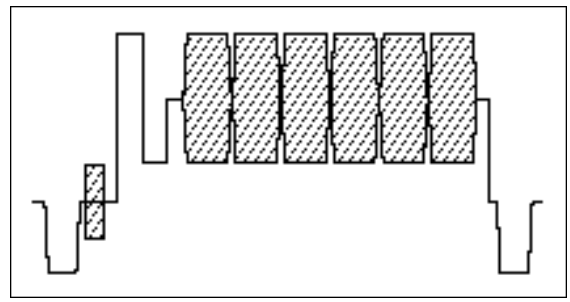

Figure 39. A multiburst test signal.

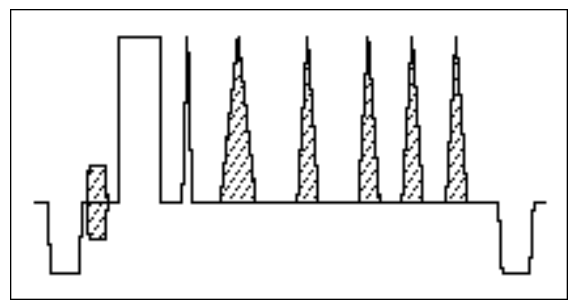

Figure 40. The multipulse test signal.

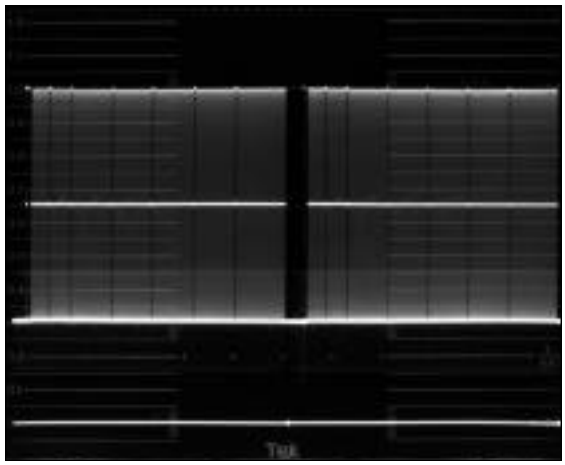

Figure 41. A 6 MHz field-rate sweep signal with markers (2-field display).

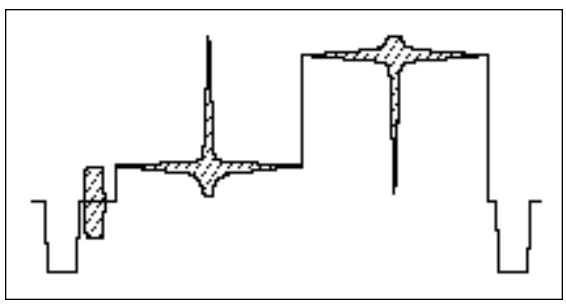

Figure 42. A time domain display of the (sin x)/x signal.

Modulated sine-squared pulses, which are also used to measure chrominance-to-luminance gain and delay errors, are discussed in the Chrominance-to-Luminance Gain and Delay section of this book. Although different high-frequency components are used in the multipulse, the same principles apply. Bowing of the baseline indicates an amplitude error between the low-frequency and high-frequency components of that pulse. Unlike the multiburst, the multipulse allows evaluation of group delay errors as well as amplitude errors.

Sweep Signal. It is sometimes recommended that line-rate 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 sweep signal is shown in Figure 41. 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 important 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 in the vertical interval and therefore permit in-service testing, field-rate sweep signals can only be used on an out-of-service basis.

(Sin x)/x. The (sin x)/x is a signal which has equal energy present at all harmonics of the horizontal scan frequency up to its cutoff frequency (see Figures 42 and 47). The (sin x)/x signal 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 the distortion. Measurement results are expressed in dB.

Waveform Monitor — Multiburst. Frequency response measurements are made with the multiburst signal by measuring the peak-to-peak amplitudes of the packets. The low-frequency square wave at the beginning of the line should be used as the amplitude reference.

Figures 43 and 44 show the 1781R voltage cursors being used to measure a frequency response distortion of 3.59 dB at 5.8 MHz. The error in dB is calculated as follows:

$$20 \log_{10} (274/414) = -3.59 \text{ dB}$$

In the RELATIVE mode, the 1781R's voltage cursors will provide results directly in dB.

Waveform Monitor — Multipulse. Frequency response distortion shows up in the multipulse signal as bowing of the pulse baseline (see Figure 45). 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 can be 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 for chrominance-to-luminance gain and delay measurements (see Figure 23) can also be used for multipulse measurements. Be sure to normalize each pulse height to 100% before making a measurement. Remember that the nomograph is intended for a 20T pulse measurements. When using a 10T pulse, the nomograph delay number must be divided by two.

When only gain distortion is present, there will be a single peak in the pulse baseline. A value of zero is therefore applied to one axis of the nomograph. If group delay distortion is also present, the baseline distortion will be sinusoidal rather than a single peak. In this case, measure both lobes and apply the two numbers to the nomograph. This will yield correct frequency response results as well as a group delay measurement.

The CHROMA/LUMA selection in the 1781R MEASURE menu can be used to make frequency response measurements with the multipulse signal. Repeat the cursor measurement procedure for the pulse corresponding to each frequency of interest.

If the system is relatively free of nonlinearity, it is also possible to estimate the amplitude error without using a nomograph. Normalize the white bar to 100% and then measure either the amount of baseline bowing or the displacement of the pulse top from the white bar (the two numbers will be equal in a linear system). The amplitude error, in percent, is approximately equal to two times either value. This method yields valid results even in the presence of some delay error which is indicated by asymmetrical baseline distortion. When delay error exceeds 150 nanoseconds, this method is not recommended.

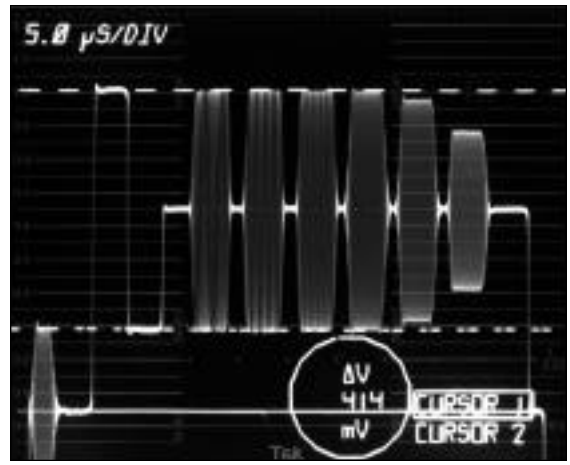

Figure 43. The low-frequency square wave is defined as the reference.

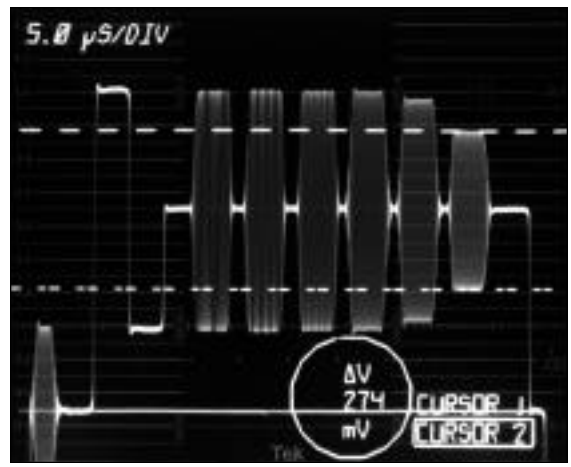

Figure 44. The peak-to-peak amplitude of the smallest packet is then measured.

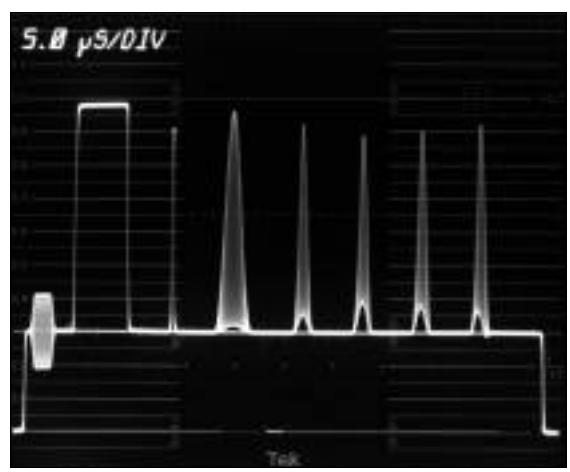

Figure 45. The multipulse signal exhibiting frequency response distortion.

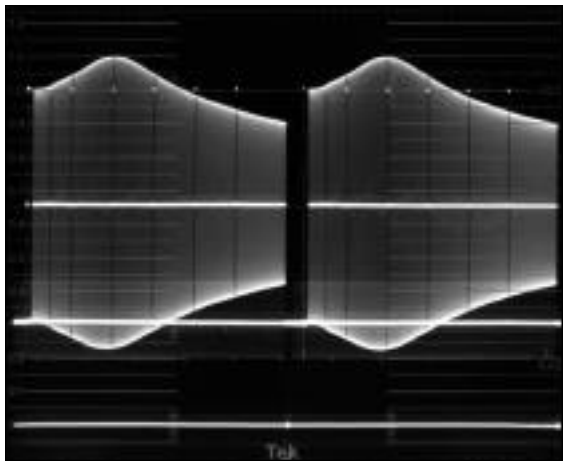

Figure 46. A sweep signal showing frequency response distortion.

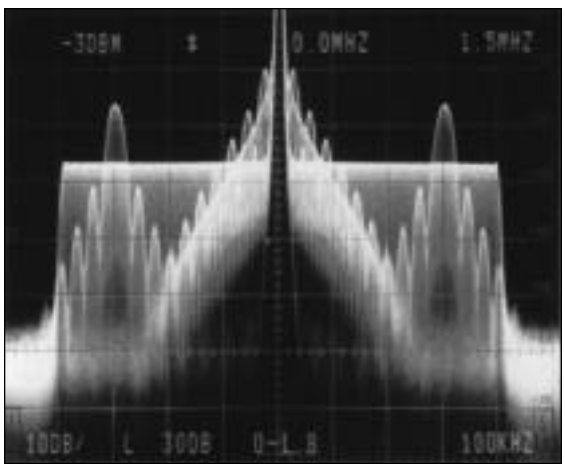

Figure 47. A spectrum analyzer display of a (sin x)/x signal with a cutoff frequency of 6 MHz.

Waveform Monitor — Sweep Signal. 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 other frequencies of interest (see Figure 46).

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 from the analyzer display in dB (see Figure 47).

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 error. 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 information for either the multiburst or (sin x)/x signal. Select MULTIBURST or GROUP DELAY (SIN X)/X in the MEASURE mode. Multiburst measurements are also available in the AUTO mode.

Notes

13. Multipulse and Nonlinear Distortions. When using the multipulse signal, the system under test must be reasonably free of nonlinearity. Distortions such as differential phase and gain can cause erroneous readings of both frequency response and group delay.

14. More Information. Further information on frequency response testing is available in Tektronix application note (25W-11149-0), "Frequency Response Testing Using a (Sin x)/x Test Signal and the VM700A/T Video Measurement Set".

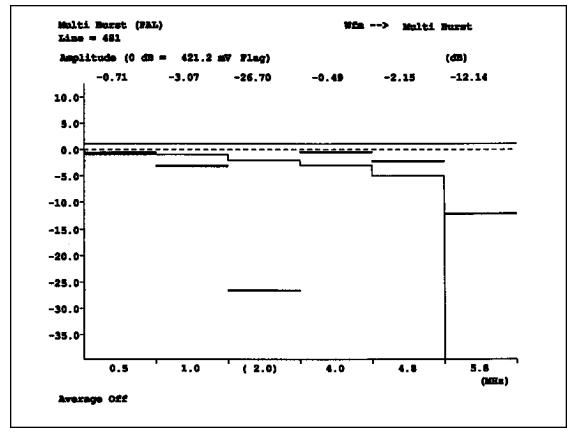

Figure 48. The VM700T Multiburst measurement.

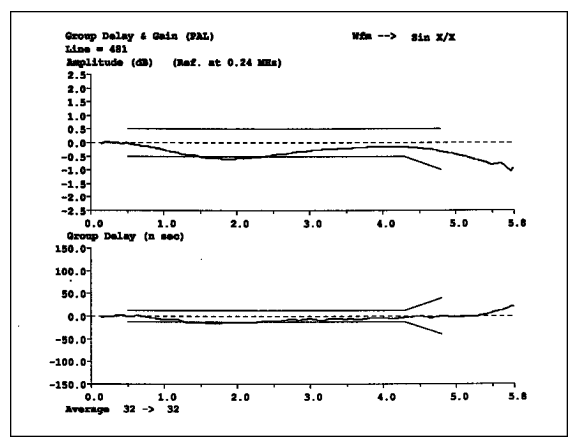

Figure 49. The VM700T Group Delay & Gain measurement made with the (sin x)/x signal.

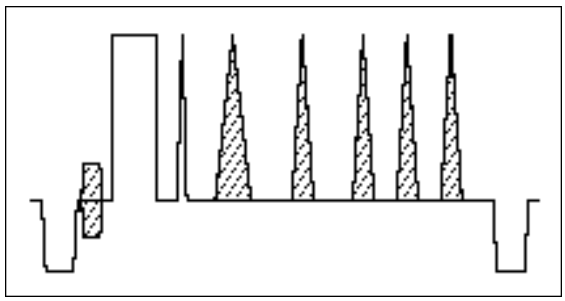

Figure 50. The multipulse test signal.

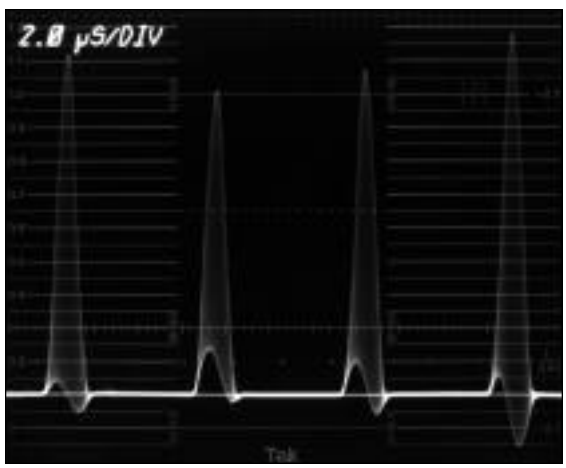

Figure 51. The multipulse signal exhibiting group delay distortion. Group delay differences between the high frequency and low frequency components of the pulse appear as sinusoidal distortion of the baseline.

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 difference in delay between a reference low frequency and the highest frequency tested is typically quoted as the group delay error.

PICTURE EFFECTS

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

TEST SIGNAL

The multipulse test signal, described in the Frequency Response section, is used to measure group delay. It is also possible to obtain a group delay measurement from 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. As discussed earlier, delay errors between the low frequency and high frequency components of the pulse appear as sinusoidal distortion of the baseline (see Figure 51). The measurement methods for group delay are very similar to those used for chrominance-to-luminance delay differing only in the number of frequencies at which delay is measured.

Waveform Monitor and Nomograph. When making group delay measurements with the multipulse signal, the baseline distortion of each pulse must be individually measured and applied to a nomograph. Normalize each pulse height to 100% and measure the positive and negative peaks of the baseline distortion. Voltage cursors in the RELATIVE mode can also be used for these measurements. Apply the numbers to the nomograph (in the Chrominance-to-Luminance Gain and Delay section of this booklet) to obtain the delay number. The largest delay measured in this way is typically quoted as the group delay error.

The first pulse in a multipulse signal is generally a 20T pulse and the others 10T pulses. The nomograph works for any modulated 20T pulse regardless of the modulation frequency. For a 10T pulse, however, the delay number from the nomograph must be divided by two. In practice, it is often easy to see which of the pulses exhibits the most delay necessitating only one measurement when maximum delay is the value of interest.

1781R Semi-Automatic Procedure. Group delay can be measured with the CHROMA/LUMA selection in the 1781R MEASURE menu. Repeat the measurement procedure for each frequency of interest.

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 at the six discrete frequencies of the multipulse signal. Select GROUP DELAY (SIN X)/X in the VM700T MEASURE mode (see Figure 52).

NOTES

15. Group Delay Definition. In mathematical terms, group delay is defined as the derivative of phase with respect to frequency $d\phi/d\omega$. In a distortion free system, the phase versus frequency response is a linear slope and the derivative is therefore a constant (see Figure 53).

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 $d\phi/d\omega$ that occurs over the frequency interval of interest is the amount of group delay (see Figure 54).

16. 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.

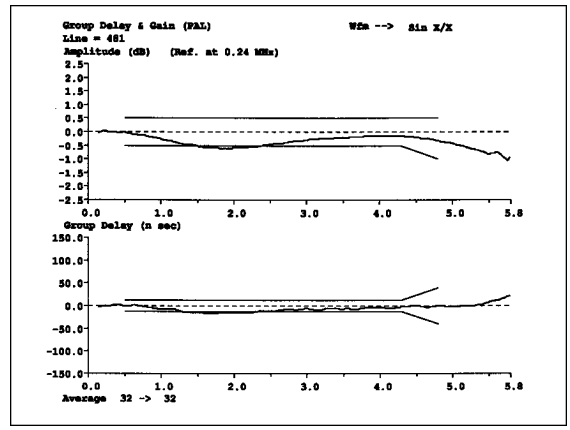

Figure 52. The VM700T Group Delay & Gain measurement made with the (sin x)/x signal.

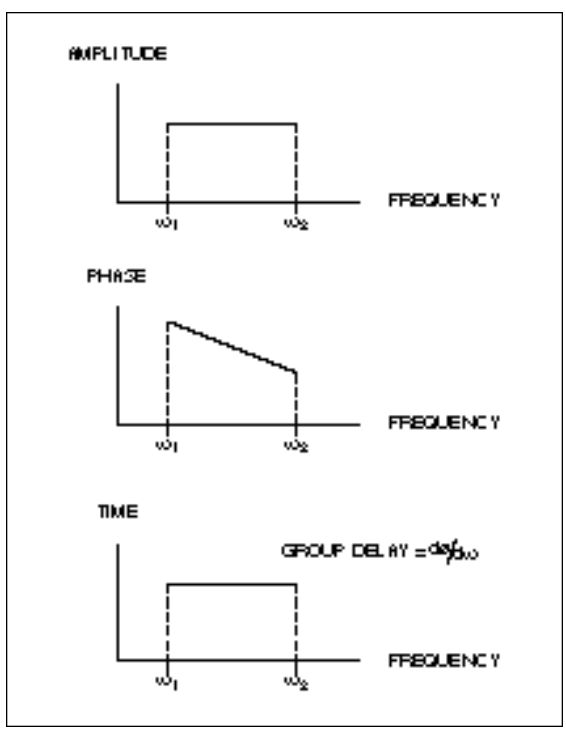

Figure 53. Response of a distortion free system.

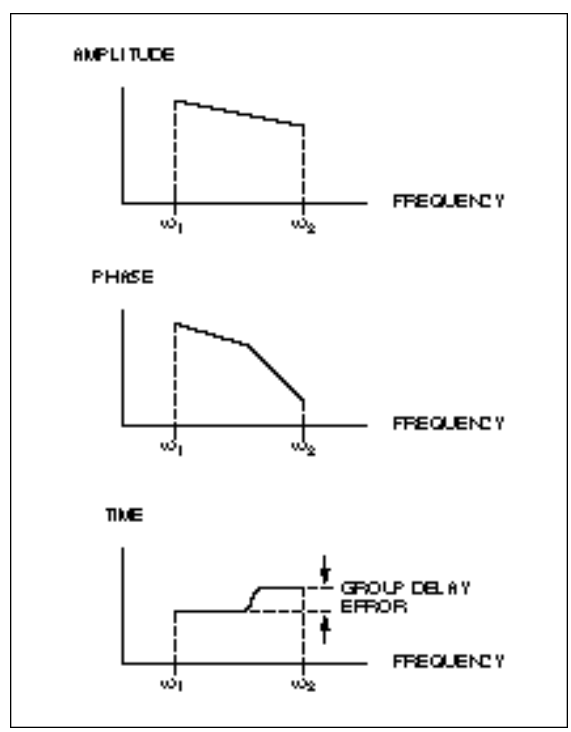

Figure 54. Response of a system with amplitude and phase distortion.

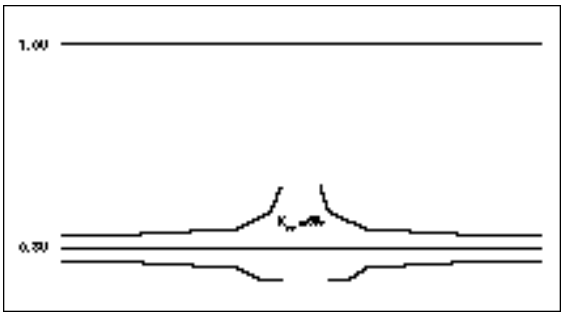

Figure 55. The 1781R external graticule includes a 5% K2T limit.

DEFINITION

The K Factor rating system maps linear distortions of 2T pulses and line bars 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}, K_{bar}, and sometimes $K_{50\ Hz}$. 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 the distortions 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. An example is shown in Figure 55.

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

1/4 [(pulse-bar)/pulse] X 100%.

It should be noted that some documents, including CCIR 567-2, recommend that the (bar-pulse) quantity be divided by the bar amplitude rather than the pulse amplitude. The two definitions will yield very nearly the same answer for practical levels of distortion. Check for the definition recommended by the appropriate broadcast authority.

There are also some definitions of $K_{pulse/bar}$ that provide signed rather than absolute value results. Since there are several different definitions in use, it is again recommended that the definition be verified.

K_{bar}. A line bar (10 or 25 microseconds) is used to measure K_{bar}. Locate the centre of the bar time, normalize that point to 100%, and measure the maximum amplitude deviation for each half. Ignore the first and last 2.5% of the bar. The larger deviation of the two, expressed in percent, is generally taken as the K_{bar} rating. The peak-to-peak deviation is sometimes quoted, particularly if a 10 microsecond bar is used. This is another case where it is recommended the definition and test signal in use be verified and the information recorded along with the measurement result.

$K_{50\ Hz}$. A field-rate square wave is used to measure this parameter. Locate the centre of the field bar time, normalize that point to 100%, and measure the maximum amplitude deviation for each half. Ignore the first and last 2.5%. The larger of the two tilt measurements, divided by two, is the $K_{50\ Hz}$ 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.

TEST SIGNAL

Any test signal containing a 2T pulse and a white bar can be used to measure K_{2T}, $K_{pulse/bar}$, and K_{bar}. A 50 Hz square wave is required for measurement of $K_{50\ Hz}$.

MEASUREMENT METHODS

Waveform Monitor. The external graticule provided with 1781R and 1481 waveform monitors includes special marks for making K Factor measurements. To make a K_{2T} measurement, use the vertical position control to set the black level to coincide with the 0.3 volt graticule mark. Then use the variable gain control to set the top of the 2T pulse to the 1 volt graticule line (see Figure 57). Set the horizontal magnification to 0.20 microseconds per division. Under these conditions, the K_{2T} graticule indicates a 5% limit. Enabling the X5 vertical gain, in addition to the variable gain required to normalize the pulse height, will change the graticule indication to a 1% limit.

The 1781R is also equipped with an electronic K_{2T} graticule. Select K FACTOR in the MEASURE menu and make sure that the horizontal magnification is set to 0.20 microseconds per division. Set the black level of the signal to overlay the dotted electronic graticule line and adjust the pulse amplitude until it reaches the small cross drawn electronically near the top of the screen. Use the large front panel knob to adjust the graticule size until it just touches the waveform at the point of greatest distortion. The readout will now indicate the K_{2T} distortion in percent.

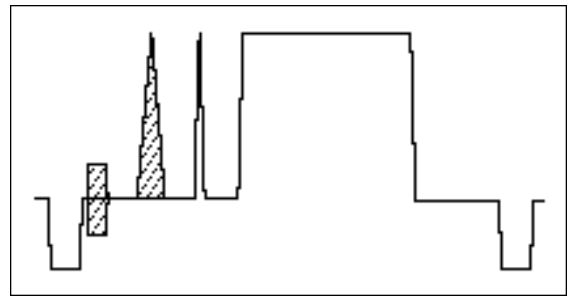

Figure 56. This signal contains the pulse and bar elements required for K Factor measurements.

Figure 57. A 2T pulse properly positioned for a K_{2T} measurement. This signal has a K_{2T} distortion of slightly more than 5%.

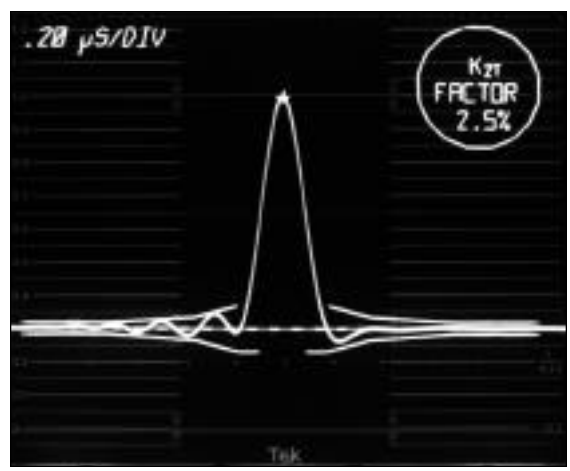

Figure 58. The 1781R electronic K Factor graticule measures a 2.5% K_{2T} distortion for this signal.

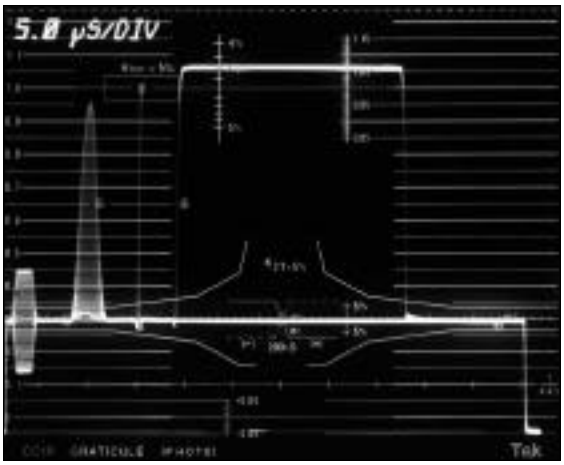

Figure 59. With the pulse taken as the reference, the 1781R graticule indicates that this signal has a $K_{pulse/bar}$ distortion of 2%.

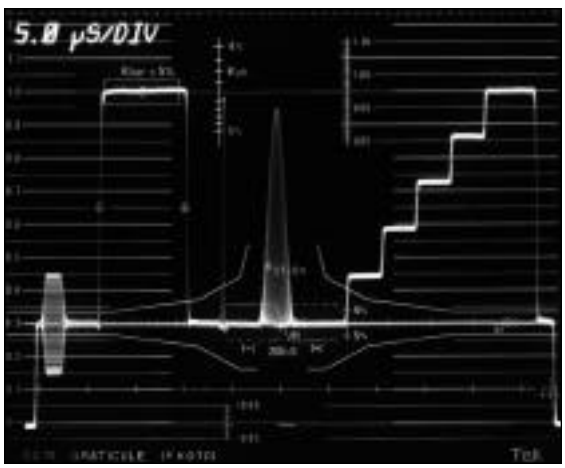

Figure 60. This signal is properly positioned for a Kbar measurement with the 1781R graticule.

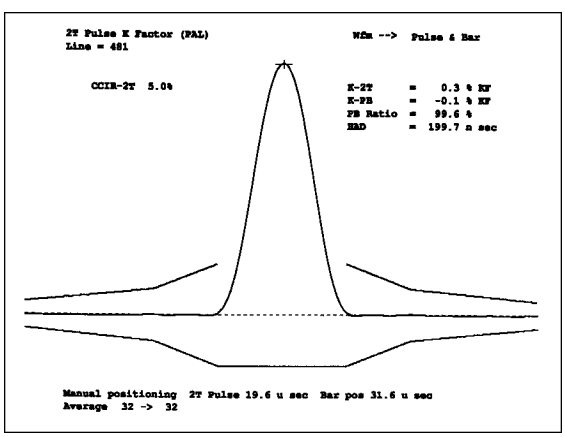

Figure 61. The VM700T 2T Pulse K Factor measurement.

The external 1781R (and 1481) graticule includes $K_{pulse/bar}$ marks in the centre near the top. To use this graticule, normalize the pulse amplitude (or the bar amplitude, depending on the definition in use) to extend from 0.3 to 1.0 volts. Then compare the other signal element to the $K_{pulse/bar}$ scale to obtain a K Factor reading in percent.

There is also a 5% K_{bar} limit near the upper left-hand corner of the external graticule. This limit is designed for use with a 10 microsecond bar when a 1H sweep is selected. Position the waveform horizontally so that the rising and falling edges of the bar pass through the graticule circles on the 0.65 volt line (see Figure 60). The waveform vertical gain should be adjusted so that the black level coincides with the 0.3 volt line and the centre of the bar passes through the cross in the centre of the K_{bar} box.

VM700T Automatic Measurement. Select K FACTOR in the VM700T MEASURE mode to obtain a measurement of K_{2T}. The graticule can be set to automatically track the waveform or manually adjusted with the front panel knob. This display also provides numeric K_{2T} and $K_{pulse/bar}$ results (see Figure 61). Measurements of these parameters are also available in the VM700T AUTO mode. The VM700T provides a signed $K_{pulse/bar}$ result that is negative when the pulse amplitude is smaller than the bar amplitude.

NOTES

17. Pulse-to-Bar Definitions. There are several different methods of expressing the relationship between pulse amplitude and bar amplitude. It is important to understand the difference and know which method is 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-TO-BAR = 1/4 [(pulse-bar)/pulse] X 100%

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 may 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 not as routinely tested, however, most measurement standards and performance checks include them.

It is generally recommended that nonlinear distortions be measured at different average picture levels. Some test signal generators provide variable APL signals by combining the test signal with a variable level pedestal. Since in-service measurements cannot be made with these test signals, measurements requiring control of APL are often eliminated from routine testing.

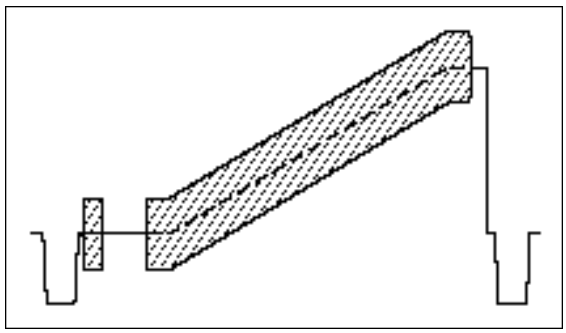

Figure 62. A modulated ramp test signal.

Figure 63. Vector display of the TG2000 phase-alternate modulated ramp.

DEFINITION

Differential phase distortion, sometimes referred to as "diff phase", is present when chrominance phase is dependent on luminance level. This phase distortion is a result of a system's inability to uniformly process the high-frequency chrominance information at all luminance levels.

The amount of 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 peak deviation from the blanking level phase is being quoted.

PAL measurement standards most frequently refer to peak deviation differential phase measurements. Two numbers are typically given to describe the distortion: the peak positive phase deviation and the peak negative phase deviation from the subcarrier phase at blanking level. Sometimes the larger of these two values is given as a single peak result.

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

PICTURE EFFECTS

Since virtually all PAL receivers now employ delay-line decoders, reasonable amounts of differential phase distortion cannot be readily detected in the picture. A delay-line decoder averages each two successive lines in the field, and the resultant information is displayed. Chrominance phase shifts are therefore cancelled out and do not result in a hue shift in the picture. (Differential phase is actually converted to differential gain in the resultant, but gain errors are much less objectionable in 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 (see Figure 62) is typically used. A ramp is normally used when performing measurements on devices and systems that convert the signal from analogue to digital and back to analogue.

Some generators, such as the Tektronix TG2000, offer a phase-alternate modulated ramp test signal. A vector display of this signal is shown in Figure 63. This signal can help detect distortions that have affected the U and V components differently. This is most likely to occur if the signal has been demodulated and the U and V components passed through separate processing channels. If this signal is available, it may be desirable to repeat the measurement procedures outlined below for both signal vectors.

MEASUREMENT METHODS

When differential phase is present, the chrominance phase will be different on the different luminance levels of the test signal. This phase information can be conveniently displayed on a vectorscope after the chrominance has been demodulated. Although a standard vector display can indicate the presence of large amounts of distortion, a vectorscope equipped with a special differential phase mode or an automatic measurement set such as the VM700T is required for precision measurements.

Vectorscope Display. In a vectorscope display, the dots corresponding to the various subcarrier packets will spread out along the circumference of the graticule circle when differential phase is present. When using a ramp signal, the dot will become elongated along the circumference. To make a measurement, first set the phase of the signal vector to the reference 9 o'clock phase position. Use the vectorscope variable gain control to bring the signal vector out to the graticule circle.

Vectorscope graticules generally have special differential phase and gain marks on the left-hand side to help quantify the distortion. Peak-to-peak phase deviation can be directly from the graticule. Obtaining peak positive and peak negative results from the vector display is less straightforward but it is possible when the signal vector lies along the 0 degree or 180 degree axis. In this case, align the bursts with the +135 and -135 degree graticule marks and obtain an approximate peak reading by noting how far positive or negative the dots extend from the 0/180 degree axis.

Demodulated R-Y Sweep. Although distortions show up in the vectorscope display, there are some advantages to be gained by examining the demodulated R-Y (V) signal in a voltage versus time display. (Recall that the weighted R-Y signal drives the vertical axis of a vectorscope, see Figure 65.) First of all, more gain and therefore more measurement resolution is possible in waveform displays. Secondly, the sweep display permits correlation of the demodulated 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.

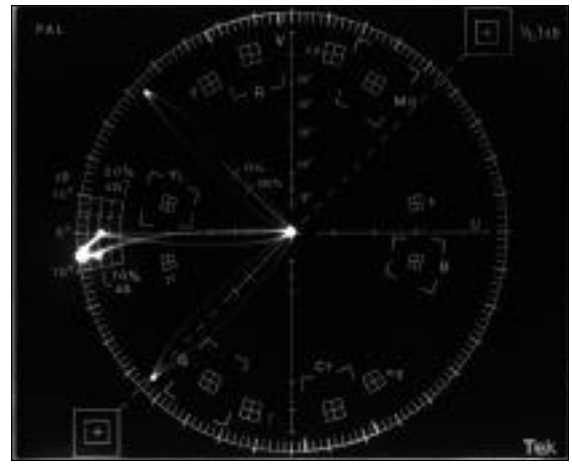

Figure 64. A vectorscope display showing a peak-to-peak differential phase distortion of about 7 degrees. Differential gain distortion is also present.

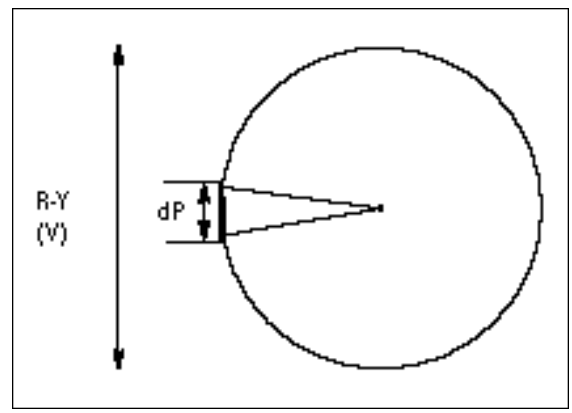

Figure 65. Differential phase distortion affects the R-Y (V) signal.

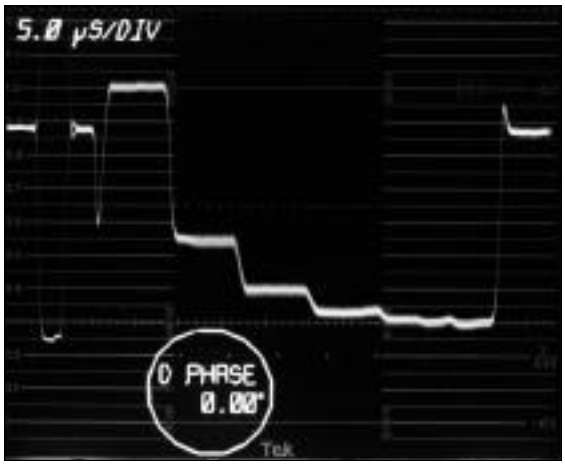

Figure 66. A single trace display indicating about 7 degrees of differential phase distortion.

Two different types of demodulated 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 1781R, 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.

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 use the vectorscope display to set the signal vector to the reference 9 o'clock phase position. Use the vectorscope variable gain control to bring the signal vector out to the edge of the vectorscope graticule circle. Make sure the 1781R 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 1781R. Each major division (100 mV) on the vertical graticule scale corresponds to one degree when the R-Y waveform is being displayed. The amount of peak-to-peak differential phase can be determined by measuring the largest vertical deviation between any two parts of the signal. To obtain peak results, measure how far positive and negative the signal extends from the level that corresponds to blanking level subcarrier.

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 amount of distortion.

The double trace display, which also appears on the waveform screen in the 1781R, is produced by displaying the single trace R-Y information non-inverted for half the lines and inverted for the other half. Since phase changes affect the amplitude of the R-Y signal, the inverted and non-inverted traces can be moved vertically with respect to each other by shifting phase. Measurements can therefore be made by introducing calibrated amounts of phase shift with the vectorscope phase control. The basic technique involves nulling the blanking level part of the signal by bringing the inverted and non-inverted traces together at that point. The amount of phase shift that is then required to overlay the two traces at the point of maximum level shift is the amount of differential phase.

Select DOUBLE in the 1781R DIFF PHASE mode to make this measurement. First look at the vectorscope screen and use the phase shifter to set the signal vector to the reference 9 o'clock phase position. Neither vectorscope nor waveform monitor gain is critical in this mode (see Note 18), but setting the vector to the graticule circle is a good starting point. Now refer to the waveform monitor (right-hand) screen and use the phase shifter to overlay the blanking level portions of the two waveforms. Press REF SET to set the phase readout to 0.00 degree (see Figure 67).

The next step is to use the phase shifter to overlay the point in the R-Y waveforms that deviates most from blanking level. The phase readout now indicates the amount of differential phase distortion (see Figure 68). In this example the phase error is all in one direction so peak and peak-to-peak results will be the same. If the signal has both positive and negative phase errors (the R-Y signal extends both positive and negative from blanking), repeat the process for the largest positive and largest negative signal excursions.

The double trace technique is similar when using a 521A Vectorscope. Start by setting the "calibrated phase" dial to zero. Use the A phase or B phase control to null the blanking level and then use the calibrated phase shifter to null the largest excursion. The number above the calibrated phase dial will now give the amount of differential phase distortion.

VM700T Automatic Measurement. To make an automatic measurement of differential phase with the VM700T, select DGDP in the MEASURE mode. Both differential phase and differential gain are shown on the same display (the lower graph is differential phase). Measurement results are also available in the AUTO mode.

NOTES

18. 1781R 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 (1 volt full scale) position. The graticule is calibrated to one degree per division only under these conditions.

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

19. Noise Reduction Filter. A digital recursive filter is available in the 1781R to facilitate differential phase and gain measurements in the presence of noise. Select the NOISE REDUCTION ON touchscreen selection in the DIFF PHASE or DIFF GAIN menu to enable this filter. The filter removes about 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.

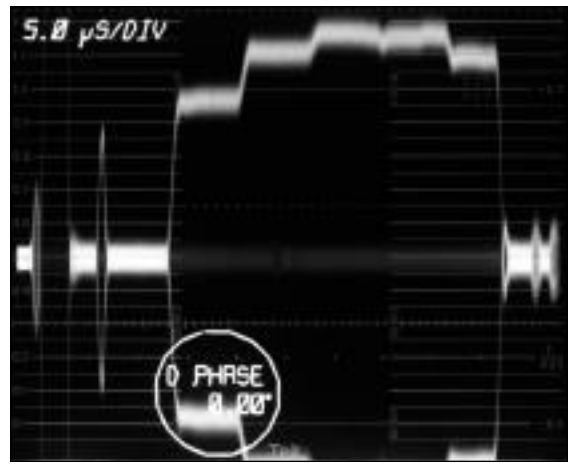

Figure 67. The 1781R double trace DIFF PHASE display with the phase readout zeroed.

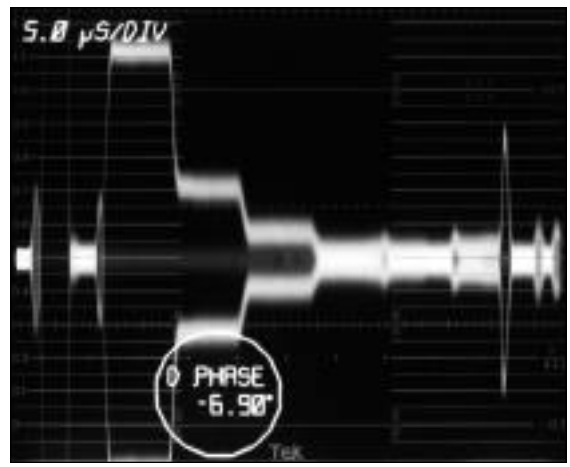

Figure 68. The double trace DIFF PHASE display with the measurement results indicated on the readout.

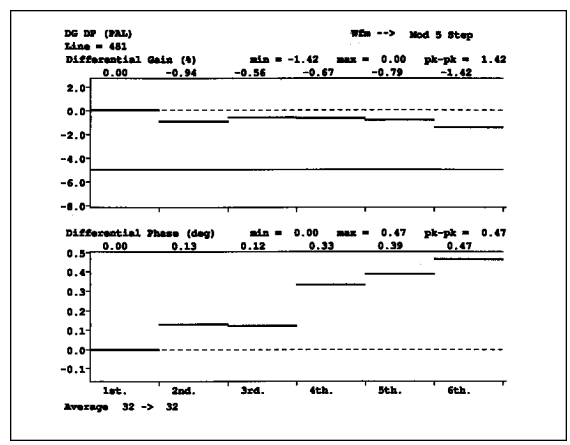

Figure 69. The VM700T DG DP display.

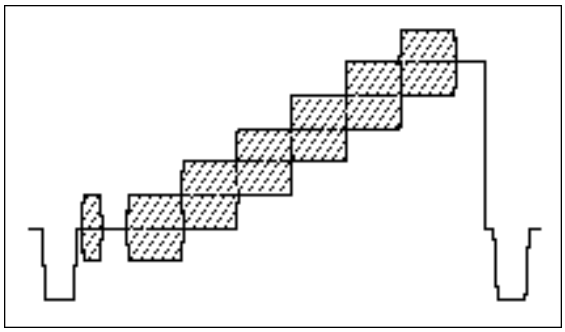

Figure 70. A modulated 5-step staircase test signal.

DEFINITION

Differential gain, often referred to as "diff gain"', is present when chrominance gain is dependent on luminance level. These amplitude errors are a result of the system's inability to uniformly process the high-frequency chrominance signal at all luminance levels.

Differential gain distortion is expressed in percent. Since both attenuation and peaking can occur in the same signal, it is important to specify whether the peak-to-peak amplitude difference or the peak deviation is being quoted. The reference for peak-to-peak results may be either the maximum chrominance amplitude or the amplitude of the chrominance packet at blanking level. Peak deviation measurements are generally referenced to the chrominance amplitude at blanking level.

PAL measurement standards generally refer to peak differential gain measurements. Two numbers are typically given to describe the amount of distortion: the peak positive deviation and the peak negative deviation in chrominance amplitude from the amplitude at blanking level. These numbers are expressed as a percentage of the blanking level chrominance amplitude. Sometimes the larger of the two values is given as a single peak result.

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

PICTURE EFFECTS

When differential gain is present, colour saturation is not correctly reproduced. Differential gain is generally most noticeable in reds and yellows.

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.

Some generators, such as the Tektronix TG2000, offer a phase-alternate modulated ramp test signal. This signal can help detect distortions that have affected the U and V components differently. This is most likely to occur if the signal has been demodulated and the U and V components passed through separate processing channels. If this signal is available, it may be desirable to repeat the measurement procedures outlined below for both signal vectors.

MEASUREMENT METHODS

Differential gain distortion 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 differential gain mode or an automatic measurement set such as the VM700T is required.

Vectorscope Display. In a vectorscope display, the dots corresponding to the various subcarrier packets will spread out in the radial direction when differential gain is present. When using a ramp signal, the dot will become elongated in the horizontal direction. To make a measurement, first set the phase of the signal vector to the reference position. Use the vectorscope variable gain control to bring the signal vector out to the graticule circle.

Vectorscope graticules generally have special differential phase and gain marks on the left-hand side to help quantify the distortion. Peak-to-peak gain deviation can be read directly from the graticule. A peak reading is more difficult to obtain from this display since there is no convenient method of establishing which amplitude corresponds to the amplitude at blanking level.

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 high-frequency chrominance portion of the signal. Peak-to-peak chrominance amplitudes can be easily compared in the resulting display.

To make a measurement, first normalize the peak-to-peak amplitude of the first chrominance packet (the one at blanking level) to 100 percent. Then measure the peak-to-peak amplitudes of the smallest and largest packets. The positive and negative peak differential gain results are the differences between these two measurements and the blanking level amplitude. Equations are given below.

Peak dG (Negative) =

$$-100\ [\ [V_{pp}(\text{Blanking}) - V_{pp}(\text{Smallest Packet})]\ /\ V_{pp}(\text{Blanking})\ ]\ \%$$

Peak dG (Positive) =

$$+100\ [\ [V_{pp}(\text{Blanking}) - V_{pp}(\text{Largest Packet})]\ /\ V_{pp}(\text{Blanking})\ ]\ \%$$

This measurement can also be made by using the 1781R voltage cursors in the RELATIVE mode. Define the peak-to-peak amplitude of the blanking level packet as 100% and then move the cursors to measure peak-to-peak amplitude of the smallest and largest packets. Use the equations above to calculate results.

Figure 71. A vectorscope display of a signal with 10% peak-to-peak differential gain. Differential phase distortion is also present.

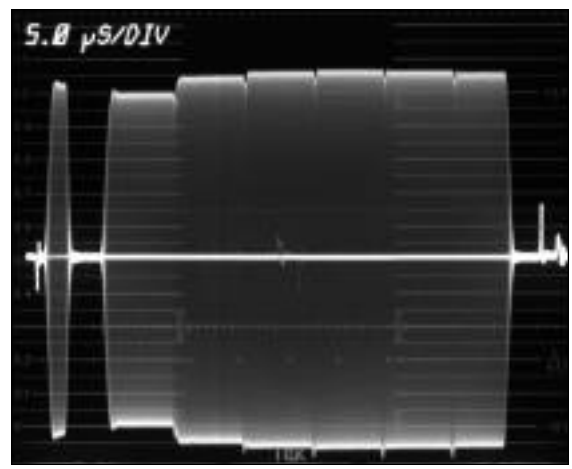

Figure 72. A chrominance filter display indicating about 6 % differential gain.

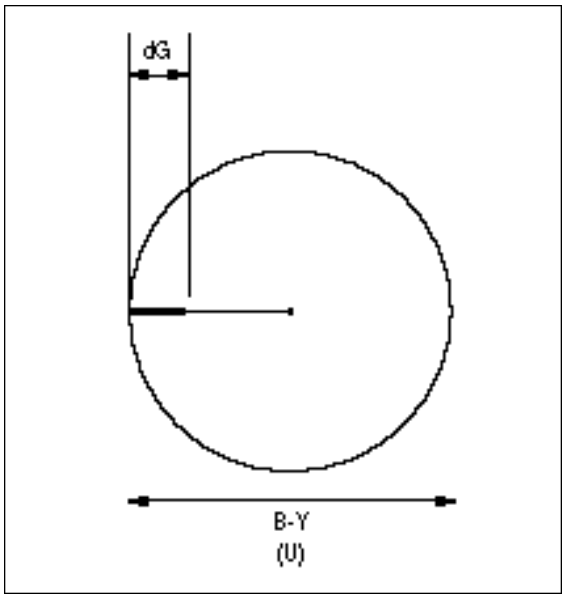

Figure 73. Differential gain distortion affects the B-Y (U) signal.

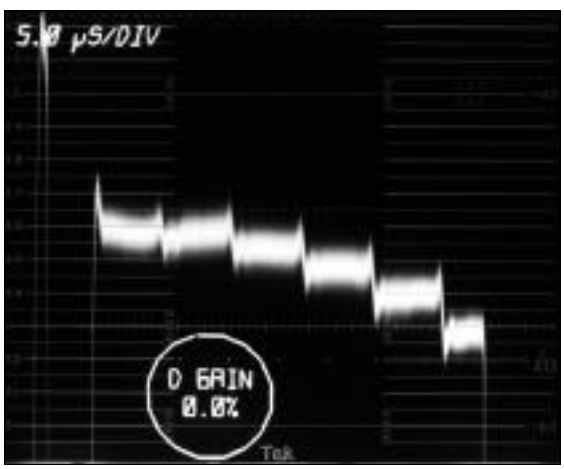

Figure 74. A single trace DIFF GAIN display indicating a distortion of about 3%.

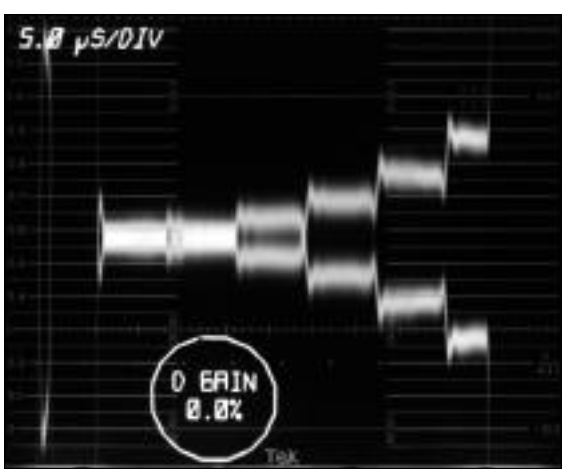

Figure 75. The 1781R double trace DIFF GAIN display with the readout zeroed.

B-Y Sweep. Some vectorscopes are equipped with a special mode for making accurate differential gain measurements. Since differential gain affects the B-Y (U axis) signal (see Figure 73), a line-rate sweep of demodulated B-Y information can be used to measure the amount of distortion. Errors manifest themselves as tilt or level changes across the line. Like the R-Y display used to measure differential phase, this display provides greater resolution and allows determination of how the distortion varies over a line. In the 1781R, both "single trace" and "double trace" versions of this display are available. Both are accessed by selecting DIFF GAIN in the MEASURE menu.

Single Trace Method. The single trace differential gain display is familiar to users of the 521A vectorscope and it is also available in the 1781R by selecting SINGLE in the DIFF GAIN menu. The amount of distortion is quantified by comparing the demodulated waveform to a vertical graticule scale.

The phase shifter should be used 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 1781R's waveform gain is in the calibrated (1 volt full scale) setting.

In the 1781R, 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 the part of the signal that corresponds to blanking-level chrominance and the largest and smallest packets. One major graticule division (100 mV) is equal to one percent.

Double Trace Method. The double trace method in the 1781R provides a highly accurate way of measuring the amount of tilt or level shift in a one-line sweep of the B-Y information. This method is very similar to the differential phase double trace method described earlier, the difference being a calibrated gain control rather than a calibrated phase control is used to null the traces.

Select DOUBLE in the 1781R DIFF GAIN menu to make this measurement. Use the phase shifter to set the signal vector to the reference phase position. The vectorscope variable gain must be adjusted so the signal vector reaches the graticule circle. The 1781R waveform monitor gain setting is not critical in this mode (see Note 21).

Now refer to the waveform (right-hand) display, and start the measurement procedure by using the large knob to overlay the blanking level portions of the inverted and non-inverted waveforms. Press REF SET to set the readout to 0.00 percent (see Figure 75). Now use the large knob to bring together the largest positive and/or negative excursions. The readout now indicates the amount of differential gain distortion (see Figure 76).

VM700T Automatic Measurement. To make an automatic measurement of differential gain with the VM700T, select DGDP in the MEASURE mode. Both differential phase and differential gain are shown on the same display (the upper graph is differential gain). Measurements results are also available in the AUTO mode.

NOTES

20. Demodulated "B-Y" Signal. It should be noted that in instruments such as the 521A Vectorscope and the 1781R, 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, but square law detection does not. Thus the presence of differential phase does not affect the differential gain result.

21. 1781R 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 only calibrated to 1 percent per division under these conditions.

In the double mode display, more waveform vertical gain (X5 or VAR) may be introduced for greater resolution. However, correct results will be obtained only when the vectorscope gain is set to the graticule circle.

22. 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 1781R MEASURE menu (see Figure 78). As noted above, the VM700T DG DP display also shows both distortions simultaneously.

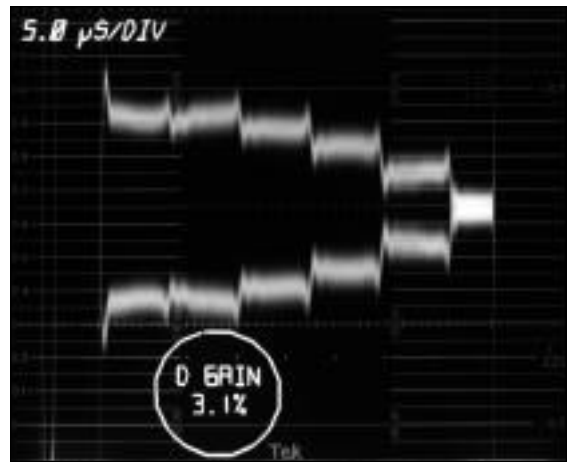

Figure 76. The 1781R double trace DIFF GAIN display showing measurement results. With attenuation only, peak and peak-to-peak results are the same.

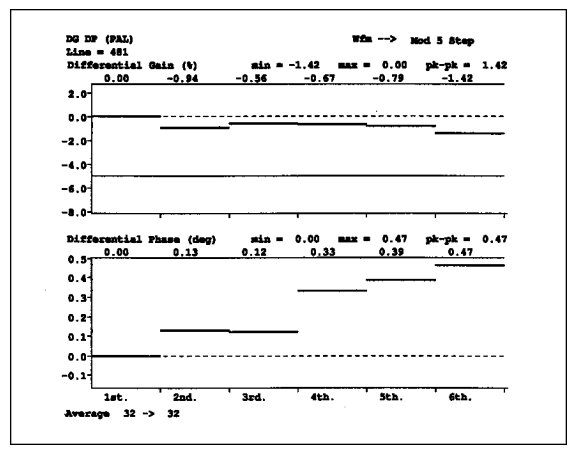

Figure 77. The VM700T DG DP display.

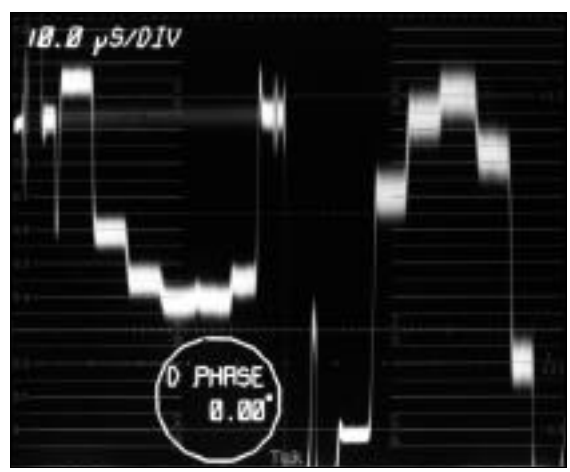

Figure 78. The 1781R DP & DG display.

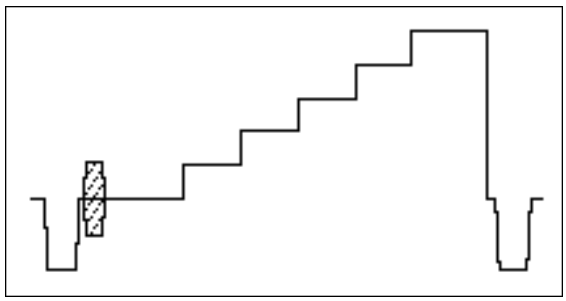

Figure 79. An unmodulated staircase signal.

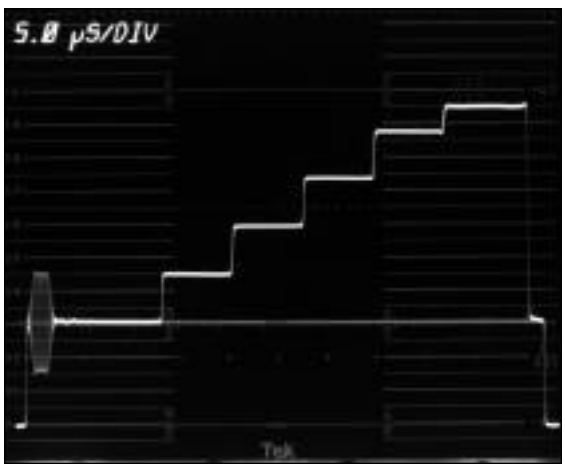

Figure 80. An example of luminance nonlinearity distortion.

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 is a result of the system's inability to uniformly process luminance information over the entire amplitude range.

The amount of luminance nonlinearity is expressed as a percentage. Measurements are made by comparing the amplitudes of the individual steps in a staircase signal. The difference between the largest and smallest steps, expressed as a percentage of the largest step amplitude, is the amount of luminance nonlinearity distortion. Measurements should be made 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, a loss of detail may be seen in the shadows and highlights. These effects correspond to crushing or clipping of the black and white information.

In colour pictures, luminance nonlinearity is often more noticeable. This is because colour 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 were initially all of uniform height, any differences are a result of this distortion. The waveform in Figure 80 exhibits luminance nonlinearity distortion. Note that the top step is shorter than the others.

Waveform Display. Luminance nonlinearity 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% (500 mV or 1 Volt) so percentage can be read directly from the graticule. Voltage cursors can also be used to measure the steps. Although this method can yield accurate results, it is very time consuming and is 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. Since it provides an accurate and convenient method of evaluating this distortion, it is generally recommended practice to use such a filter for this measurement. External filters can be used if the waveform monitor is not equipped with the filter.

When the differentiated step filter is enabled, 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% when using the graticule. The difference between the largest and smallest spikes, expressed as a percentage of the largest, is the amount of luminance nonlinearity.

The 1781R 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 81).

VM700T Automatic Measurement. Select LUMINANCE NONLINEARITY in the VM700T MEASURE menu to obtain a display of this distortion. The VM700T uses an internal differentiated step filter to make this measurement. Measurement results are also available in the AUTO mode.

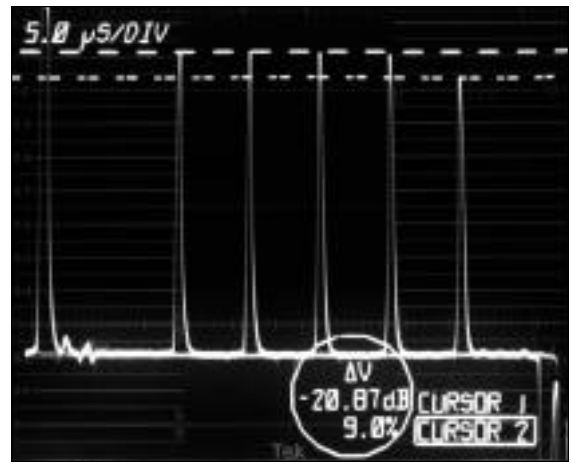

Figure 81. This photograph shows a 5 step staircase after it has been passed through a differentiated step filter. The 1781R voltage cursors indicate 9% luminance nonlinearity.

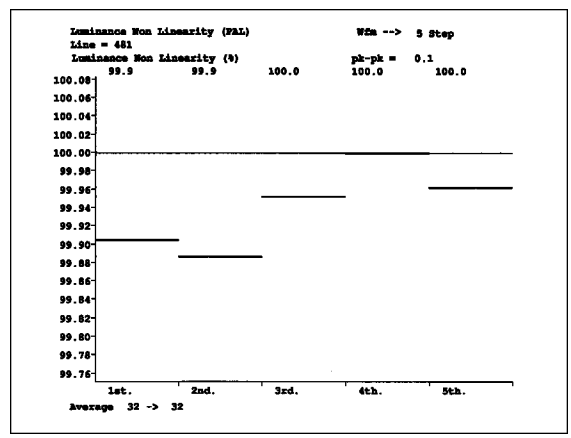

Figure 82. The VM700T Luminance Nonlinearity display.

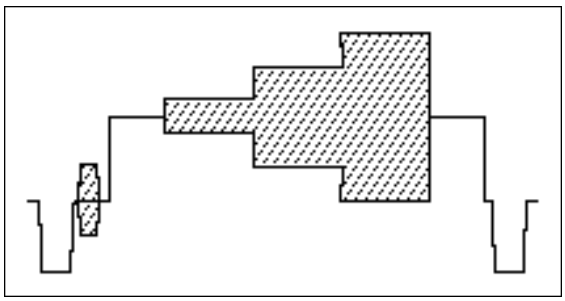

Figure 83. A modulated pedestal test signal.

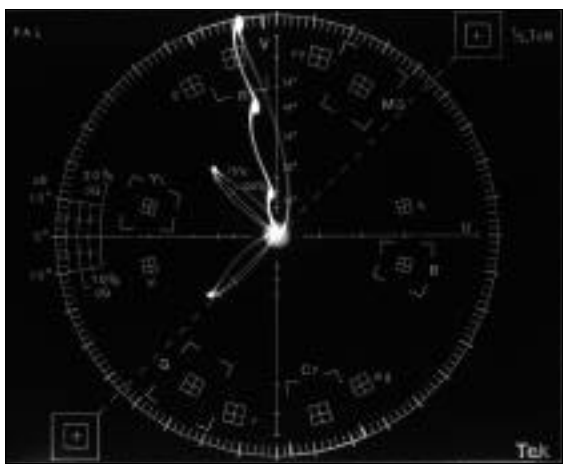

Figure 84. The 1781R vectorscope display showing a signal that suffers from chrominance nonlinear phase distortion.

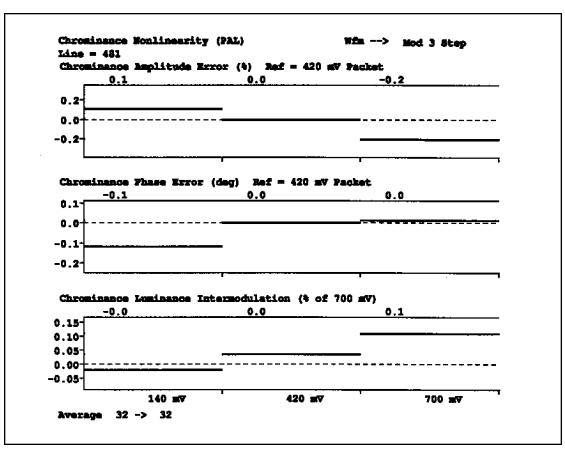

Figure 85. The VM700T Chrominance Nonlinearity display.

DEFINITION

Chrominance nonlinear phase distortion is present when chrominance phase is affected by chrominance amplitude. These phase errors are a result of the system's inability to uniformly process all amplitudes of chrominance information.

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

Like differential phase, the effects of chrominance nonlinear phase are averaged out in delay-line PAL decoders. Hue shifts therefore cannot be detected in the picture.

TEST SIGNAL

A modulated pedestal signal, sometimes called a three level chrominance bar, is used to measure this distortion. This signal consists of a single phase, three level chrominance packet superimposed on a constant luminance level. A typical modulated pedestal signal will have a 350 mV luminance level and 140, 420, and 700 mV chrominance levels. This signal element is sometimes part of combination signals used as ITS.

MEASUREMENT METHODS

Chrominance nonlinear phase is quantified by measuring the phase differences between the chrominance packets of the modulated pedestal signal.

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. When using a 1781R or a 521A Vectorscope, the calibrated phase shifter can be used to obtain a precise reading.

VM700T Automatic Measurement. Select CHROMINANCE 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 85). Measurement results are also available in the VM700T AUTO mode.

DEFINITION

Chrominance nonlinear gain distortion is present when chrominance gain is affected by chrominance amplitude. These amplitude errors are a result of the system's inability to uniformly process all amplitudes of chrominance information.

Chrominance nonlinear gain distortion is the amplitude deviation expressed as a percentage of the nominal amplitude. This measurement is made on the lowest and highest chrominance levels with the middle level normalized to its nominal value. The larger of the two resulting numbers is generally taken as the overall result.

This distortion should be measured at different average picture levels and the worst distortion should be quoted.

PICTURE EFFECTS

Chrominance nonlinear gain is often seen as attenuation of relatively high amplitude chrominance signals. It will appear in the TV picture as incorrect colour saturation.

TEST SIGNAL

A modulated pedestal signal, sometimes called a three level chrominance bar, is used to measure this distortion. This signal consists of a single phase, three level chrominance packet superimposed on a constant luminance level. A typical modulated pedestal signal will have a 350 mV luminance level and 140, 420, and 700 mV chrominance levels. This signal element is sometimes part of combination signals used as ITS.

MEASUREMENT METHODS

Chrominance nonlinear gain distortion is quantified by measuring how much the amplitudes of the chrominance packets deviate from their nominal values.

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 prescribed value of 420 mV. The amount of chrominance nonlinear gain distortion is the largest deviation from nominal value for the other two packets expressed as a percentage of the nominal amplitude of the affected packet.

VM700T Automatic Measurement. Select CHROMINANCE NONLINEARITY in the VM700T MEASURE menu to make this measurement. Chrominance nonlinear gain is shown on the upper graph. This parameter can also be measured in the VM700T AUTO mode.

NOTES

23. Chroma Filter. It is sometimes recommended that waveform monitor chroma filter 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.

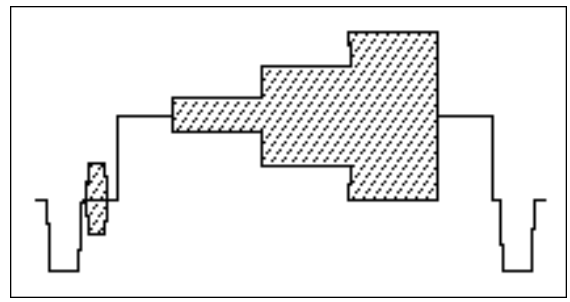

Figure 86. A modulated pedestal test signal.

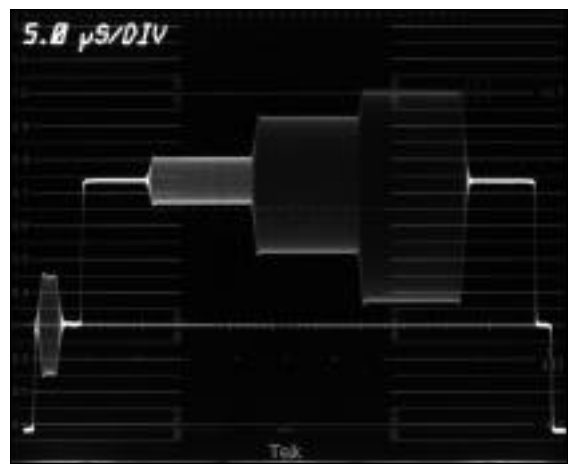

Figure 87. This signal exhibits chrominance nonlinear gain distortion. Note that the amplitude of the largest packet is reduced.

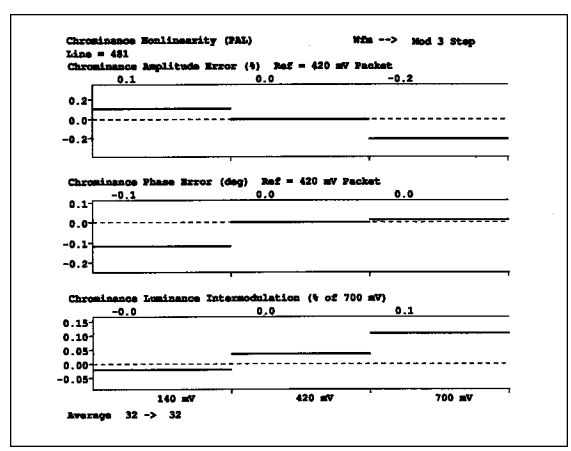

Figure 88. The VM700T Chrominance Nonlinearity display.

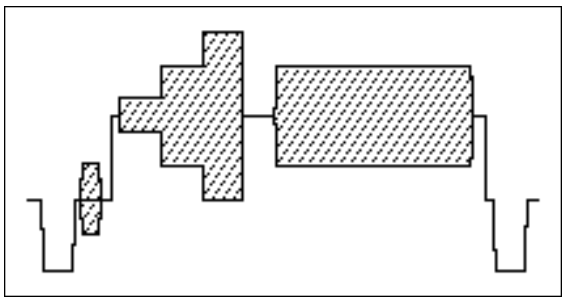

Figure 89. This combination ITS contains the Modulated Pedestal signal element (CCIR Line 331).

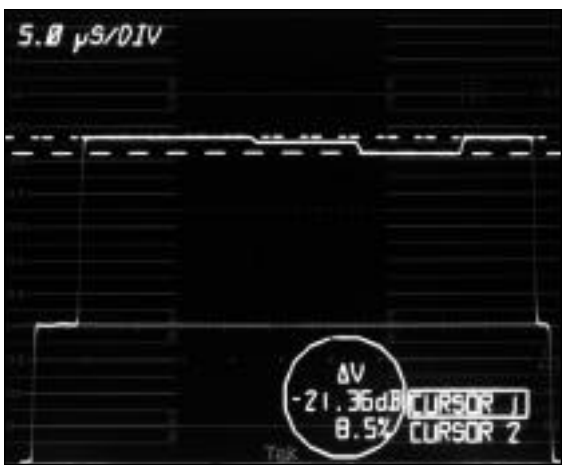

Figure 90. A chrominance-to-luminance intermodulation distortion of 8.5% referenced to the pedestal level.

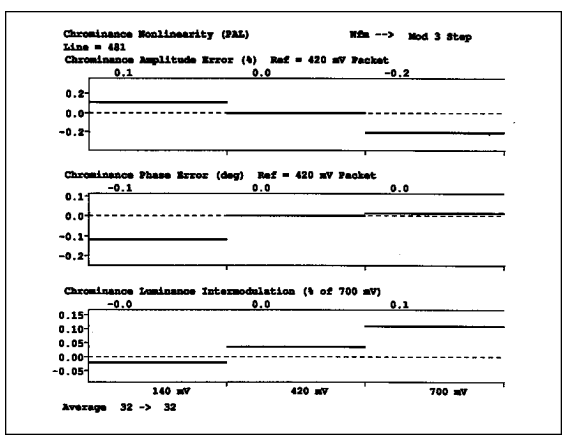

Figure 91. The VM700T Chrominance Nonlinearity display.

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 various crosstalk and intermodulation effects.

The deviation in the pedestal level may be expressed:

- As a percentage of the pedestal level
- As a percentage of the measured white bar amplitude
- As a percentage of 700 millivolts

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

PICTURE EFFECTS

When intermodulation distortion is present, colour saturation will not be accurately represented in affected pictures.

TEST SIGNALS

A modulated pedestal signal, sometimes called a three level chrominance bar, is used to measure this distortion. This signal consists of a single phase, three level chrominance packet superimposed on a constant luminance level. A typical modulated pedestal signal will have a 350 mV luminance level and 140, 420, and 700 mV chrominance levels. This signal element is sometimes part of combination signals used as ITS.

MEASUREMENT METHODS

Chrominance-to-luminance intermodulation is quantified by measuring the effects that chrominance packets of different amplitudes have on the luminance level that they are superimposed on. 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 1781R. The Y display of the 521A Vectorscope also works well.

Details of the measurement method will depend on the method chosen to express the amount of distortion. In general, the appropriate part of the signal must be normalized using the waveform monitor variable gain control. Then measure the largest level shift in the top of the luminance pedestal.

The 1781R voltage cursors can be used in the relative mode to make this measurement. In Figure 90, the level shift is 8.5% of the pedestal level.

VM700T Automatic Measurement. Select CHROMINANCE NONLINEARITY in the VM700T MEASURE menu to measure chrominance-to-luminance intermodulation. This parameter is shown on the lower graph. Measurement results are also available in the VM700T AUTO mode.

DEFINITION

Transient sync gain distortion, also referred to as transient nonlinearity, is present when abrupt changes in APL temporarily affect sync amplitude. The amount of distortion is defined as the maximum transient departure in the amplitude of sync from the amplitude that existed before the change in APL. It is generally expressed as a percentage of the original amplitude, however, some standards specify the distortion as 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

Sudden switches between high APL and low APL pictures can cause transient brightness or saturation effects in the picture.

TEST SIGNAL

Transient gain distortion is measured with a flat field 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.

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 the step amplitudes). Be sure the DC restorer is turned off for this measurement.

Depending on the nature of the distortion, it may be possible to observe it when the waveform monitor is in the field sweep mode. Otherwise it will be necessary to use the 1781R SLOW SWEEP mode. (Some 1481 Waveform Monitors 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 that corresponds to the trailing edge of sync equal to 100%. Switch between APL extremes, typically 12.5% and 87.5%. The resulting envelope of the sync spikes represents the transient distortion. Measure the maximum departure from 100% to obtain the amount of transient sync nonlinearity.

The 1781R 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.

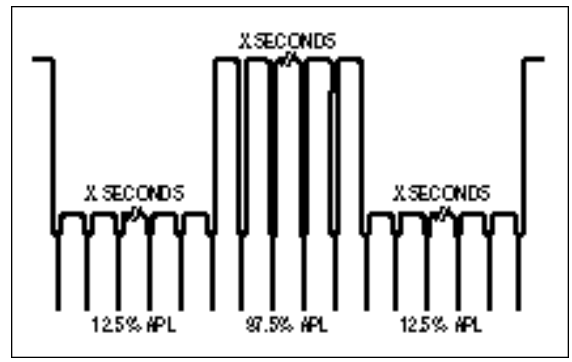

Figure 92. A flat field bounce test signal.

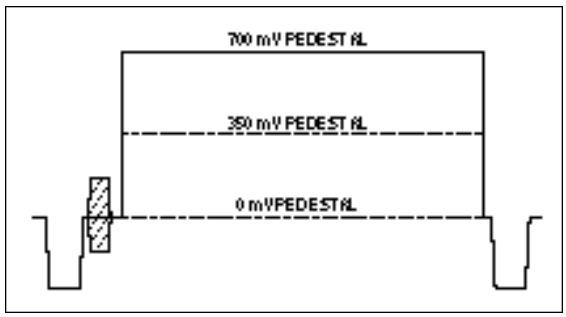

Figure 93. A staircase signal with variable APL.

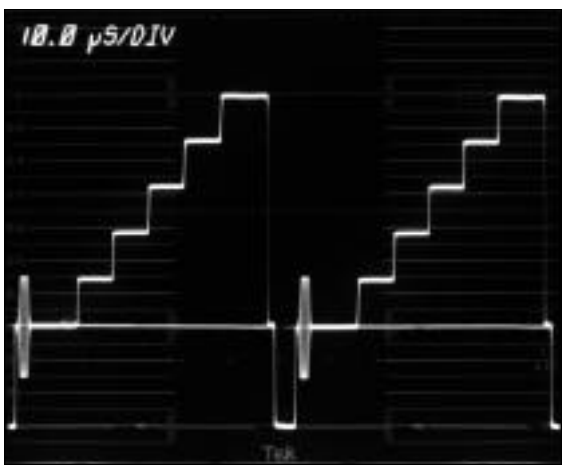

Figure 94. The sync pulse measures 300 mV at 50% APL.

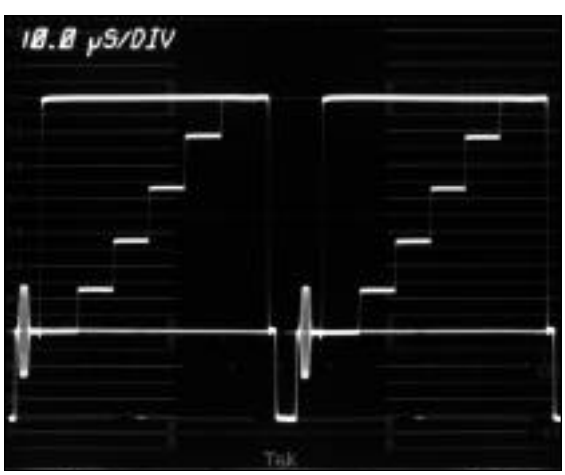

Figure 95. At 87.5 APL, the sync pulse measures 260 mV. This indicates a steady-state distortion of about 13%.

DEFINITION

Steady state gain distortion of the sync signal is present when horizontal sync amplitude is dependent on APL. This parameter is evaluated by measuring sync amplitude at high and low APL (typically 12.5% and 87.5%). The amount of distortion may be expressed as a percentage of the amplitude at 50% APL or as a percentage of the maximum amplitude. This is an out-of-service test.

Steady-state gain distortion of the picture signal is also sometimes measured. In this case, the effects of APL changes on peak white are evaluated.

PICTURE EFFECTS

If only sync is affected, small amounts of static gain distortion will not be noticeable in the picture. Large amounts of distortion may affect the ability of some equipment to derive synchronization information and/or to clamp the signal. If the picture signal is also affected, luminance levels will be APL dependent if this type of distortion is present.

TEST SIGNAL

Any test signal with variable APL can be used to measure steady-state sync gain. A 700 mV signal element such as a white bar is required for steady-state picture gain measurements.

MEASUREMENT METHODS

Waveform Monitor. To make a measurement, first select 50% APL and use the waveform monitor variable gain to set the sync amplitude to 100%. Vary the APL of the signal to 12.5% and then to 87.5%. At each APL level, record the amplitude of sync. The peak-to-peak variation for the three levels, expressed in per-cent, is typically quoted as the steady-state sync gain distortion. This measurement can be made with the 1781R voltage cursors in the RELATIVE mode. Figures 94 and 95 illustrate the measurement procedure.

The electrical fluctuations that we refer to as noise form a very complex signal that 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 which apply to television systems are discussed 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 measurement 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 1781R.

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.

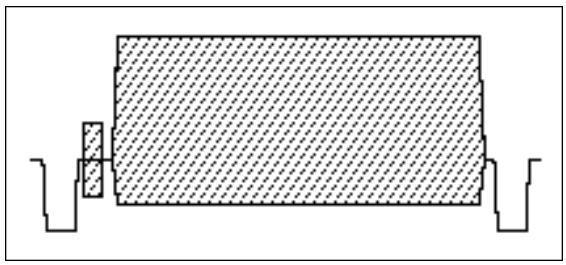

Figure 96. A red field test signal.

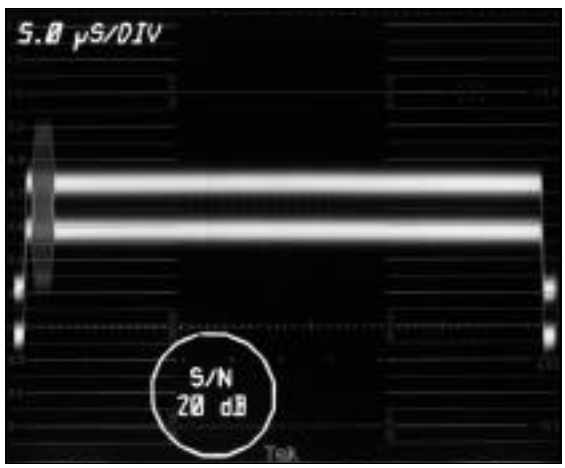

Figure 97. The 1781R tangential noise measurement mode showing excessive trace separation.

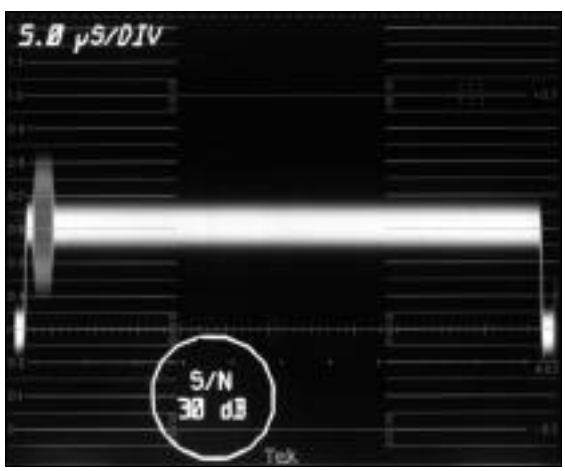

Figure 98. The 1781R tangential noise measurement mode with trace separation properly adjusted. This signal has a signal-to-noise ratio of 30 dB.

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 of interest.

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 as 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, measurements of signal-to-noise ratios, expressed in dB, are made.

PICTURE EFFECTS

Noisy pictures often appear grainy or snowy and sparkles of colour may be noticeable. Extremely noisy signals may be difficult for equipment to synchronize to and the picture may suffer from blurriness and a general lack of resolution.

TEST SIGNALS

The tangential method can be used on any video signal with a constant luminance level without chrominance. The measurement can be made on a single 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 Chrominance AM/PM noise measurement requires a red field test signal (see Figure 96).

MEASUREMENT METHODS

Tangential Method. Tangential noise measurements can be made with a 1781R. The method is accurate 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 the DC restorer to OFF or FAST. Select NOISE in the 1781R MEASURE menu. (In the 1481, use the WAVEFORM COMPARISON mode to split the luminance level of interest in half and overlay the two parts).

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. In the 1781R, the large knob is used to control the offset and the on screen readout provides the dB reading. In the 1481, 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 and numeric results are provided in this mode (see Figure 99).

Several lowpass, highpass, and weighting filters are available in this mode. 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 AMPM selection in the VM700T MEASURE mode, which requires a red field test signal, provides information about the noise that affects the chrominance portion of the signal. Since the chrominance signal is sensitive to both amplitude (AM) and phase (PM) components of noise, two separate measurements are provided. A selection of filters is available in this mode.

Noise measurements are also available in the VM700T AUTO mode.

NOTES

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

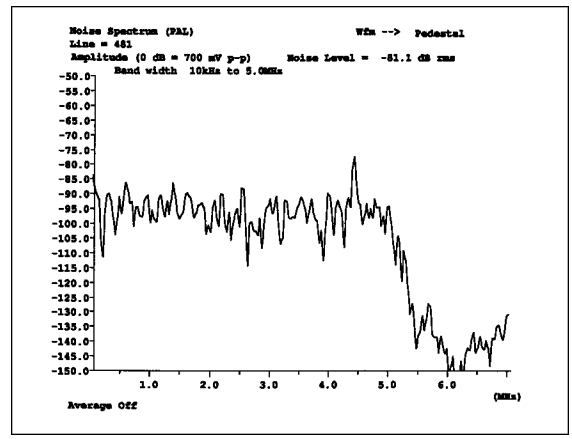

Figure 99. The VM700T Noise Spectrum display.

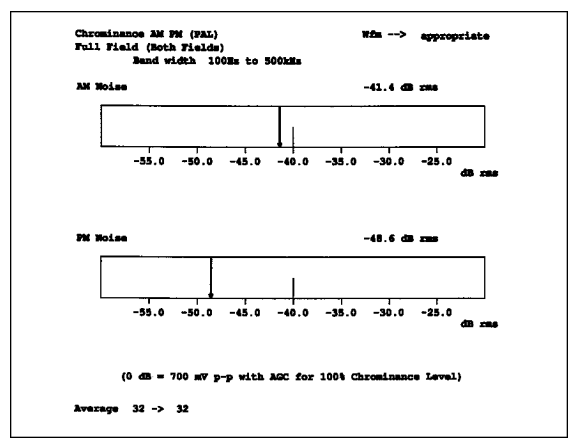

Figure 100. The VM700T Chrominance AM PM display.

In this section, we discuss two parameters which should be monitored and adjusted at the 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.

In order 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 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.

DEFINITION

ICPM (Incidental Carrier Phase Modulation) is present when picture carrier phase is affected by video signal level. ICPM distortion is 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 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 SIGNAL

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 by examining 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 obtain an ICPM display with a waveform monitor, connect the demodulator outputs to the waveform monitor inputs as shown in Figure 101. Select ICPM in the 1781R MEASURE menu or EXT HORIZ on the 1481 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 1781R or the 1481, this can be accomplished in the vertical channel by selecting the LOW-PASS filter. Use an external 250 kHz lowpass filter for the horizontal. Figure 101 shows a typical measurement setup.

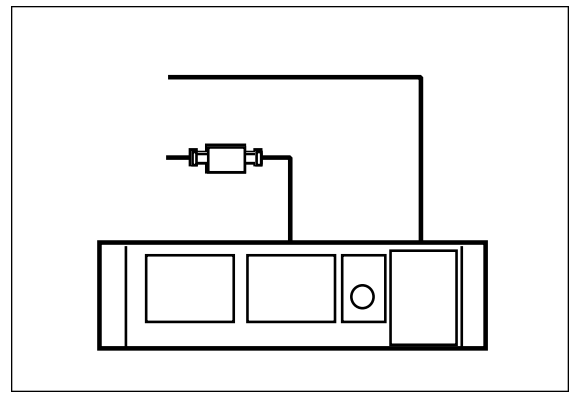

Figure 101. How to set up the 1781R for ICPM measurements.

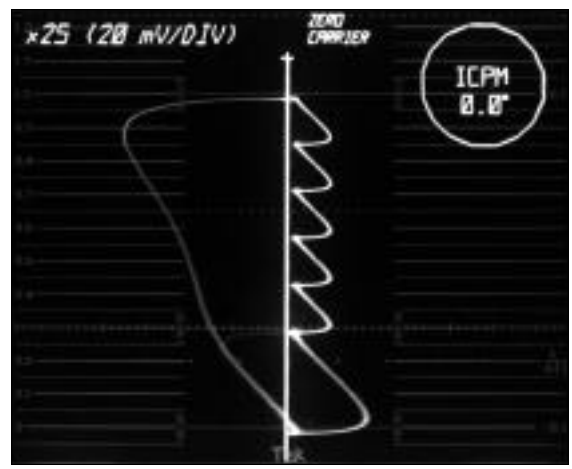

Figure 102. 1781R ICPM display with no distortion present.

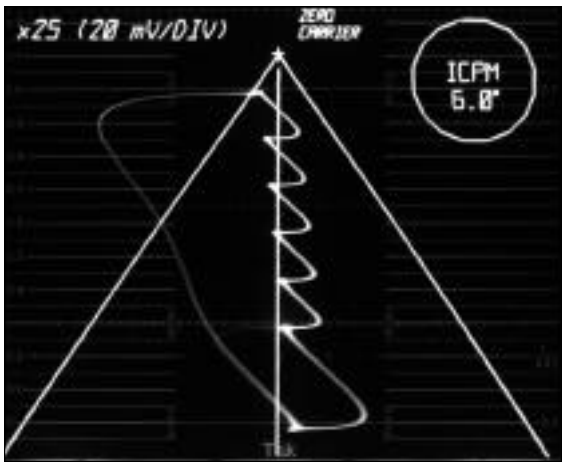

Figure 103. The 1781R electronic graticule indicating an ICPM distortion of 6 degrees.

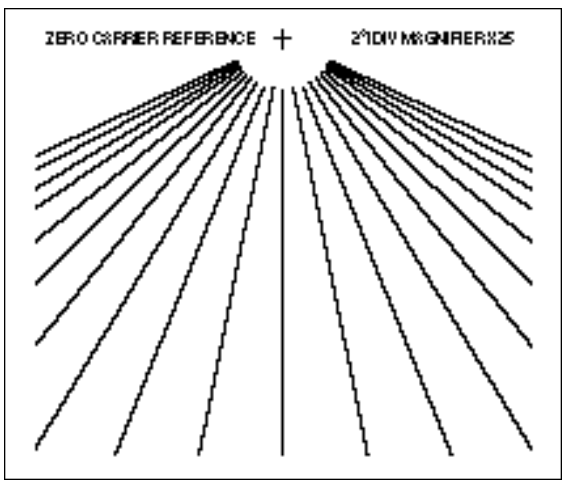

Figure 104. The 1481 ICPM graticule.

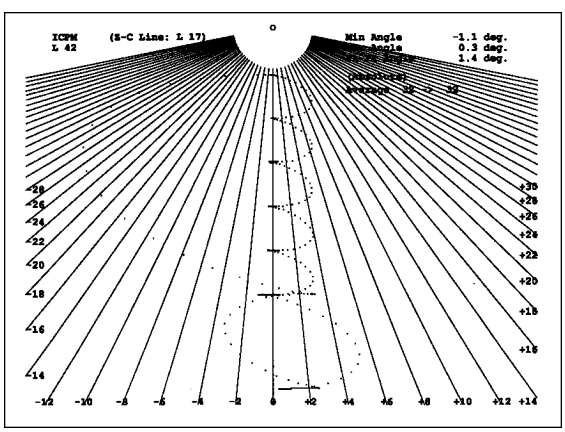

Figure 105. The VM700T ICPM display.

The display resulting from this configuration, which appears on the right-hand screen in the 1781R, is shown in Figure 102. The amount of tilt (deviation from the vertical) is an indication of ICPM. There is no ICPM in the signal shown in Figure 102, while distortion is present in Figure 103. To adjust for minimum ICPM, make the line as nearly vertical as possible.

The 1781R 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. X50 magnification can be used for greater resolution. Start with the two graticule lines widely separated and use the large knob to move them together to the point where a graticule line first contacts one of the dots. Disregard the "loops" in the display. These correspond to the level transitions and are not indicative of distortion. The amount of ICPM distortion is indicated on the screen (see Figure 103).

An external ICPM graticule is available for the 1481. 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 radial division when the horizontal magnifier is set to X25 or 1 degree per division with 50X horizontal magnification. Read the amount of ICPM from the graticule at the point of maximum distortion.

VM700T Automatic Measurement. The ICPM selection in the VM700T MEASURE mode provides an ICPM display and numeric results. An ICPM measurement is also provided in the AUTO mode. The quadrature output must be connected to VM700T "C" input.

NOTES

25. Configuring the 1481. 1481 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 measurements, the unblanking must be enabled. Instructions on how to accomplish this can be found in the OPERATING CHANGES section of the 1481 manual.

26. 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 61 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.

27. Phase Noise. Some demodulators have large amounts of phase noise which makes it difficult to make ICPM measurements on waveform monitors. The VM700T AVERAGE mode can eliminate this effect. The Tektronix 1450 has sufficiently low phase noise for measurements with a waveform monitor, 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.

DEFINITION

Depth of modulation (percentage of modulation) measurements indicate whether or not video signal levels are properly represented in the RF signal.

The PAL System I modulation scheme (see Note 29) 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 76% and white to 20%. The zero carrier reference level corresponds to 0% (see Figure 106).

PICTURE EFFECTS

Overmodulation often shows up as nonlinear distortions such as differential phase and gain and picture effects correspond to those caused by the various distortions. ICPM or white clipping may also result. Undermodulation often results in degraded signal-to-noise performance.

TEST SIGNAL

A signal with black and white levels is required for depth of modulation measurements. This signal is used in conjunction with the zero carrier reference pulse, which the demodulator typically places on one line in the vertical interval. In the composite signal the zero carrier pulse appears as a 0.95 volt (above blanking) bar approximately 30 microseconds in duration (see Figure 107).

MEASUREMENT METHODS

Modulation depth is measured at the output of a precision demodulator by verifying that the ratios between the parts of the signal are correct. Overall amplitude is not critical, but it should be adjusted in the system to be approximately 1.25 volts 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 provide a depth of modulation scale on the graticule. Use the variable gain to position the zero carrier reference pulse at 1.25 volts and sync tip at 0 volts. Verify that blanking level and white level occur at the prescribed points (0.3 and 1.0 volts respectively). The voltage cursors can also be used for this measurement.

NOTES

28. Envelope Detection Mode. 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.)

29. Depth of Modulation Numbers. The depth of modulation numbers used in this section are for System I PAL. For PAL Systems B, G, D and K, the CCIR specifies blanking level at 75% ±2.5% of peak carrier, and peak white at 10% to 12.5%. To make measurements that correspond to these specifications, use an overall video amplitude of approximately 1.12 volts. Verify that the white level is at about 11% of the overall amplitude, and that blanking is at about 73%. Since different countries may use different RF levels, be sure to note the recommendations of your broadcast authority.

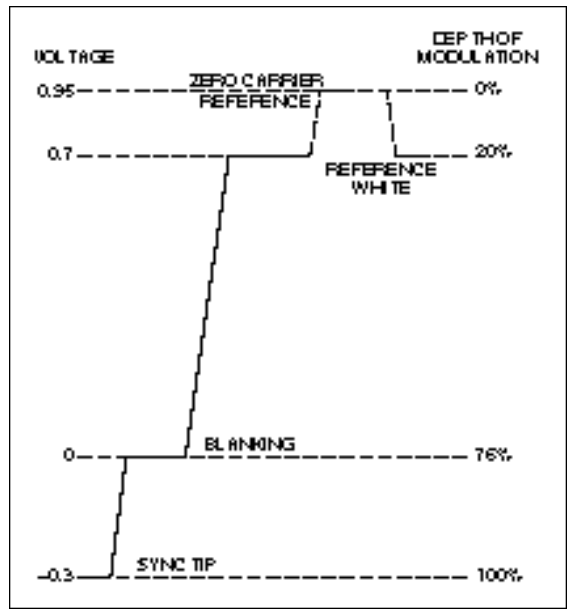

Figure 106. Depth of modulation levels for System I.

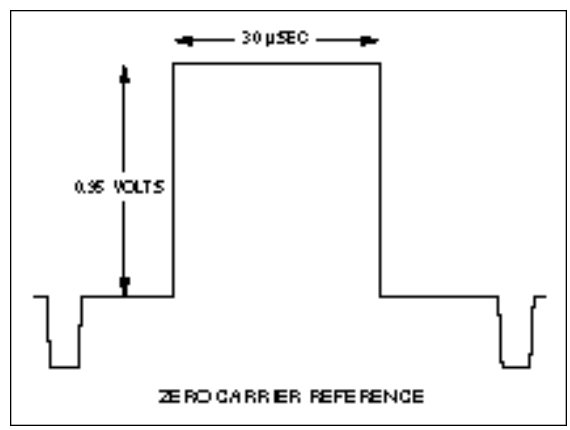

Figure 107. The zero carrier reference pulse as it appears in a baseband signal (System I).

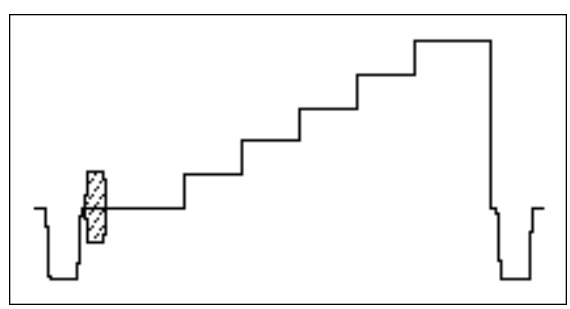

Figure 108. A signal that extends to 700 mV, such as this staircase signal, is used in conjunction with the zero carrier pulse to verify modulation levels.

AC-COUPLED — A connection which removes the constant voltage (DC component) on which the signal (AC component) is riding. 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 PAL television system, AM is used to encode the colour information and to transmit the picture.

Several different forms of AM are differentiated by various methods of sideband filtering and carrier suppression. Double sideband suppressed carrier is used to encode the PAL colour information, while the signal is transmitted with a large-carrier 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 that 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 through a studio and used for recording is at baseband.

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

BLANKING LEVEL — Refers to the 0.3 volt level (with respect to sync tip) which exists before and after horizontal sync and during the vertical interval.

BREEZEWAY — The portion of the video signal that 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 inter-val. These pulses are long enough to be distinguished from all others, and are the part of the signal actually detected by vertical sync separators.

BRUCH BLANKING — A 4-field burst blanking sequence employed in PAL signals to ensure that burst phase is the same at the end of each vertical interval.

BURST — A small reference packet of the subcarrier sine wave sent during the horizontal blanking interval on every line of video. Since the carrier is suppressed, this phase and frequency reference is required for synchronous demodulation of the colour difference signals in the receiver.

B-Y — One of the colour difference signals used in the PAL system, obtained by subtracting luminance (Y) from the blue camera signal (B).

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

CHROMINANCE SIGNAL — The high-frequency portion of the video signal, obtained by quadrature amplitude modulation of a 4.43 MHz subcarrier with R-Y and B-Y information.

COLOUR BLACK — See Black Burst.

COLOUR DIFFERENCE SIGNALS — Signals used by colour television systems to convey colour information in such a way that the signals go to zero when there is no colour in the picture. U and V are colour 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 colour 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 colour picture. Created by adding quadrature amplitude modulated U and V 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, $dB = 20 \text{ Log}_{10} (V_1 / V_2)$.

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 onto the picture carrier) and converts it to baseband.

(2) The circuits that recover U and V from the composite signal.

EQUALIZING PULSE — The pulses that 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 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 PAL television system, audio information is transmitted using FM.

FRAME — A frame (sometimes called a "picture") 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 non-linear 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 $R^{1/\gamma}$, $G^{1/\gamma}$ and $B^{1/\gamma}$. Values for gamma range from 2.2 to 2.8.

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

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 non-linearities 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 300 mV pulse occurring at the beginning of each line. This pulse tells 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 colour that allows us to distinguish between colours such as red, yellow, purple, etc.

HUM — Hum refers to the undesirable coupling of the 50 Hz power sine wave into other electrical circuits.

INTERCARRIER SOUND — A method used to recover audio information in the PAL system. Sound is separated from video by beating the sound carrier against the video carrier, producing a 5.5 MHz IF that contains the sound information.

ITS — Insertion Test Signal. A test signal which is inserted in one line of the vertical interval to facilitate in-service testing.

LINEAR DISTORTION — Refers to distortions that 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 colour systems it is obtained as a weighted sum (Y = 0.3R + 0.59G + 0.11B) of the R, G and B signs.

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

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

NON-LINEAR DISTORTION — Refers to distortions that are amplitude-dependent.

NTSC — National Television System Committee. The organization that 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 one of the television systems used in Europe and many other parts of the world. The phase of one of the colour difference signals alternates from line to line to help cancel out phase errors.

QUADRATURE AM — A process which allows two 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 colours used in colour television's additive colour reproduction system. These are the three colour components generated by the camera and used by the picture monitor to produce a picture.

R-Y — One of the colour difference signals used in the PAL system, obtained by subtracting luminance (Y) from the red camera signal (R).

SATURATION — The property of colour which relates to the proportion of white light in the colour. Highly saturated colours are vivid, while less saturated colours have more white mixed in and therefore appear pastel. For example, red is highly saturated, while pink is the same hue but much less saturated.

In signal terms, saturation is determined by the ratio between luminance level and chrominance amplitude. It should be noted that a vectorscope does not display saturation: the length of the vectors represents chrominance amplitude. In order to verify that the saturation of the colours in a colour bar signal is correct, you must check luminance amplitudes with a waveform monitor in addition to observing the vectors.

SUBCARRIER — Refers to the high-frequency signal used for quadrature amplitude modulation of the colour difference signals. For PAL, subcarrier frequency is 4,433,618.75 Hz.

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.

U — The B-Y signal after a weighting factor of 0.493 has been applied. The weighting is necessary to reduce peak modulation in the composite signal.

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

V — The R-Y signal after a weighting factor of 0.877 has been applied. The weighting is necessary to reduce peak modulation in the composite signal.

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

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

Y — Abbreviation for luminance.

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

There are several varieties of PAL colour bars, three of which are in common use. These three varieties, shown in Figure 109, are frequently referred to as 100% colour bars, 95% colour bars, and EBU colour bars. In this case, the 100% and 95% distinction refers to saturation, however, this convention is not universal. The maximum amplitudes of the R, G and B signals are also sometimes used to describe the various types of bars. (Recall from page 9 that Tektronix vectorscopes use the 75%/100% designation to refer to amplitude.)

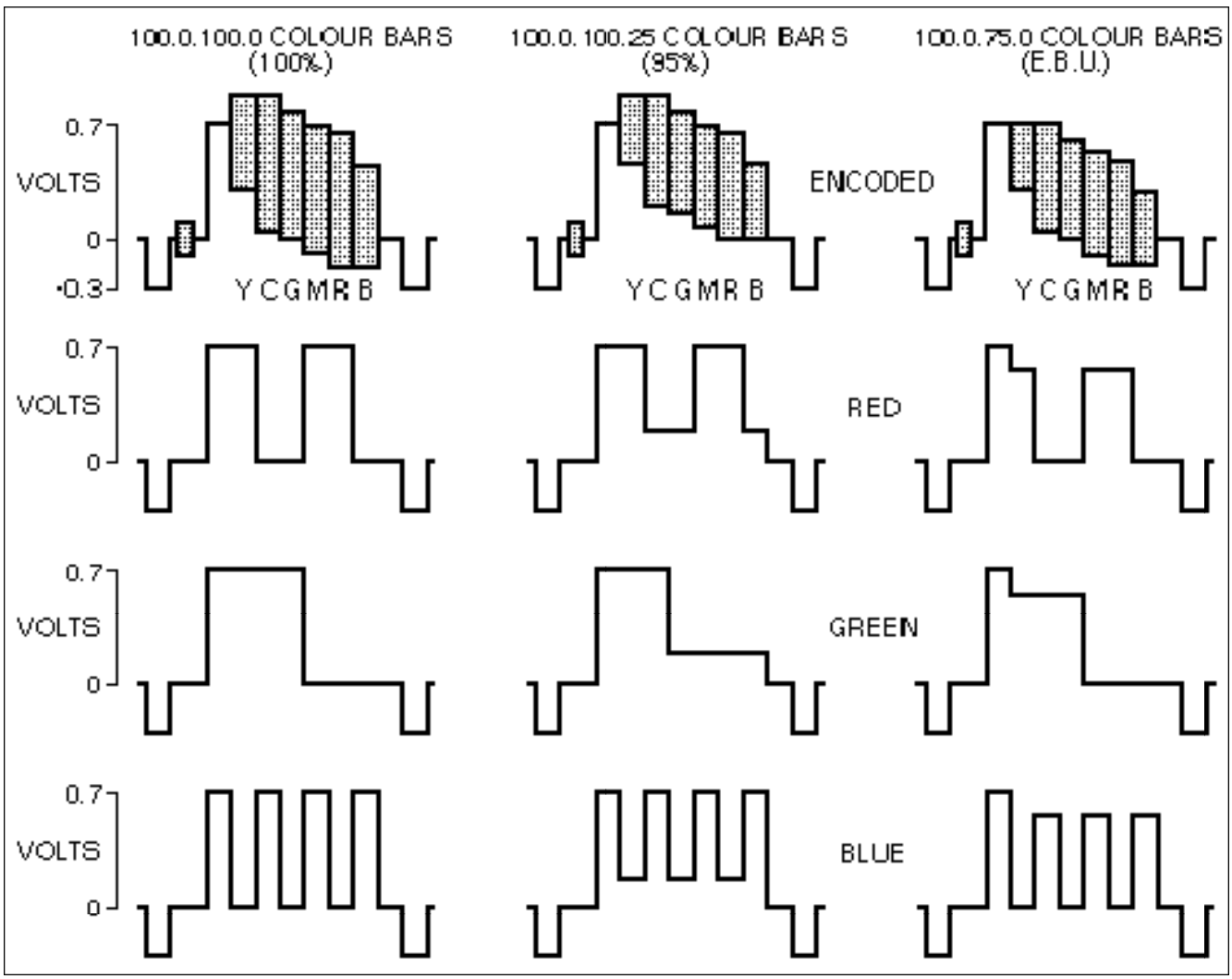

Figure 109. Waveforms and RGB voltages for three types of PAL colour bars.

Nomenclature. It is confusing to use a single number to distinguish between the various types of colour bars, particularly if it is not clear which parameter that number describes. Furthermore, a single number is inadequate to completely and uniquely define a given signal. For these reasons, a four-parameter system of colour bar specification has been developed. The following four parameters are used to describe the signal:

(a) Maximum value of ER´, EG´ or EB´ for an uncoloured bar.

(b) Minimum value of ER´, EG´ or EB´ for an uncoloured bar.

(c)Maximum value of ER´, EG´ or EB´ for a coloured bar.

(d)Minimum value of ER´, EG´ or EB´ for a coloured bar.

ER´, EG´ and EB´ are the three colour signals. Each parameter is specified as a percentage of the maximum voltage excursion allowable for PAL colour signals, which is 700 millivolts.

With this system of nomenclature, the three common types of bars can be uniquely described as 100.0.100.0 bars, 100.0.100.25 bars, and 100.0.75.0 bars. These numbers can readily be correlated with the Red, Green and Blue signals corresponding to each type of colour bars (see Figure 109).

Saturation. Note that saturation is not included in this list of parameters. Saturation is a particularly difficult parameter to use for uniquely specifying a colour bar signal because it depends on the value of Gamma. Saturation is calculated as follows:

$$\text{Saturation}(\%) = [1 - (E_{min}/E_{max})^{\gamma}] \times 100$$

Thus 100.0.100.25 colour bars have a saturation value of 95% if a value of 2.2 is used for Gamma. However, CCIR standards currently call for a Gamma value of 2.8 which yields a saturation value of 98% for 100.0.100.25 bars. Clearly, then, the saturation nomenclature is best avoided altogether.

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

Description of the Pulse. The sine-squared pulse looks like one cycle of a sine wave (see Figure 110).

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.

Bandwidth limited systems are tested with pulses having an HAD that is a multiple of the time interval T. T, 2T, 10T and 20T are common examples. T is the Nyquist interval, or 1/2fc, where fc is the cutoff frequency of the system to be measured. For PAL systems, fc is usually taken to be 5 MHz and T is therefore 100 nanoseconds. Most PAL test signals use this default value for T, even though the system under test may have a bandwidth of 5.5 or 6 MHz.

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 100 nanoseconds (see Figure 111). A 2T step has a rise time of nominally 200 nanoseconds.

Mathematically, a T step is obtained by integrating a sine-squared pulse. (This is why the T step has a rise time that is only nominally equal to T. The integral actually yields a rise time of 0.964T for a T step.) 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/(2HAD) is one-half of the amplitude at zero frequency. Energy distributions for a T pulse, 2T pulse, and T step are shown in Figure 112.

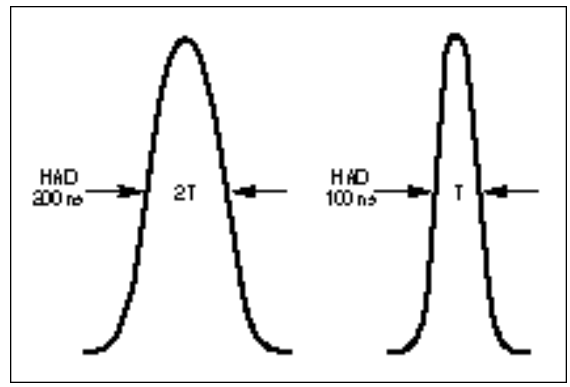

Figure 110. 2T pulse and 1T pulses for PAL systems.

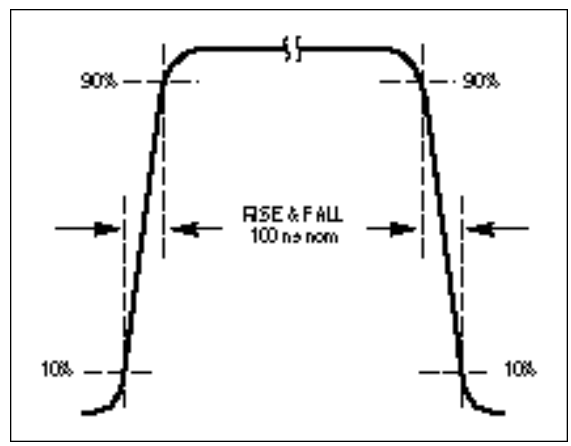

Figure 111. T rise time step.

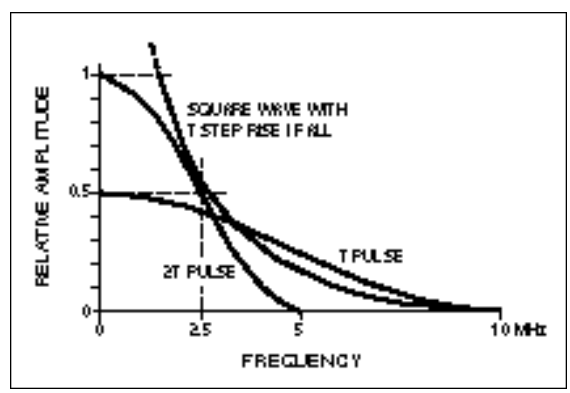

Figure 112. Frequency spectra of T pulse, 2T pulse, and T step.

For further information, contact Tektronix:

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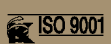

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