AN INTRODUCTION TO TELEVISION MEASUREMENTS

INTRODUCTION

When assessing the performance of a video circuit (or item of video equipment) either on a routine basis or at the installation stage a number of parameters have to be tested. This information sheet describes those parameters, and outlines the way in which they are assessed. It is intended that this information sheet should be supported by practical experience gained from the work sheets covering Pulse and Bar and Non-linearity Measurements. (27P and 27S). The detailed theory of measurement techniques will be covered on later courses.

1. THE PARAMETERS TO BE TESTED

1.1 Types of Distortion

With the possible exception of overall gain/attenuation all other parameters account for some form of distortion of the television waveform. Such distortions can be broadly grouped into one of three categories:

1. Linear Distortions
2. Non-linear Distortions
3. Noise

1.2 Linear Distortions

Linear distortions are those in which the distortion varies as a function of frequency, or more fundamentally, time. Frequency response is a good example of a linear distortion. Generally an overall measurement of frequency response for a video circuit is not made. Tests are carried out however to determine the responses at the h.f. and l.f ends of the spectrum relative to the midband response. The following measurements will be made to assess linear distortions.

h.f. response	a measure of the system's ability to transmit fine detail.
l.f. response	a poor l.f. response leads to shading and streaking, possibly over large areas of the picture.

phase response	this is a measure of the delay characteristics of the circuit. Ideally it should have the same delay at all frequencies, correspondingly a rising phase shift with frequency response is required.
chrominance - luminance gain	this is an extension of the h.f response measurement specifically engineered to reveal deficiencies around the subcarrier region.
chrominance - luminance delay	similarly this extends the phase measurement to be more sensitive at subcarrier frequencies.

1.3 Non-Linear Distortions

Distortions which vary as a function of signal amplitude are non-linear distortions. Harmonic distortion of an audio signal is an example. The following non-linear distortions are measured:

luminance non-linearity	a measure of the overall amplitude transfer characteristics.
differential gain	the variation of chrominance level with variations in the luminance signal amplitude.
differential phase	the variation of subcarrier phase with variations in the luminance signal amplitude.
chrominance - luminance intermodulation	if the response to the chrominance signal causes any assymmetry then a shift in the luminance level will result.

1.4 Noise

Noise is generally taken to include all forms of interfering signals. Generally it sub-divides into below line frequency noise (e.g. hum) and above line frequency noise (e.g. random noise).

The sections that follow describe briefly how the various parameters are measured.

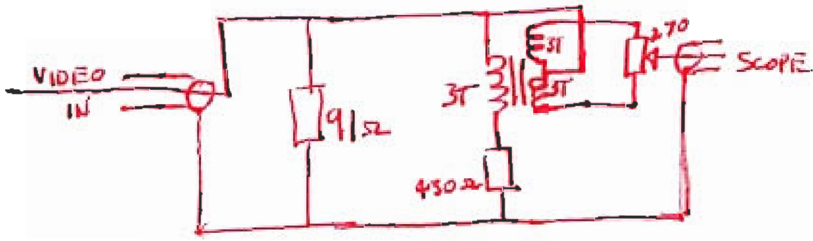
2. GAIN MEASUREMENT

There are two problems associated with the measurement of gain. Firstly there is the need for an accurate means of measuring the level of the video waveform. Secondly the choice of test waveform is important if the measurement is not to be influenced by extremes of frequency response.

2.1 Measurement of Signal Level

The obvious means of signal level measurement is with an oscilloscope, however this is notoriously inaccurate, at best no more than 5% can be achieved, whereas typically 1% (0.1dB) is required. One way to improve this figure is by a differential measurement, however this can only be of value if the input and output of the circuit are physically co-sited.

Most level measurements are now made using the "Weaver" method in which a square wave of known amplitude is compared with the signal under test. A diagram of a typical signal level measuring set (colloquially referred to as a Weaver Box or 1 Volt Box) is shown in figure 1.



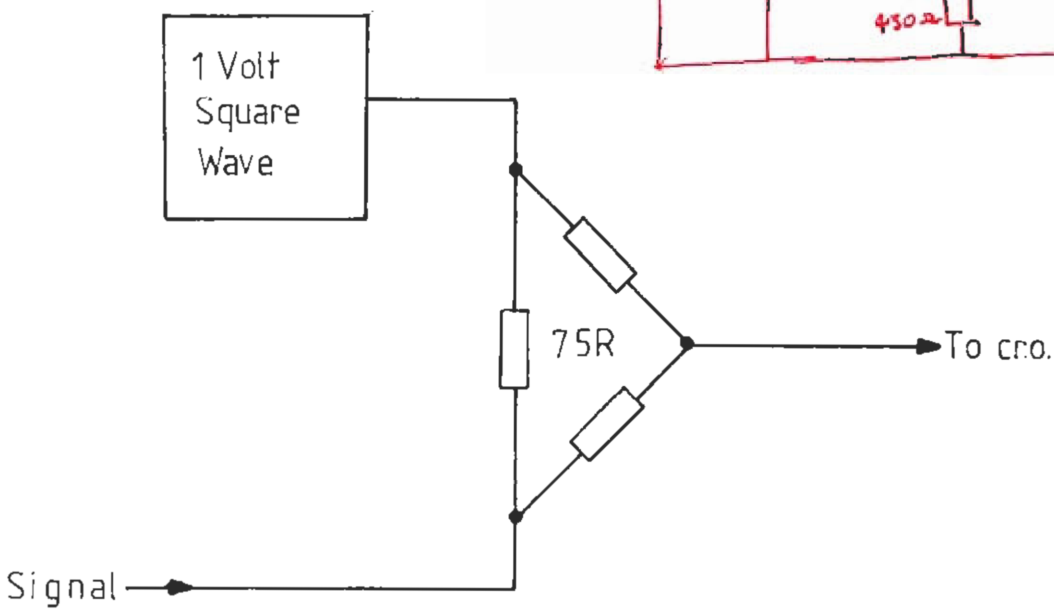


Figure 1 Diagram of a Level Measuring Set

The square wave free runs at typically 11 kHz, and when mixed with the video signal results in a c.r.o. trace very similar to that of a conventional chop mode display i.e. two traces of the signal under test separated by the square wave signal. This is shown in figure 2, where it will be apparent that if the oscilloscope is locked to the line frequency of the test signal and the square wave free runs then two continuous television waveforms will be displayed. Furthermore if the peak to peak amplitude of the signal under test is exactly the same as that of the square wave then the two traces will just touch. This is also shown in figure 2.

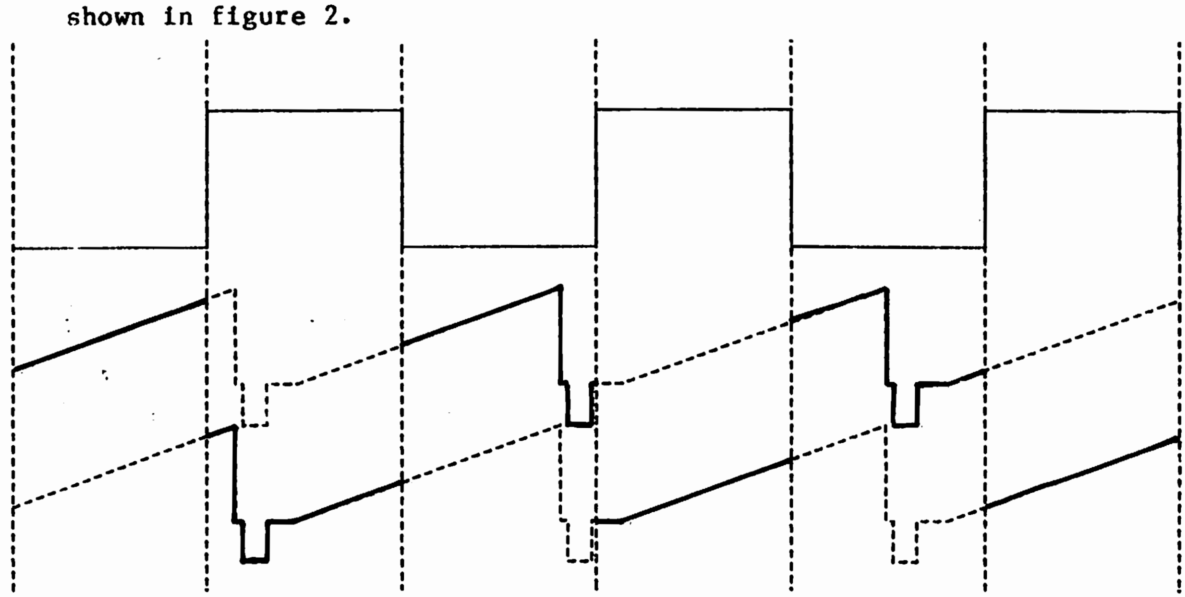


Figure 2 Adding the Square Wave and Test Signal

To enable an accurate measurement of level to be made the square wave can be altered until the traces just touch. The latest level measuring set provides for an adjustment of ±2dB relative to a coarse setting (1V, 0.7V, 0.3V etc.), the level being displayed on an L.E.D. indicator with a resolution of 0.01dB.

It should be noted that if the measurement is to be made on the chrominance component of a coded video signal then the oscilloscope must be correctly equalised. This will be covered more fully in the practical experiments.

2.2 A Suitable Test Signal

It is essential that any measurement of gain is independent of extremes of frequency response. To facilitate this a waveform based on the use of a line frequency square wave is used.

If the square wave amplitude is measured exactly in the centre of each half cycle then the measurement will be unaffected by reasonable amounts of h.f. and l.f. distortions. This is shown in figure 3.

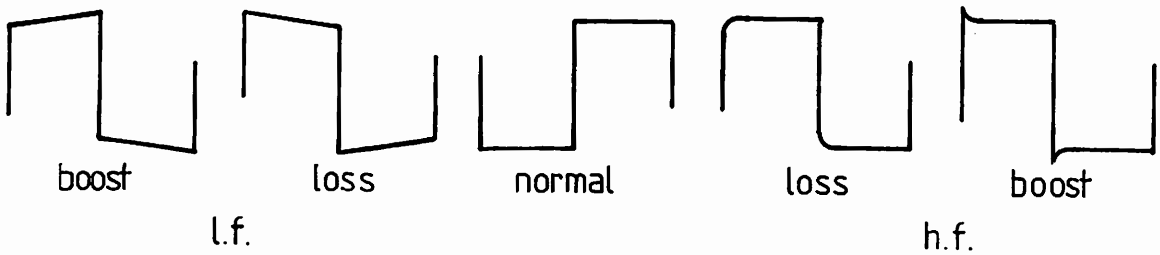


Figure 3 Affect of h.f. and l.f. distortions on a line rate square wave

In order that the technique may be used with a video circuit sync pulses must be added. The resulting waveform is shown in figure 4.

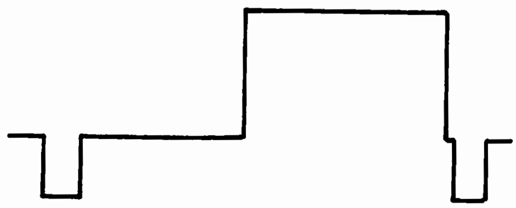


Figure 4 Basic Waveform for Level Measurement

3. MEASUREMENT OF LINEAR DISTORTIONS

3.1 Frequency Response Measurement

The concept of frequency response measurement usually conjures up a vision of frequency sweeps and log - lin graph paper. Whilst this might be perfectly feasible for a video circuit (providing the need for sync pulses is met) it is unlikely that the results so obtained will be particularly revealing as to the performance of the circuit. A more appropriate technique is one which takes into account the subjective nature of the television system. In particular the two extremes mentioned in 1.2 should be catered for; i.e. the effects of h.f and l.f. response.

3.2 Requirements of a Suitable Test Signal

As discussed in 1.2 a poor h.f. response affects the fine details in a scene, whilst a poor l.f. response affects relatively large areas of the picture. In order to assess the frequency response subjectively a test signal which includes some fine detail and a large area of constant brightness is needed. The waveform shown in figure 4 would admirably meet both requirements if it were supplemented by some fine detail.

It is possible to determine the smallest element of fine detail which the television system is capable of resolving. The U.K. 625 line system has an upper band width limit of 5.5 MHz, however, for measurement purposes, and to conform with other systems, 5 MHz will be used. The smallest element of fine detail therefore correponds to one half-cycle of a 5 MHz sine wave, as shown in figure 5.

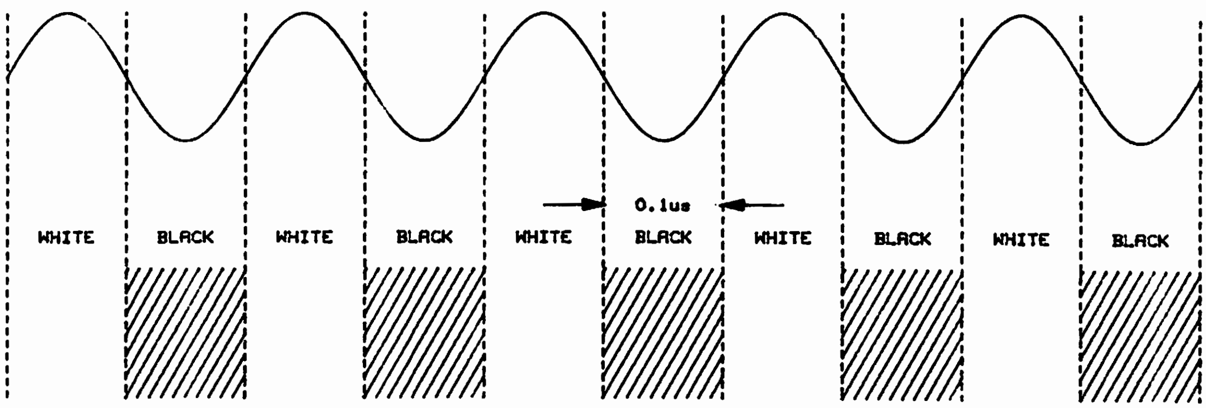


Figure 5 Determining the smallest element of fine detail

The duration of this element is defined as a T unit, where 1T = 0.1 μs. It might be thought that a short rectangular pulse of 0.1 μs duration might be suitable as a test waveform, however when the frequency spectrum of a rectangular pulse is considered it is found to consist of many harmonics which would extend well outside the video pass band. Such a pulse would be unsuitable. It is possible however to generate a suitable component in the form of the sine squared pulse.

3.3 The Sine Squared Pulse and Bar Test Signal

The sine squared pulse is so described because its envelope corresponds to a graph of $\sin^2 x$ plotted against x over 180°, and is shown in figure 6.

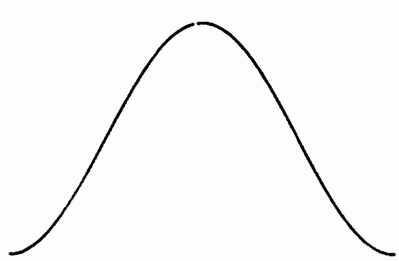


Figure 6 Outline of a Sine Squared Pulse

The significance of the sine squared pulse is that it has very little energy above a particular extinction frequency. The extinction frequency is related to the half amplitude duration of the pulse. It might be thought that a sine squared pulse of 1T (100 ns) H.A.D. would be required, however an investigation as to the spectrum of such a pulse shows that its extinction frequency is 10 MHz. Consequently for normal testing a 2T pulse is used with a H.A.D. of 200 ns. Figure 7 shows the relative responses of the two pulses.

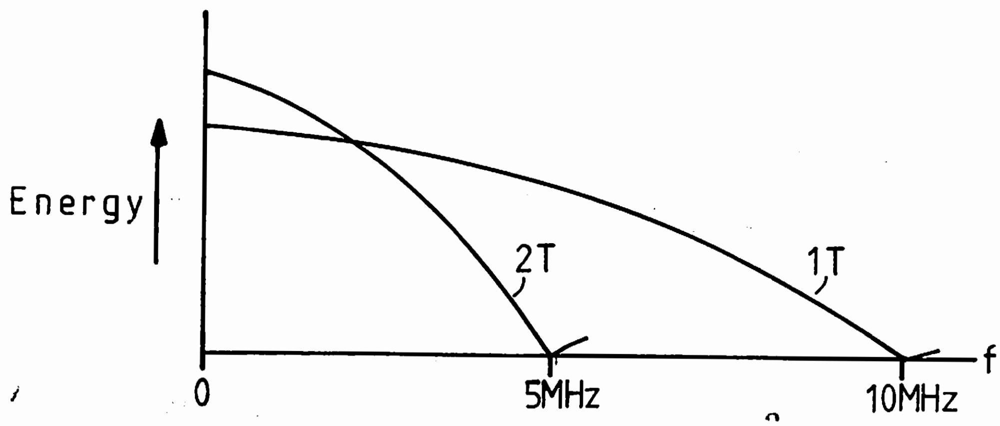


Figure 7 Spectrum of 1T and 2T Sin^2 Pulses

The 1T pulse is sometimes used to check the out of band response, which if particularly bad can lead to ringing on transients.

When combined with the waveform of figure 4 the basic "pulse and bar" test signal results, and is shown in figure 8.

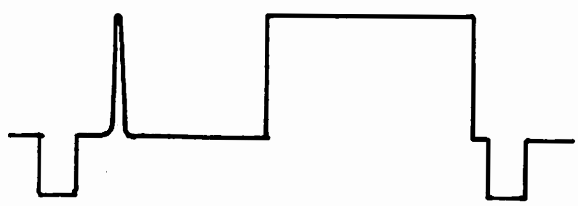


Figure 8 Basic Pulse and Bar Waveform

It should be noted that the edges of the bar have the same shape as the Sin^2 pulse.

3.4 Using the Sin^2 Pulse and Bar - K-Ratings

In order to take into account the subjective effects of any distortion a system of measurements known as K-Rating is employed. This ensures that equally measured amounts of distortion have equal annoyance values, irrespective of the type of distortion present. To enable the measurements to be made quickly and easily a special graticule is fitted to the oscilloscope. The graticule is illustrated in figure 9.

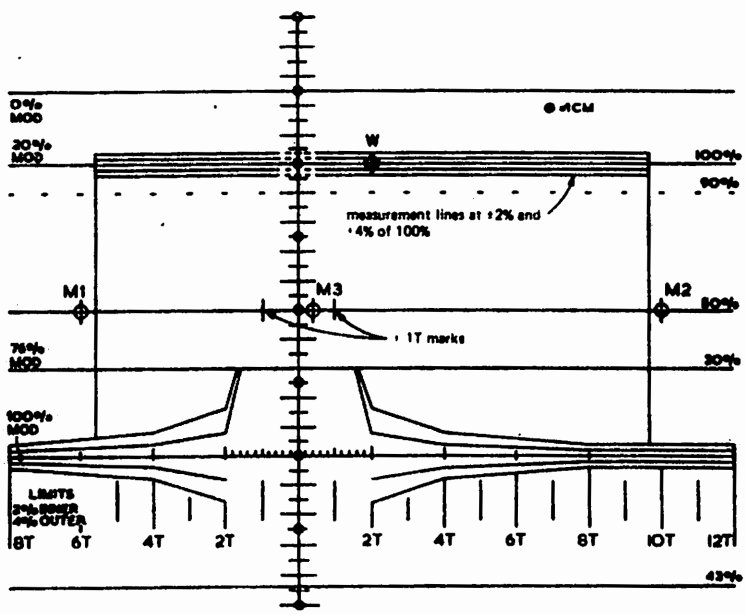


Figure 12 Pulse and Bar Graticule

Before attempting to make distortion measurements on a circuit the signal level is first measured, using the signal Level Measuring Set as described earlier. After this the sensitivity of the oscilloscope is 'calibrated' by means of the luminance bar - all other measurements being made relative to the actual bar amplitude.

3.5 Measurements Made Using the K-Rating Graticule

The first measurement to be made will determine the l.f. response, and is referred to as K Bar. The oscilloscope is first calibrated against the bar amplitude and duration, as shown in figure 13, and then the l.f. response assessed by measuring the sag on each half of the bar in turn - the worst figure being quoted.

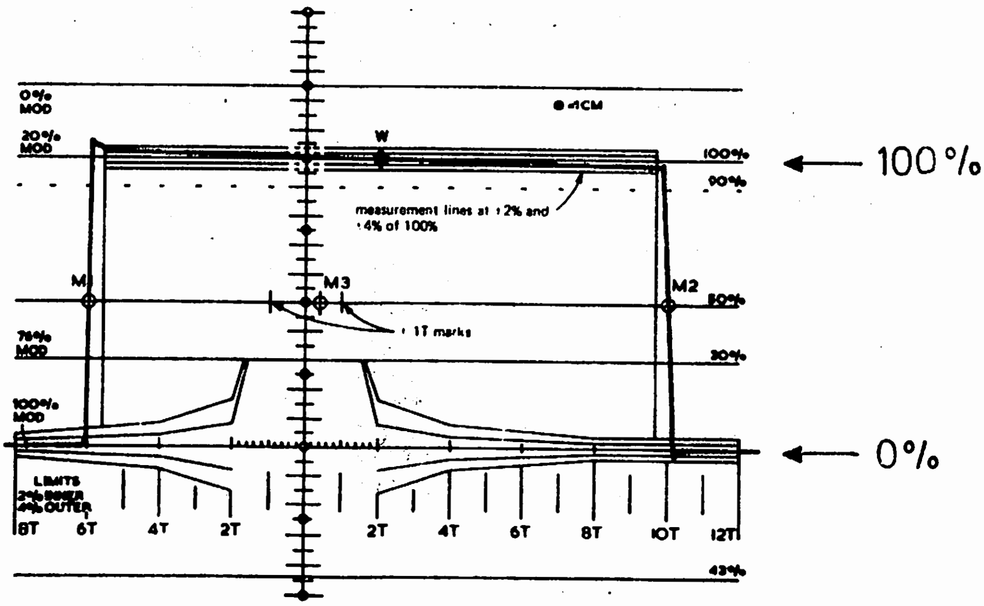


Figure 13   Setting Up the Oscilloscope for K Bar Measurement

After this the 2T pulse is positioned alongside the percentage scale in the centre of the graticule and the h.f. response assessed by measuring the pulse to bar ratio. Finally the phase response is measured by an examination of the shape of the 2T pulse. Figure 14 shows how the waveform is "fitted" to the graticule for this measurement.

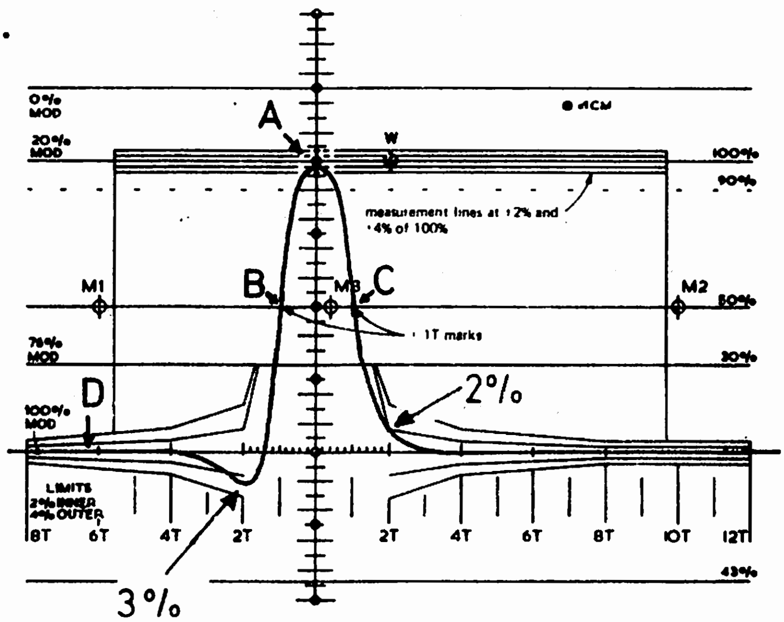


Figure 14   Measurement of Phase Response - K2T

3.6 Chrominance - Luminance Gain and Delay Inequality Measurement

The measurement of the amplitude and delay responses of the chrominance channel relative to the luminance channel uses two additional components added to the basic pulse and bar waveform as shown in figure 15.

Figure 15 The Chrominance - Luminance Pulse and Bar Waveform

The additional components are:

The chrominance minibar	a full amplitude (0.7V) chrominance envelope superimposed on a half amplitude (0.35V) luminance pedestal.
The chrominance - luminance pulse	A composite chrominance - luminance pulse formed by modulating a subcarrier signal with a 10T luminance pulse and combining the two.

Chrominance luminance gain inequality will show up as variations in the peak to peak amplitude of the chrominance minibar relative to the luminance bar. This is most easily carrrried out at the same time as pulse to bar ratio is measured, however it is most important that the full peak to peak amplitude is measured, as shown in figure 16.

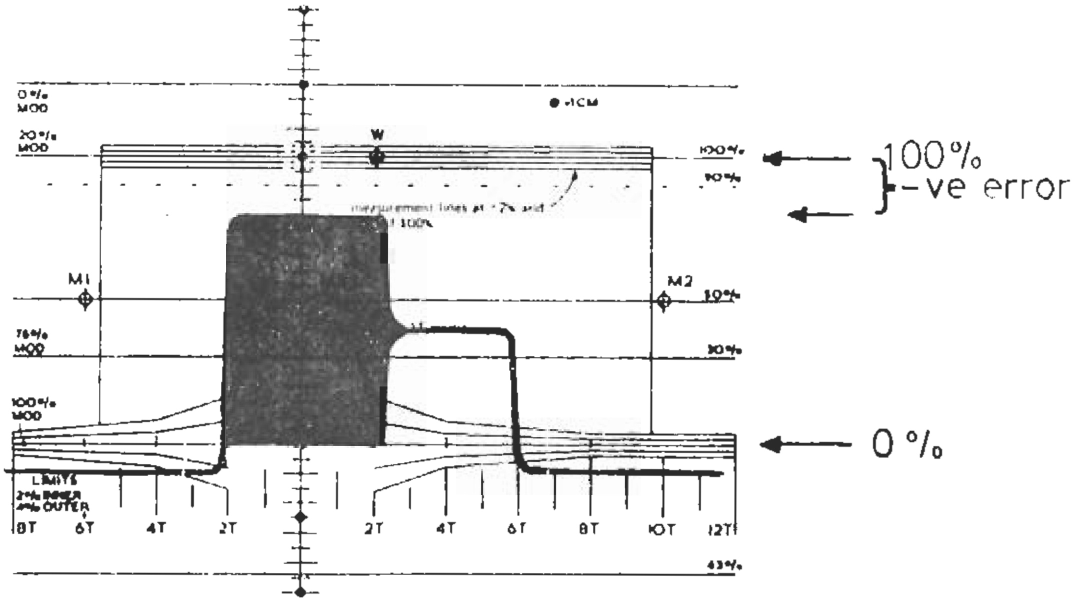


Figure 16 Measurement of C - L Gain Inequality

Chrominance - luminance delay errors show up as an assymetry at the base of the 10T pulse, as shown in figure 17.

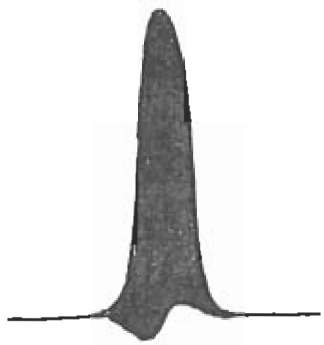


Figure 17 The Effect of C - L Delay of the 10T Pulse

The distortion has to be measured by means of a gain and delay tester. The earlier version is used in conjunction with the oscilloscope and is adjusted to make the 10T pulse symmetrical by introducing a C - L delay equal and opposite to that of the distortion. In the later tester delay errors are indicated directly on a meter. This type of instrument can also be used to display gain errors as well.

4. NON-LINEARITY MEASUREMENTS

4.1 The Basic Test Signal

As with most television measurements a principle factor in determining the choice of waveform is that generally the output and input of a circuit will not be available for comparison. The basic waveform that was chosen for non-linearity measurement is a five riser staircase as shown in figure 18.

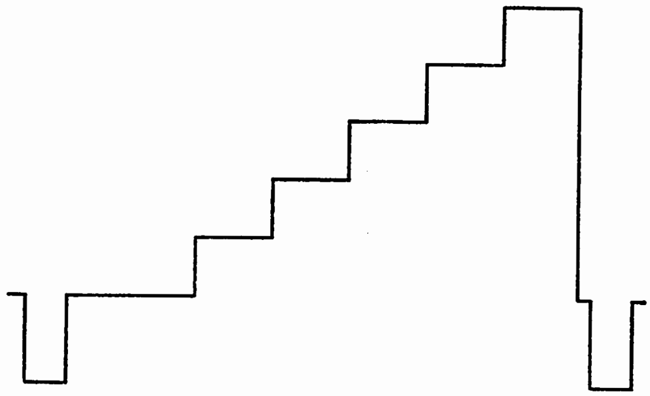


Figure 18 Staircase used for Non-Linearity Measurements

Any non-linearity will result in the staircase "risers" having different heights. The method of measuring this will be described shortly.

4.2 Mean Level Variations with A.C. Coupling

One normally thinks of the television waveform as being a standard 1 volt signal. However, when the effects of a.c. coupling are considered it will be seen that the range of absolute voltage covered by the signal will be somewhat greater than this. Figure 19 shows three examples of different mean level signals.

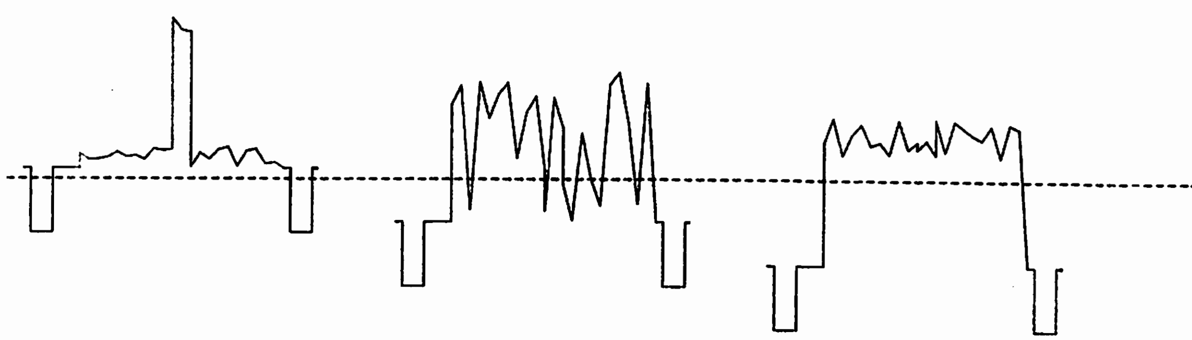


Figure 19 Mean Level Variation with A.C. Coupling

Any assessment of non-linearity should therefore test the system over as wide a range of levels as possible, consequently the test waveform is modified such that the staircase is only present every fourth line. The three lines intervening are either all black (low mean level) or all white (high mean level).

4.3 The Composite Non-Linearity Test Waveform

Non-linearity measurements also have to take account of differential gain and phase distortions of the chrominance channel. To measure these a subcarrier component is clearly needed at different luminance levels. A subcarrier component of peak to peak amplitude equal to the riser height (140 mV) is added to the staircase. The combined waveform resulting is shown in figure 20.

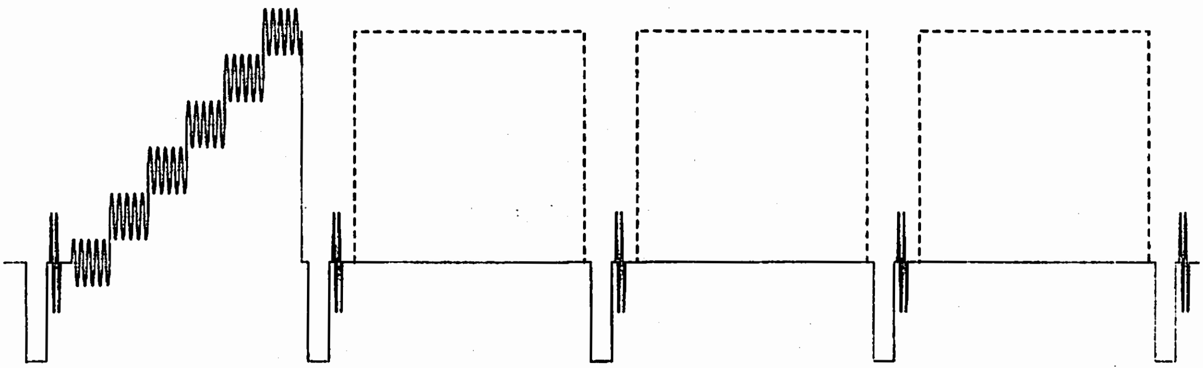


Figure 20 The Non-Linearity Test Waveform

4.4 Measurement of Luminance Non-Linearity

As mentioned in 4.1 luminance non-linearity results in the risers of the staircase having different amplitudes. To make measurement easy the staircase is differentiated, and filtered to remove the subcarrier component, and then displayed on the oscilloscope. Non-linearity is defined as the difference between the largest and smallest spikes, expressed as a percentage in terms of the largest. This is shown in figure 21.

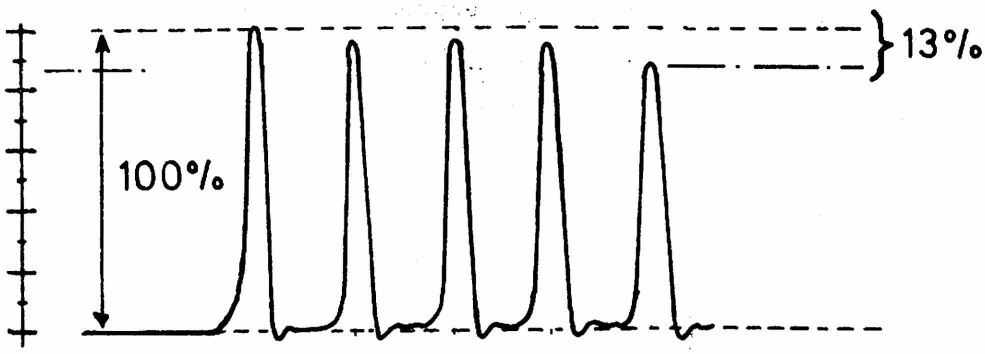


Figure 21 Measurement of luminance non-linearity

As with all non-linearity measurements four tests may be made. First with black and white staircases, and then repeated with a 3dB increase in signal amplitude.

4.5 Differential Gain Measurement

Differential gain distortion results in the amplitude of the chrominance signal changing as the luminance level varies. To measure this the chrominance component is separated from the staircase by means of a band pass filter and displayed on the oscilloscope, the burst normally being removed by gating. If no differential gain distortion is present than a display related to that of figure 22b, where differential gain is present, will be seen.

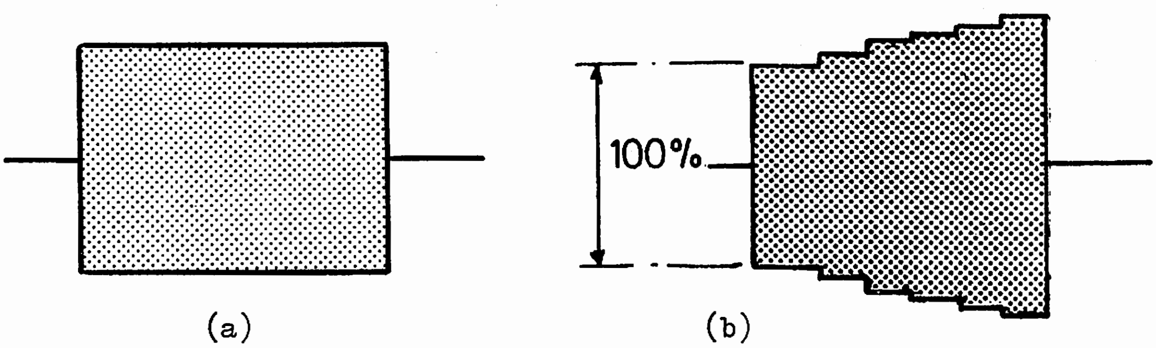


Figure 22 Appearance of the Chrominance Envelope

Differential gain is defined as the greatest difference in amplitude from the black level step, expressed as a percentage of the black level step. The black level step is always taken as the reference for "differential" measurements as it is at the same luminance level as the colour burst - the true reference for the chrominance channel.

4.6 Differential Phase Measurement

In order to measure the phase of the chrominance component it must first be demodulated in a synchronous demodulator. You will remember from your study of colour coding that a synchronous demodulator produces a maximum positive output when its two inputs are in phase, maximum negative when they are out of phase and zero when at 90° to each other. As the only level that can be reliably detected is zero, phase measurement must be made by phase shifting the inputs so that the zero condition is achieved. Any variations in phase can then be measured by varying the phase shift applied to the inputs and noting the change. These functions are provided by the Remote Signal Analyser, a block diagram of the essential components of which is shown in figure 23.

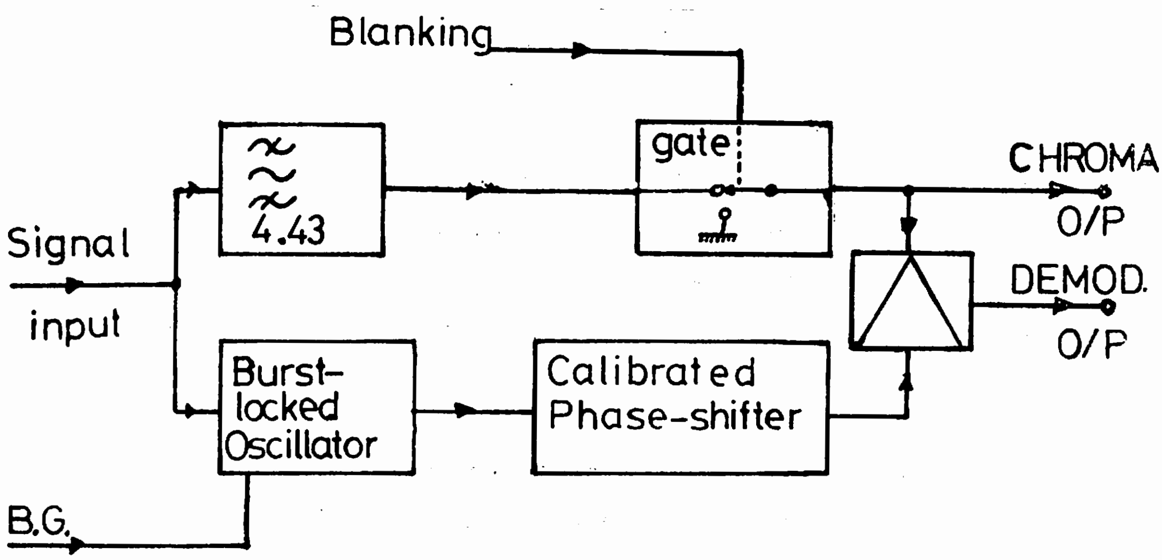


Figure 23 The Remote Signal Analyser

The subcarrier envelope is separated from the staircase, the burst removed by gating and the resultant chrominance signal applied to one input of a synchronous demodulator. The other input to the demodulator is a reference subcarrier derived from an oscillator locked to the colour burst and fed through a calibrated, variable phase shifter. The output of the demodulator is a d.c., the level and polarity of which depends on the relative phase relationship of the modulator inputs.

If the phase of all six steps of subcarrier is the same, i.e. there is no differential phase distortion, then a constant d.c. will result. In practice however, a display similar to that of figure 24 will be seen, where differential phase is present.

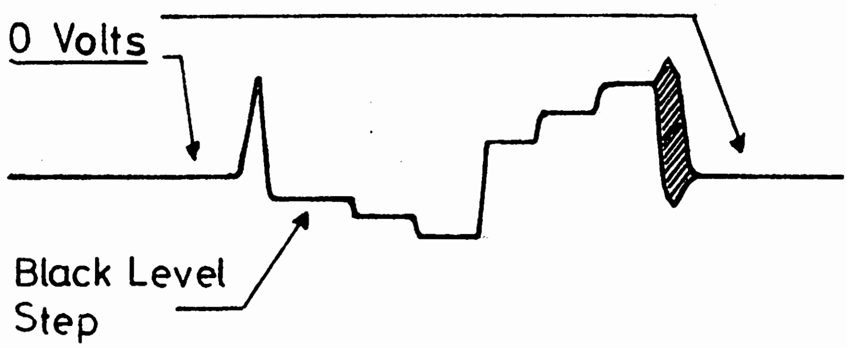


Figure 24 Typical Demodulated Staircase

The phase of the various steps is measured by adjusting the calibrated phase shifter controls to zero the display for the step being measured. By this method the phase difference between the various steps can be determined. As with differential gain measurements the black level step is the reference, consequently the distortion present is the greatest phase difference from the black level step.

4.7 Chrominance - Luminance Intermodulation (Crosstalk)

It is possible that the luminance level can be modulated by the chrominance component, particularly if the subcarrier becomes assymmetric. The effect is very similar to the rectification effects that occur when composite signals are applied to a monochrome c.r.t.

Any intermodulation is measured using the Pulse and Bar waveform, and in particular the chrominance mini-bar and pedestal. The chrominance envelope is filtered off, any intermodulation then shows up as a change in pedestal height during the period corresponding the the chrominance envelope. Figure 25 illustrates this.

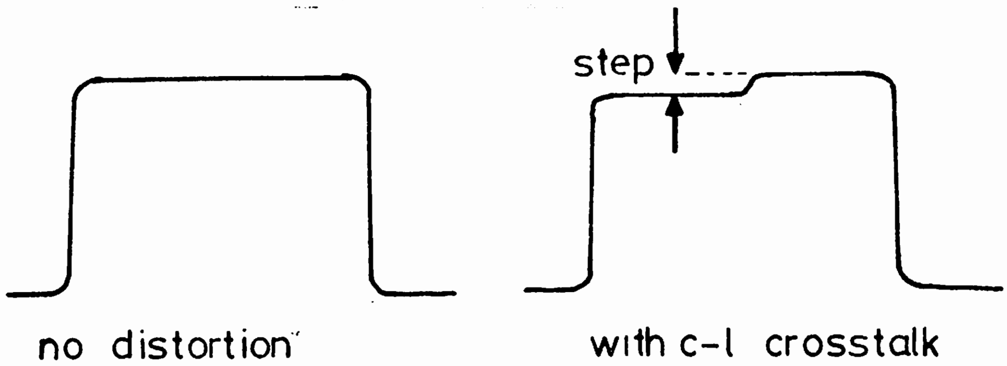


Figure 25 Effect of Chrominance - Luminance Intermodulation

Chrominance - luminance intermodulation can also be measured with the later type of gain and delay tester.

5. NOISE MEASUREMENT

For the purposes of this information sheet only the measurement of random (above line frequency) noise will be considered.

The annoyance value of any noise present depends on its peak value - the larger the peak the more visible it will be. Owing to its random nature however it is extremely difficult to measure, or even to estimate, the peak value of the noise. For this reason its R.M.S. value is measured, and the signal to noise ratio defined as:

$$\text{S/N RATIO} = 20 \lg \frac{\text{Peak Signal}}{\text{R.M.S. Noise}}$$

The R.M.S. noise voltage is determined by measuring the heating effect of the noise in a non-linear resistor (e.g. themistor), and the result displayed on a meter. There are two problems associated with noise measurement however. The first is that generally it will not be possible to measure the noise in the same way as with audio - i.e. terminate the input to the circuit and see what's left! Most video circuits will only function in the presence of syncs. Most noise meters in current use therefore work on the gating principle, usually gating out a selected line in the field blanking interval.

The second problem concerns the subjective appearance of different noise spectra. The eye is far more tolerent of h.f. noise than l.f. noise as it is far less visible. To assess the subjective annoyance more fully weighted noise measurements are made. A filter with a characteristic like that of figure 26 is inserted, such that equally measured signal to noise ratios have equal subjective annoyance values irrespective of their spectra.

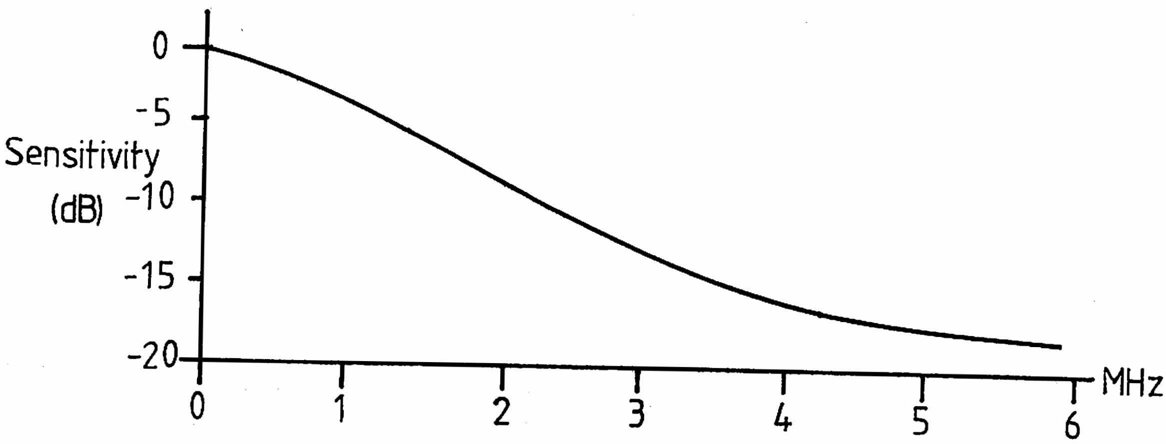


Figure 26 Filter Characteristic for the Measurement of Luminance Weighted Noise

The only exception to this is that a large amount of h.f. noise can produce very annoying results with colour television systems. Noise occurring around the subcarrier region will be demodulated to the chrominance base band, and will consequently be displayed with a coarser grain pattern having a coloured appearance. To check this a separate measurement of chrominance weighted noise, specifically centred on the subcarrier frequency, is made.

S/N ratio in dB

$= 20 \lg \frac{\text{Peak Sig}}{\text{rms noise}}$

M.B. Tancock/MG/INTROTEL

20th October 1982