NON-LINEARITY IN A VIDEO SIGNAL PATH

This information sheet revises the waveforms and test apparatus used to assess non-linearity. The evolution of the standard series of tests is described, to show that accuracy and repeatability are largely independent of the observer and his test equipment.

1. THE EFFECT OF NON-LINEAR DISTORTIONS

Non-linear distortion occurs when some parameter, e.g. Gain or Delay, of a video system varies with the instantaneous amplitude of a video signal.

It is useful to think of the composite colour signal as two entirely separate signals, luminance and chrominance, travelling down a common transmission path:

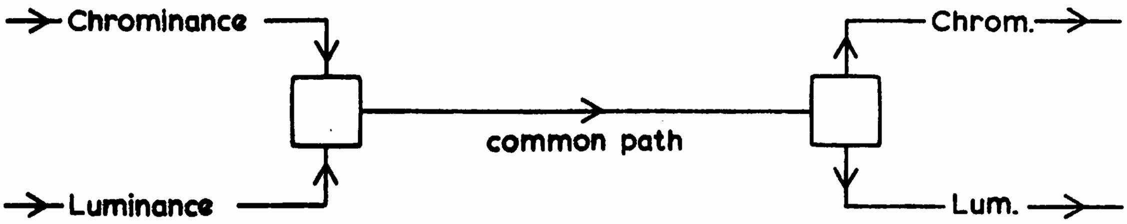

Figure 1: Luminance and Chrominance signals

In a colour picture a change in instantaneous amplitude can be caused by variation of either the Luminance or Chrominance signal (or both together).

Take the example of a continuously varying small signal (e.g. Luminance or Chrominance detail) which is superimposed on a relatively large amplitude signal. Any change in the instantaneous amplitude of the large signal could well result in a change in the way the small signal is treated by a video circuit.

Table 1 analyses the effects which could arise from different large signal variations.

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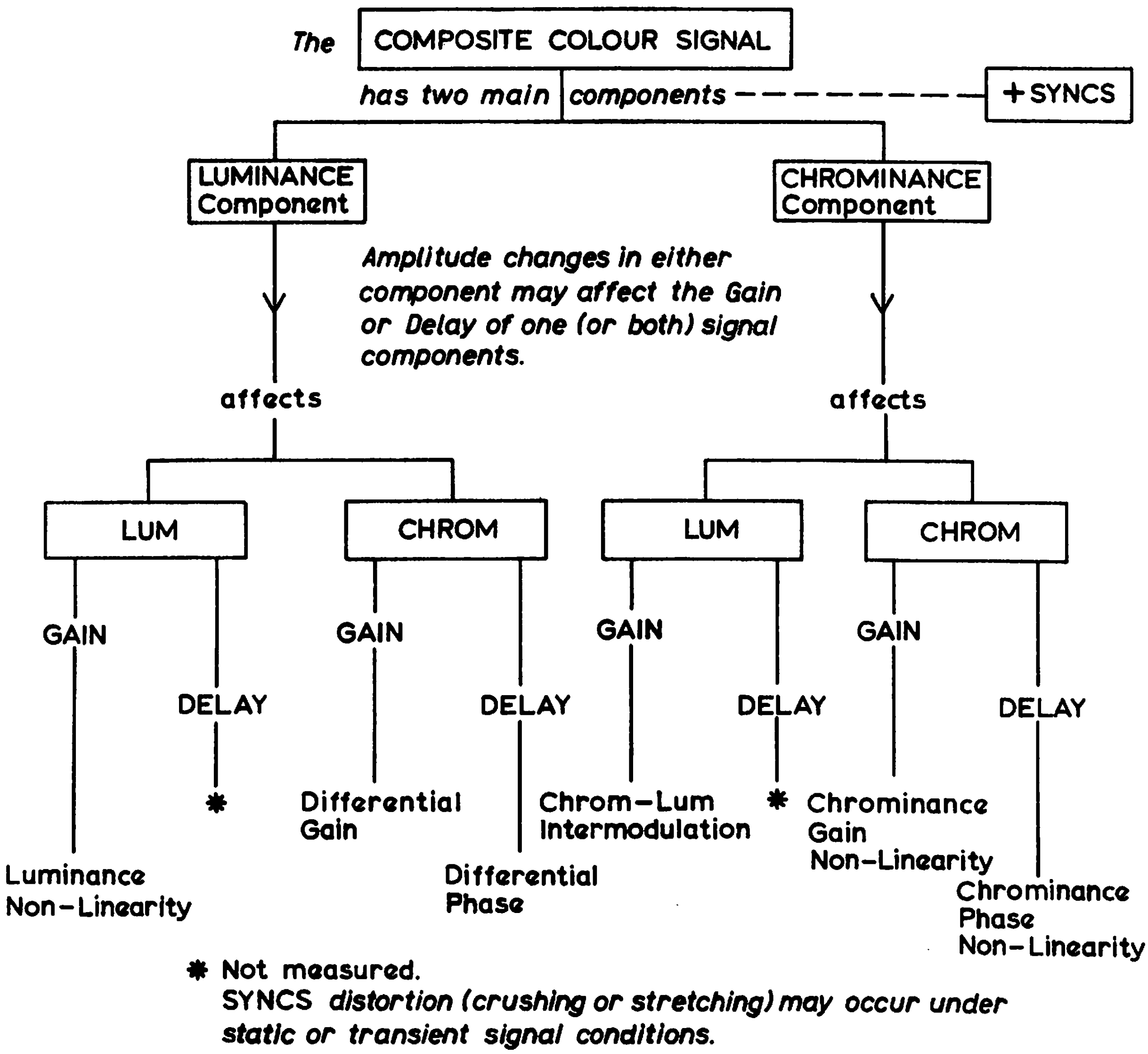
TABLE 1



Note that most colour signals are of low saturation (look at a vectorscope display during a typical programme) and so the most significant changes in instantaneous amplitude are due to the Luminance component.

The common non-linearity tests therefore assess the result of Luminance level changes on the signal in:

the Luminance channel,

the Chrominance channel.

Gain variation in the luminance channel with signal level causes 'crushing' or 'stretching' of the brightness signal at particular luminance levels.

Gain variation in the chrominance channel causes changes in scene saturation from the original, at particular luminance levels.

Typical delay variations caused by luminance level changes are of the order of a few nano-seconds. This has little effect on the luminance channel, where the smallest picture element is 100ns wide. However, in the chrominance channel, 1ns of delay represents a phase change of 1.5° at Colour subcarrier (C.S.C.).

To summarise the non-linear distortions caused by luminance level changes:-

1. Luminance Non-linearity (gain variations in the LUM channel) called L.T.N.L. on older forms. Line-Time Non-Linearity.
2. Differential Gain (gain variations in the CHROM channel)
3. Differential Phase (delay variations in the CHROM channel)

Note, that Chrominance-Luminance Intermodulation, (often called Chrominance-Luminance X-talk, Chrominance Axis Shift, or Subcarrier Rectification, which are now obsolete terms) is measured on the Chrominance Minibar of the P & B waveform, even though it is a non-linear distortion.

These four are the main non-linear distortions measured.

On long circuits and links, sync distortion is important. It is possible for the syncs to be severely crushed without causing unacceptable distortions to the picture signal. A comparison of picture sync ratios is normally made.

2. MEASUREMENT OF NON-LINEAR CIRCUITS

For testing devices designed to introduce a planned amount of non-linearity, e.g. a gamma corrector, there are two basic methods:-

2.1 Differential 'Scope and Special Graticule

The signals before and after the device under test are taken to the two Y inputs of the 'scope and subtracted.

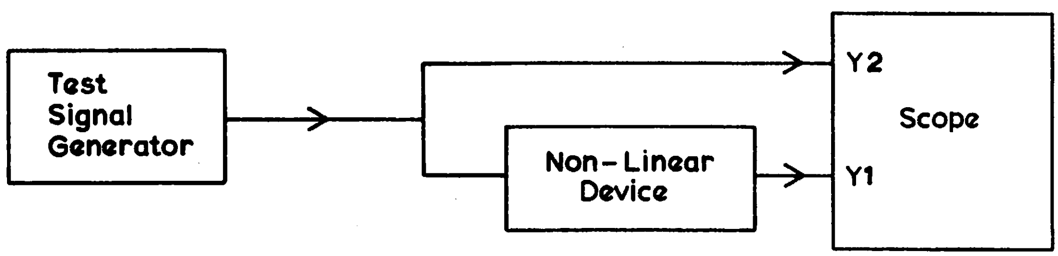


Figure 2: Comparison of signals using a differential 'scope

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The difference between the two signals is the non-linearity produced and the stage is aligned to make the curve fit the specially designed graticule markings using the correct scope Y sensitivity, figure 3.

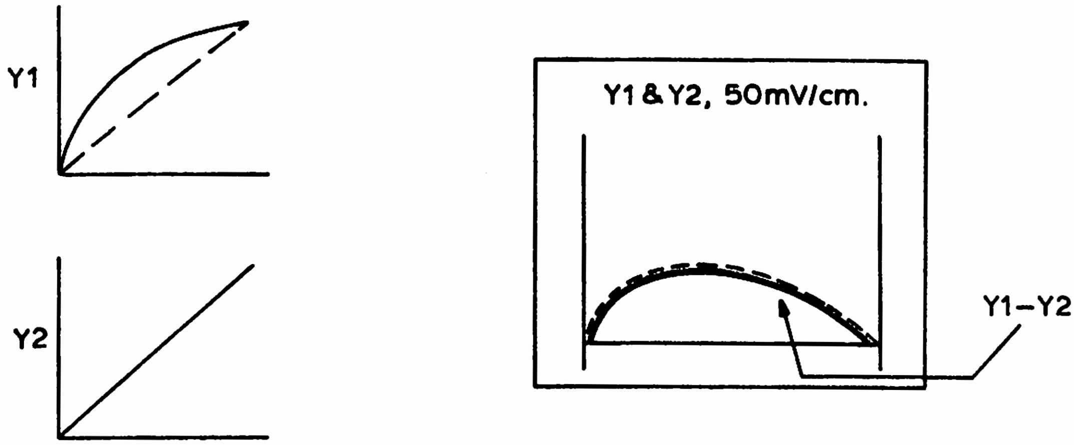


Figure 3: Gamma alignment using diff scope and graticule

This method was used in cameras when gamma stages were less stable than the present designs, and required frequenct line-up.

2.2 Pre-distorted Test Waveform

A pre-distorted test waveform, with the opposite sense of distortion to the gamma stage, is connected to the input. The output from the corrected aligned gamma corrector will have a linear amplitude/time relationship, figure 4.

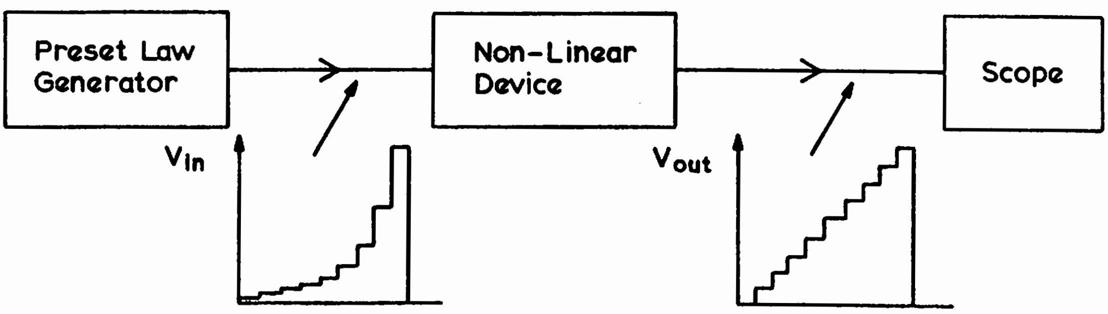


Figure 4: Pre-distorted Test Signal

Method 2.1 is shown using a sawtooth waveform because it is easy to generate and use.

Method 2.2 is shown with a staircase because it is much easier to generate this to an accurate law, than to generate a correctly bent sawtooth.

When considering tests on a video circuit, (or a VTR) the input and output waveforms are not usually available for comparison.

A method of testing using only the distorted (output) signal must be adopted, and is derived from the staircase method of 2.2.

3. NON-LINEARITY TEST WAVEFORMS

3.1 Basic 5-riser staircase

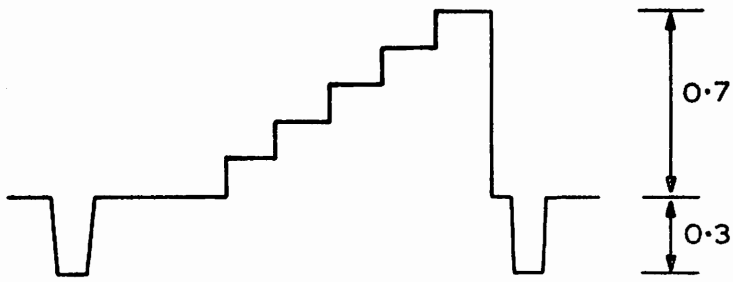


Figure 5.1: Five riser staircase waveform

The 5-riser staircase provides six different luminance levels from black to white, and five equal risers. The relative heights of the five risers at the output of a system, give a measure of the luminance non-linearity.

3.2 Staircase + subcarrier

For chrominance measurements, a burst and a 140 mV subcarrier envelope are added to the staircase. This subcarrier is carried through the circuit under test at six different luminance levels, and any changes in gain and delay with level can be detected at the system output.

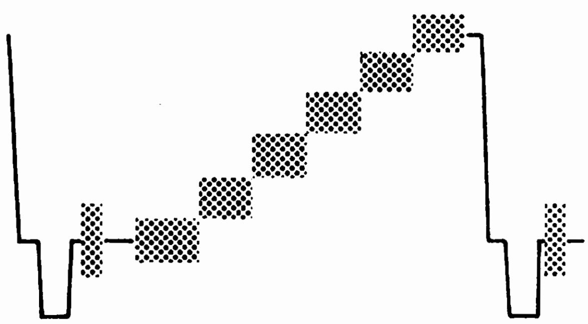


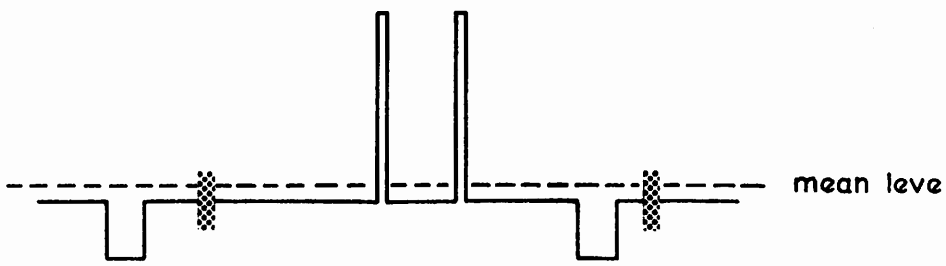
Figure 5.2: Staircase + subcarrier

3.3 The Effect of Mean Level Variations

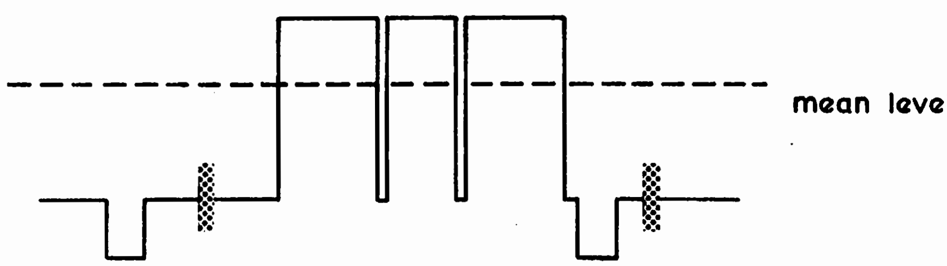
With a staircase on each active line of the 625-line picture period, the mean level of the signal is 200mV above blanking, about the same as an 'average picture'.

However, there are two possible extremes of the transmitted picture which give rise to two extreme of mean level.

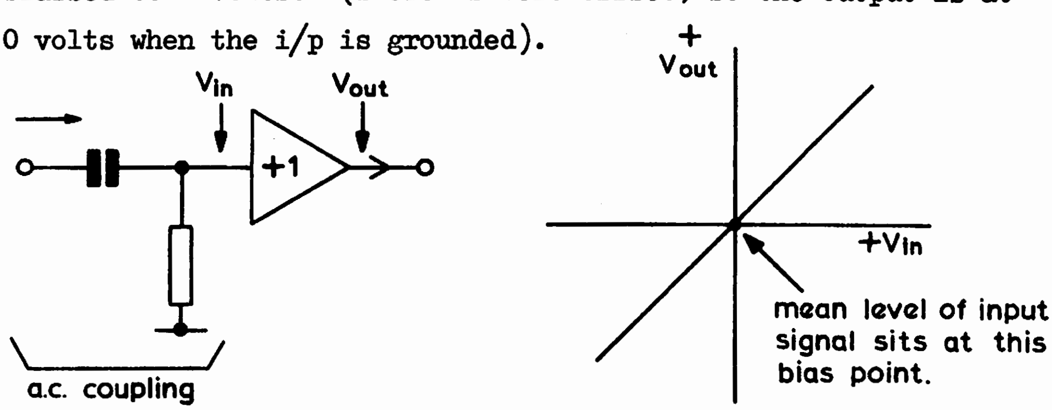
3.3.1 Mostly black picture with a few white areas having a mean level near black level. A typical scene would be white letters on a black background, i.e. a caption card or slide.



3.3.2 Mostly white picture with a few black areas, having a mean level nearer white level, e.g. a black kitten against the 'Blue Peter' cyclorama!



Now take a unity gain amplifier, as an example, whose input is biassed to 0 volts. (There is zero offset, so the output is at 0 volts when the i/p is grounded).



Video signals are applied to the input via a capacitor so that the signal mean level sits on this 0 volts.

Any signal excursion above mean level is applied to the positive part of the amplifier transfer characteristic, and vice versa.

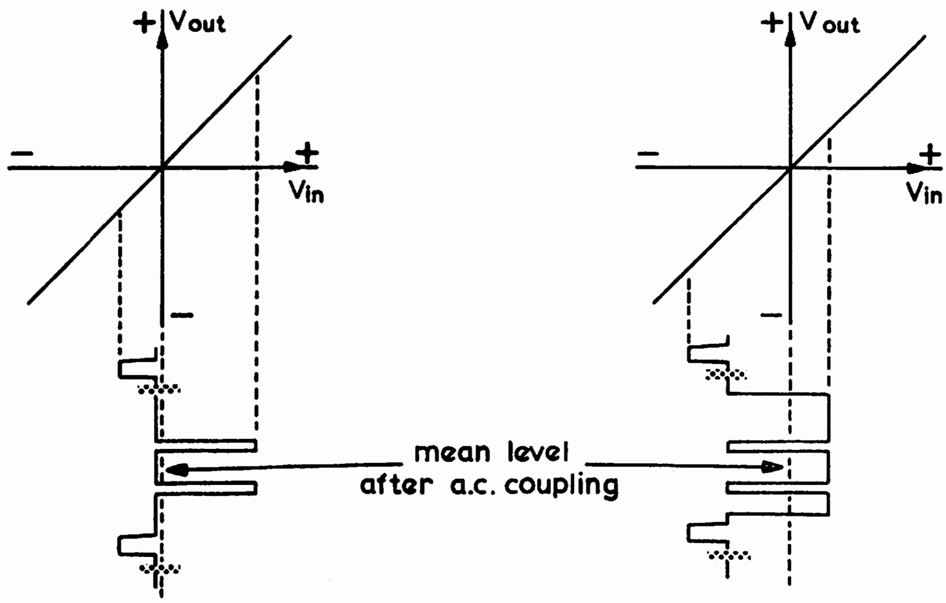


Fig. 6 Fig. 7

Figure 6 shows the part of the amplifier characteristic occupied by the mainly black picture, and figure 7 shows where the mainly white scene is placed on the characteristic. For a normal 1 volt of video the amplifier output must be linear over a range of 1.4 volts in order to handle the most positive excursion of figure 6 and the most negative excursion of figure 7 as programme content varies.

3.4 Black and White Staircase Waveforms

Since the mean level of programme material will vary between these extremes, a test signal of fixed mean level is not sufficient. Instead, a test signal is generated to test near each extreme.

The 'Black Staircase' is a repetitive waveform consisting of 1 line of staircase followed by 3 lines of black level. Its mean level is 40mV above blanking level. Figure 8.

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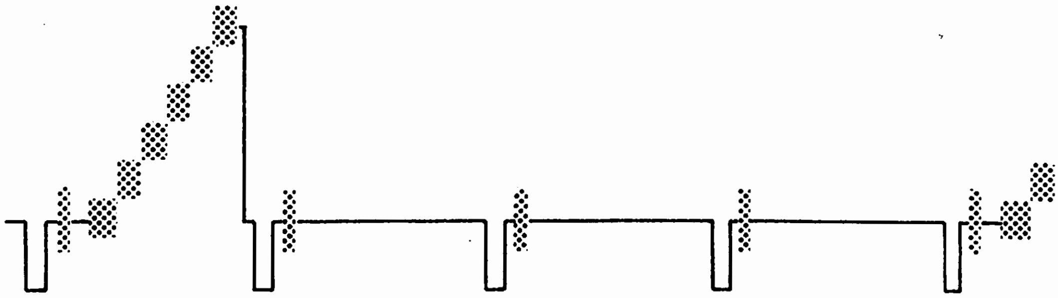

Figure 8: Black Staircase

The white staircase is 1 line of staircase followed by 3 lines of white level, figure 9, and has a level 440mV above balnking.

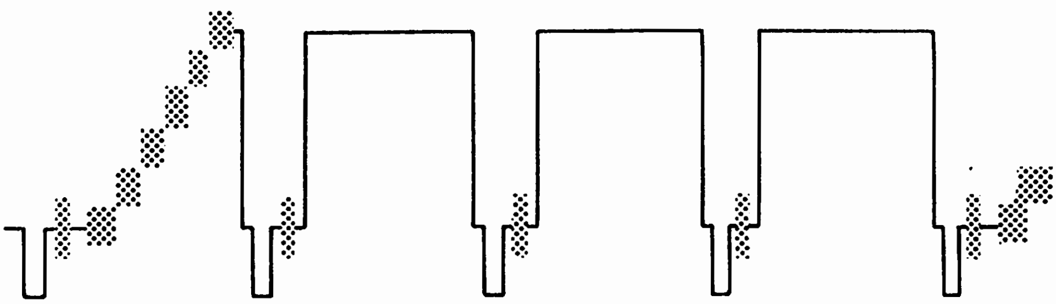

Figure 9: White Staircase

These are often referred to as the CCIR waveforms.

Each of the following test is performed for both black and white staircase waveforms, giving two readings for each test.

Each test may then be repeated at +3dB sending level from the Test Signal Generator. This indicated how the device or circuit performs under overload conditions.

4. MEASUREMENT OF LUMINANCE CHANNEL NON-LINEARITY

The height of the staircase risers gives a measure of the lum. gain at each luminance level.

If the distorted signal were coupled directly to the scope, and the height of each step measured, any non-linearity of the scope Y amplifier would also be included. It would be possible for a perfect signal to appear distorted, when the only distortion was being introduced by the scope itself.

The standard test procedure uses a differentiating filter to produce a series of 'spikes' from the transitions in the waveform. See figure 10. Each spike is positioned on the same part of the scope Y amplifier transfer characteristic. Therefore, Y amplifier non-linearity has minimum effect on the test result.

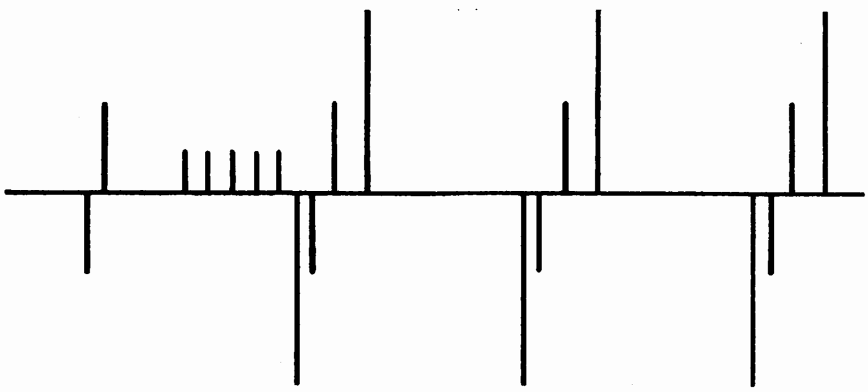

Figure 10: Differentiating the staircase waveform

The five pulses corresponding to the staircase risers are measured. The Lum non-linearity is expressed as the difference between the largest and the smallest, as a percentage of the largest, figure 11.

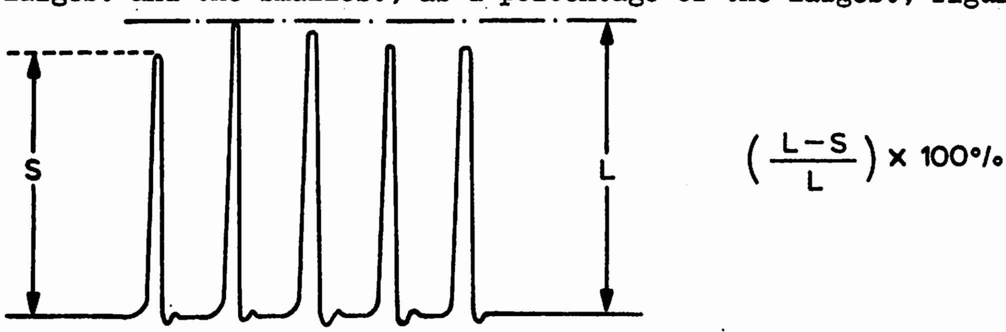

Figure 11: Calculation of Luminance non-linearity

The normal test waveform is 'staircase with added subcarrier'. This test can still be performed since the differentiating filter also contains a subcarrier rejection filter.

However the presence of severe Chrom-Lum Intermodulation may upset the result, despite these precautions, in which case this test should be performed with the CSC turned off at the generator.

5. MEASUREMENT OF CHROMINANCE CHANNEL DISTORTIONS DUE TO LUMIANCE

Gain variation in the chrominance channel is called DIFFERENTIAL GAIN.

Delay variation in the chrominance channel is called DIFFERENTIAL PHASE.

5.1 Diff. Gain

The gain variations at 4.43 with signal level, may be unrelated to the luminance channel non-linearity measurement result.

Before measuring the diff. gain distortion, all other frequencies are filtered out, using a 4.43 MHz band-pass filter. The subcarrier envelope in this displayed over the same part of the scope Y amp characteristic, (c/f section 4).

The standard measurement takes the black level step as reference and quotes the % "worst case" error between the black level step, and any other, figure 12.

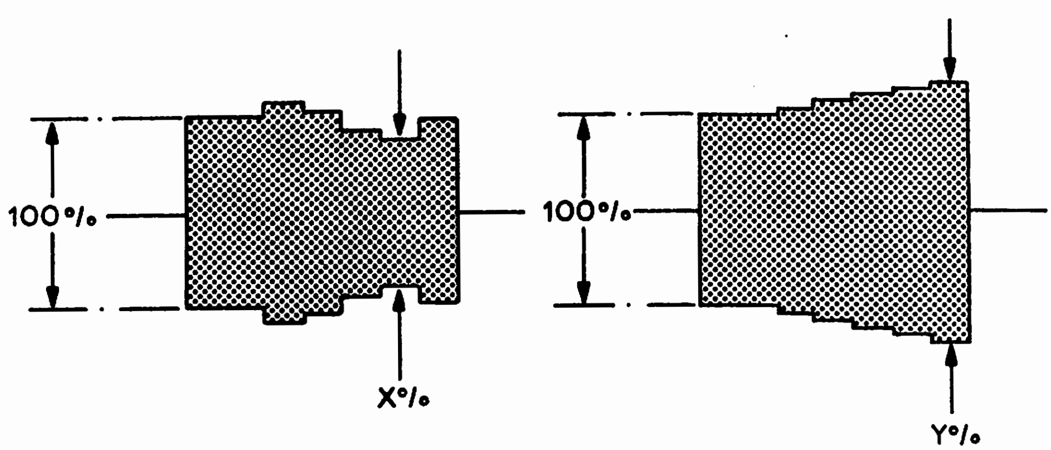

Figure 12: Two typical diff. gain displays

Diff. gain in figure 12.1 is (x - 100%), a -ve quantity.
Diff. gain in figure 12.2 is (y - 100%), a +ve quantity.

Achroma bandpass filter for removing the staircase is contained in the Remote Signal Analyser, but the main purpose of this equipment is to measure Diff. Phase.

5.2 Diff. Phase Measurement

The heart of the diff. phase measurement is a comparison between the phase of two feeds of subcarrier at 4.43 MHz.

1. The reference subcarrier is the output of a burst-locked oscillator, locked to the mean phase of the burst.

2. The measurement subcarrier is the output of the chroma filter i.e. subcarrier filtered from the distorted 'staircase + subcarrier' waveform. The changing luminance level of the staircase may have caused a phase change on each step.

A perfect signal has the same phase difference between separated chroma and reference csc on each step.

The phase comparison is performed in a balanced demodulator. Since the inputs are two signals at 4.43 MHz, the output is a 'd.c.' level proportional to the phase difference between the signals, (difference frequency) and an 8.86 MHz component, (sum frequency) which is filtered out.

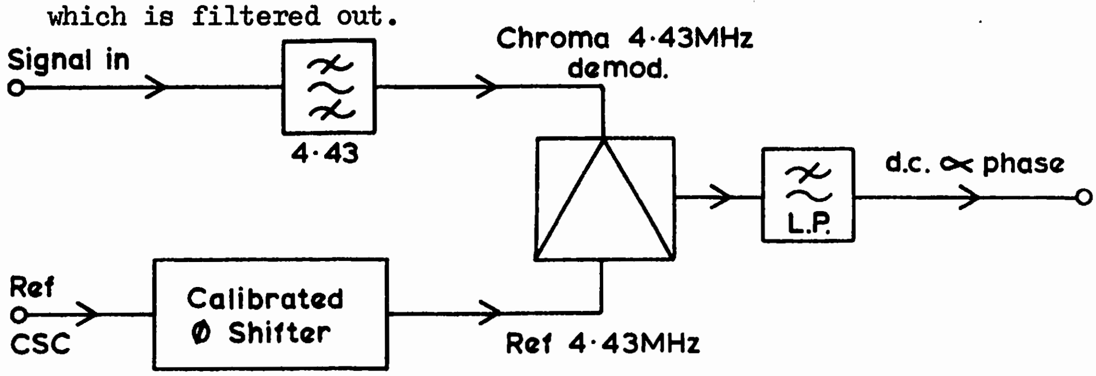

Figure 13: Simplified diagram of the phase detector

The demodulator is arranged to work as a 'null' detector, producing zero d.c. output when its inputs are at 90° (or 270°). Using a calibrated phase shifter in the reference path, the phase of the reference, at the demodulator, is adjusted to be 90° to the phase of the subcarrier on the black level step, i.e. zero volts output. A display such as figure 14 might be seen as this adjustment is being done.

The phase shift controls are used to 'null' the most positive step and then the most negative step.

The diff. phase error is the greatest change made to the phase shift

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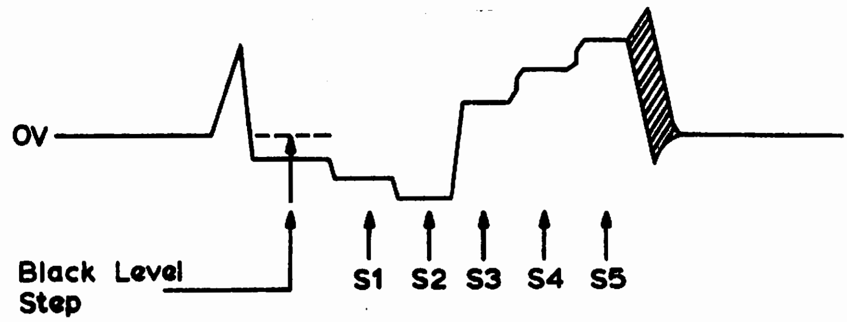


Figure 14: Typical diff. phase measurement display

controls, away from the black level setting, to zero any step. The sign of the phase change, + or -, is noted.

6. REMOTE SIGNAL ANALYSER

The main function of the Remote Signal Analyser is to provide outputs for diff. gain and phase measurements.

The phase detector can be put to a number of other uses, and its reference subcarrier can be supplied from station CSC for greater accuracy, since the BLO has 0.5° jitter when locked to a PAL burst.

It can be used to compare the phase at the input and output of a device, for jigging time delay in, say, D.A's; or for measuring the± relative phases of two sources to assist accurate cable cutting, (1° = 4.5" in PSF 1/2 or 1/3); or measuring the jitter on bust-locked oscillators, etc.

6.1 Description

The EP1/508 has 5 main units, and a PSU

The distorted waveform is looped to a UN1/540 sync separator, where syncs are stripped and a burst gate pulse derived. The buffered signal and the B.G. pass to an OS2/502 B.L.O. whose output is a reference burst-locked subcarrier.

The UN1/576 Processor unit applies enable waveforms to switches in both the reference and measurement signal paths.

In BUST mode, only signals at burst time are gated through. In CHROMA mode, the gates are enabled by the detection of the presence of subcarrier occurring in active line time.

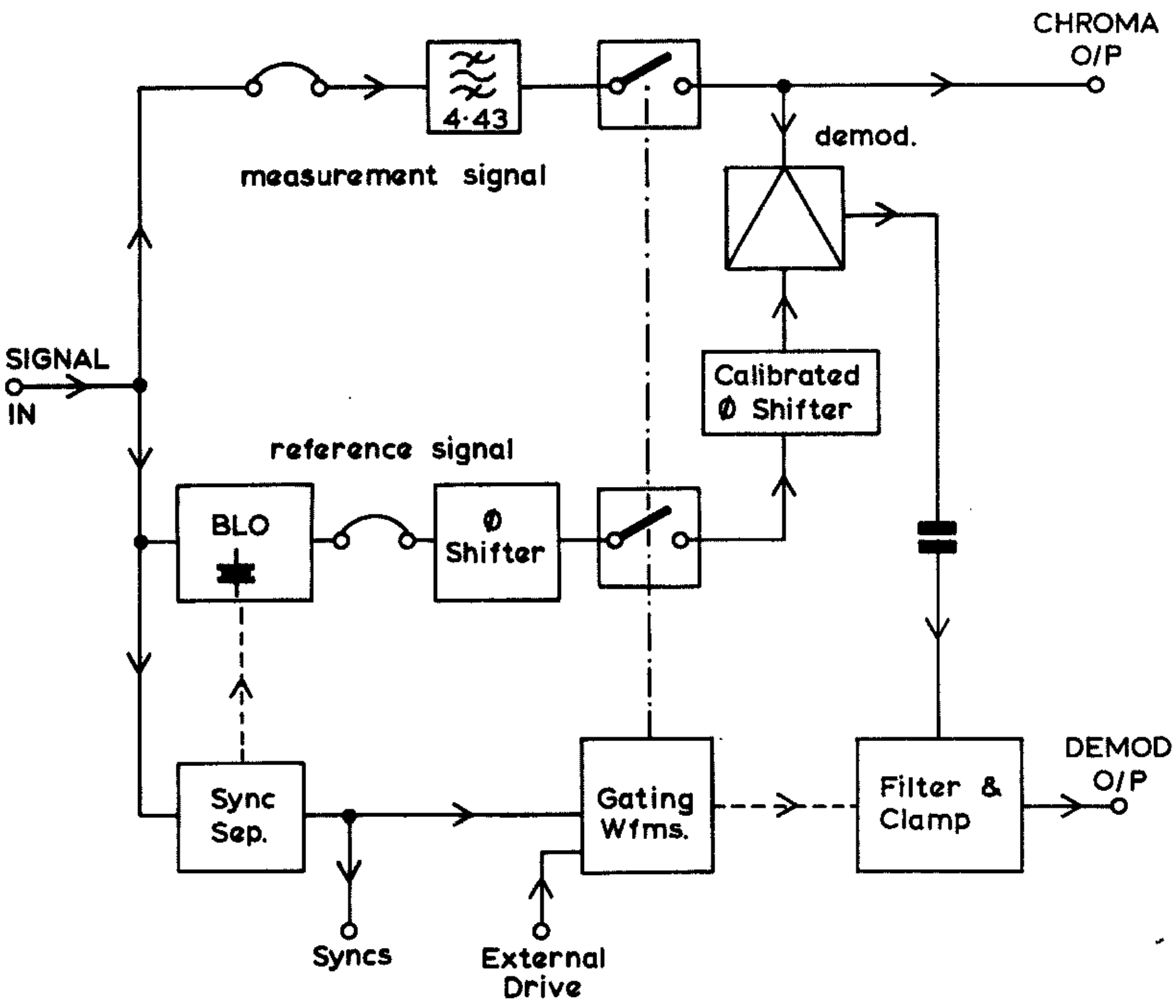
External gate drive can be used for other applications.

The balanced demodulator (in the UN1/541 colour signal analyser) has no signal inputs when the gates in the Processor unit are off, and its output corresponds to zero phase difference. This is a.c. coupled (to remove d.c. offsets) and clamped to 0 volts. The scope is d.c. coupled to the clamped output to give an easily read display.

The fifth unit derives a pulse on a selected line in the field blanking period. This can be used both as a scope trigger and as external drive to the Processor unit gates for I.T.S. measurements.

6.2 Block diagram of the Remote Signal Analyser

(Can also be used for Cable Length Cutting) 45°/1°



P.J. Harris/SJW
1st May 1981

SIGNAL LEVEL MEASURE-MENT

Scope Accuracy ± 5% At best. Reading + Y CAL.

– improve Y CAL. – internal CAL.? 1% But doesn't include termination (75Ω) <1% Tol.

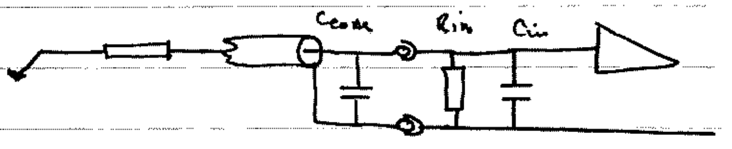
In a large station – spreads between scopes.

use ext Cal. – 1 volt source. ⊓⊓⊓ – Cal all scopes. to same spec. (Cal source Accurate to ±0.08db or .5%)

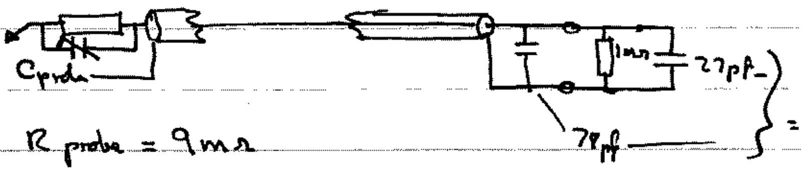
0.1 db or 1%

×10 PROBE.

Aim is to reduce sensitivity & reduce input Capacitance.



V input to scope Amp $E_{LF} \dfrac{\times R_{in}}{R_{probe} + R_{in}}$

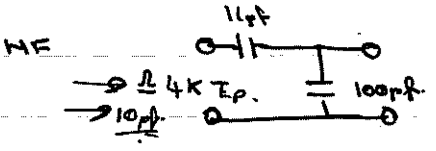


R probe = 9MΩ

} = 100pf ±.

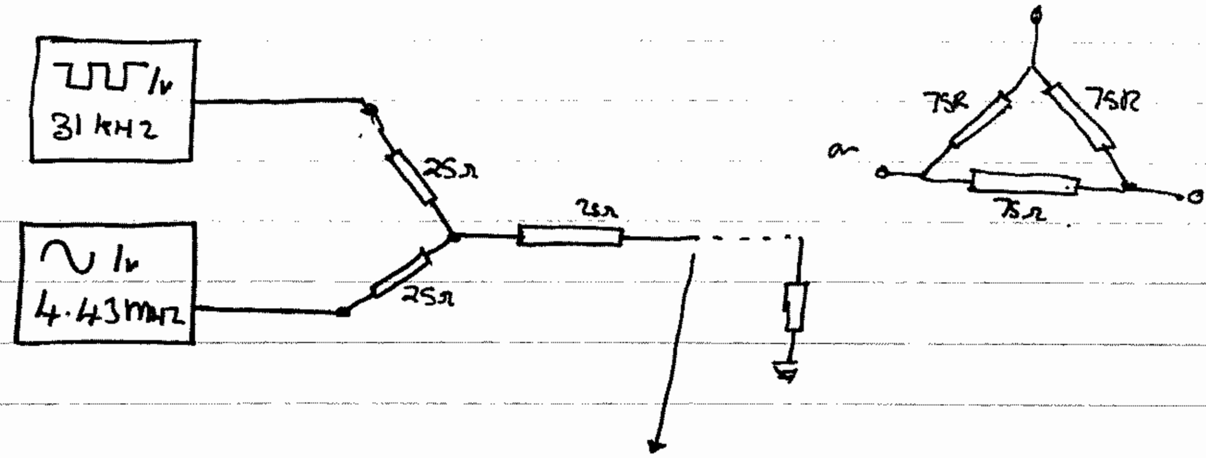
Therefore C_{probe} = 11pf ± or $\frac{1}{9}$.

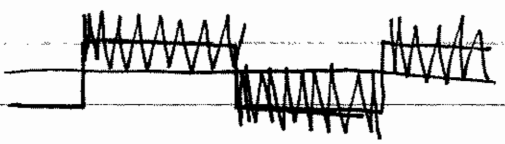
V input At HF $E_{HF} = \dfrac{X C_{in}}{XC_{probe} + X_{cin}}$



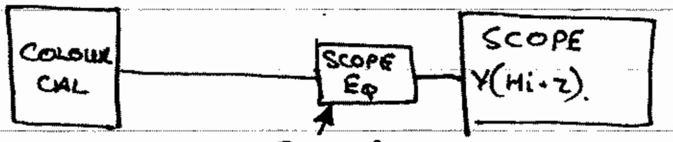
check probe eq before using line up field blanking to line blanking level. (ie Compare LF & HF responses).

Colour Calibrator.



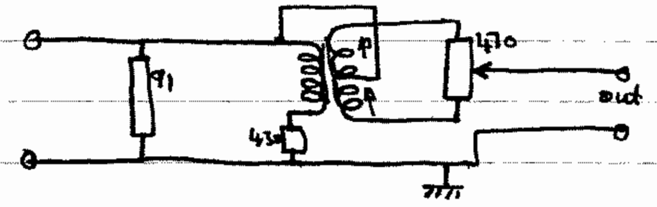


SCOPE Eq.



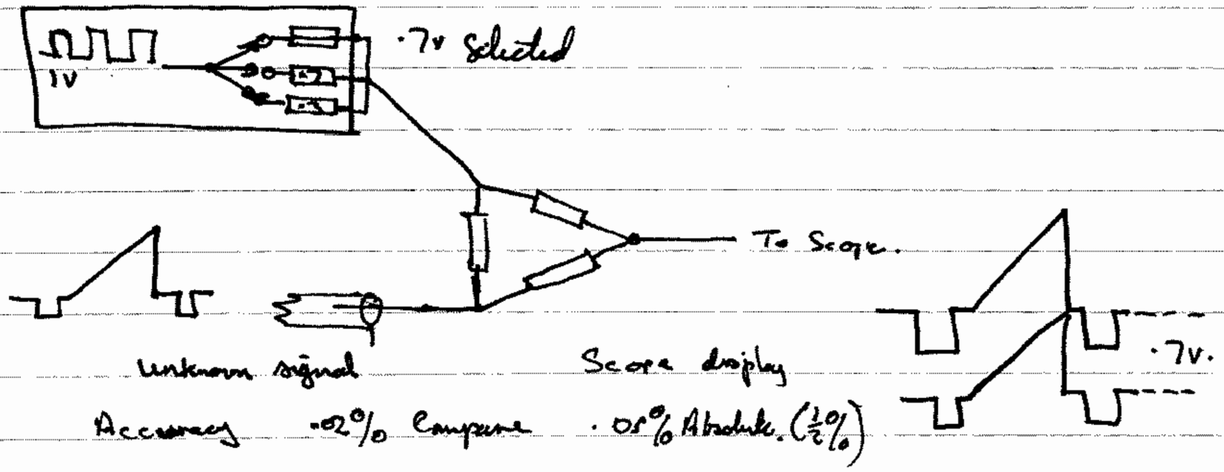
Provides 75Ω Term

Scope Eq Transformer Action only above 3MHz



Coax Chroma Loss 0.1 db/10ft.

Amplitude measurement



Accuracy .02% Compare .05% Absolute. (1/2%)