NON-LINEAR DISTORTION MEASUREMENT

INTRODUCTION

If any parameter, eg 'Gain' or 'Delay', of a video system changes with the instantaneous amplitude of the video signal, a non-linear distortion is taking place.

It is convenient to think of the luminance and chrominance components of a composite video signal, as separate signals occupying a common transmission path. Normal pictures contain mostly low-saturation colours, i.e. the chrominance amplitude is relatively small, and so non-linearity measurements are concerned with how changes in Luminance level affect the gain and delay of signals in:-

the luminance channel,
the chrominance channel.

Gain changes in the luminance channel will cause 'crushing' or 'stretching' of the brightness signal.
Gain changes in the chrominance channel will cause variation in saturation.
The practical figures for delay changes, in either channel, due to luminance level variations are of the order of nanoseconds. This has relatively little effect on the luminance signal, (smallest picture element is 100ns), but will cause a significant effect on the phase of colour subcarrier signals (1 nanosecond = 1.5 degrees).
Thus, we will take one measurement for the luminance channel, and two for the chrominance channel.

1. OBJECTIVES.

This experiement is intended to be an introduction to the measurement of non-linear distortion and the test wave forms used.
The equipment required is:-

GE4M/520 Test Signal Generator,
FL1/509B Filter for luminance channel non-linearity,
EP1L/508 Remote Signal Analyser, for chrominance non-linearity,
Dual trace osilloscope, + 2 x EQ1/520 oscilloscope equalisers,
UN1/503 Colour calibrator, shared with Pulse and Bar bench,
Non linear Amplifier, AM5/505A.

NON-LINEAR DISTORTION MEASUREMENT

2. OSCILLOSCOPE CALIBRATION

To check the Test Signal Generator output, it is necessary to first calibrate the oscilloscope response at low and high frequencies. Connect the UN1/503 Colour Calibrator via the 3dB attenuator (giving 0.7 volt output) to the Y_1 input. The oscilloscope equaliser should be connected in circuit at the oscilloscope input socket.
Calibrate the low frequency sensitivity of the oscilloscope, for say 5 divisions = 0.7 volt, using the 'LUM' square wabe output of the calibrator. Switch to 'LUM + CHROM', and adjust the equaliser screw-head preset for the correct display, shown below.

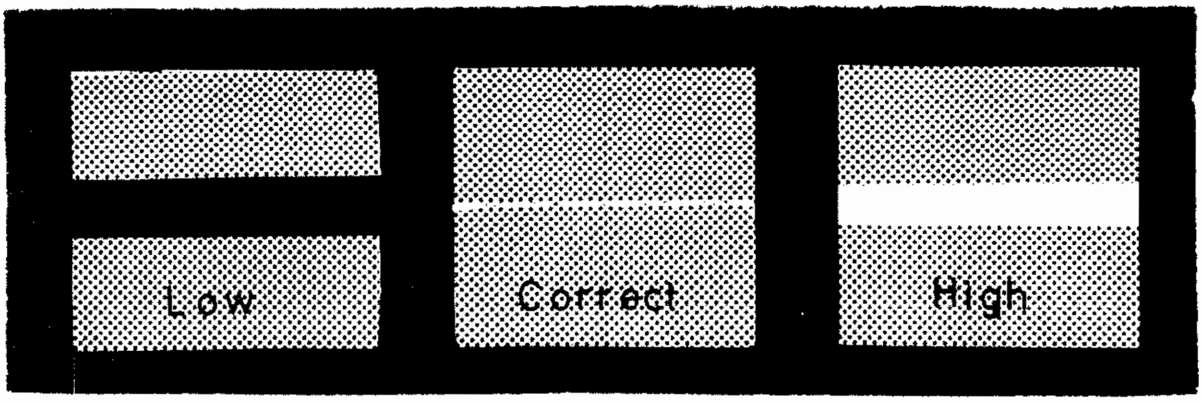


Figure 1: Oscilloscope equaliser calibration displays

3. TEST SIGNAL GENERATOR CHECK (GE4M/520)

Ensure that the 'NORMAL/+3dB' switch is at 'NORMAL'.

Select	TRIGGER MODE	TO	'FREE'	
	TEST W/F	TO	'STEP'	
	BAR		'OFF'	(up)
	AUTO		'OFF'	(up)
	PED		'OFF'	(up)
Select	SUBCARRIER		'OFF'	
	BURST		'ON'	
	ALL LINES - CCIR		'CCIR'	

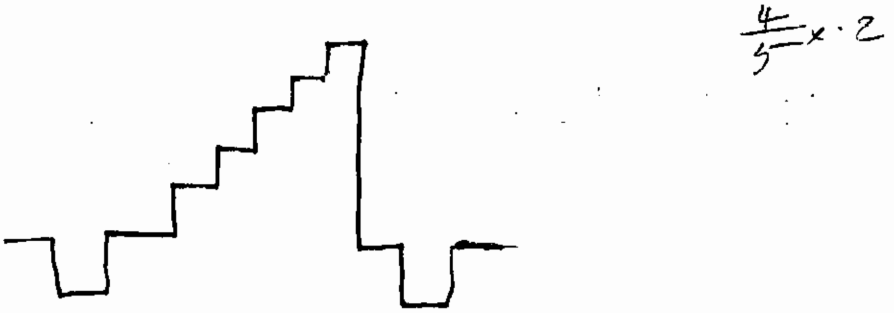
3.1 Connect the oscilloscope Y_1 channel to the output of the generator, and check that:-

staircase amplitude = 0.7 volt,

sync amplitude = 0.3 volt.

Do not adjust the presets unnecessarily as they tend to wear out.

Sketch the staircase waveform in the space below.



Step amplitude = ..160.......mV

Figure 2: Luminance staricase

3.2 Switch SUBCARRIER to 'INT', when the waveform shown below should be obtained.

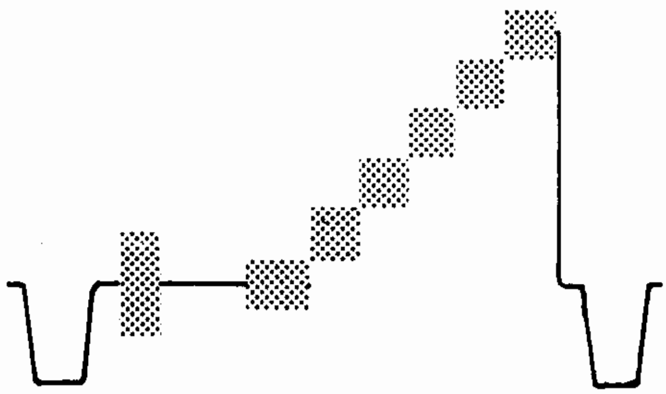


Figure 3: Staircase with added subcarrier

Measure the subcarrier amplitude on each step = .160.......mV.

3.3 Switch TEST W/F from STEP to CCIR. (Check BAR OFF, AUTO OFF)
The generator provides a trigger source output, which should be used to trigger the oscilloscope, via 'external trigger'.
The CCIR waveform is a repeated 4-line sequence and the trigger waveform identifies the first line of each group of 4.
Set the oscilloscope to display 4 lines, and sketch the display below.

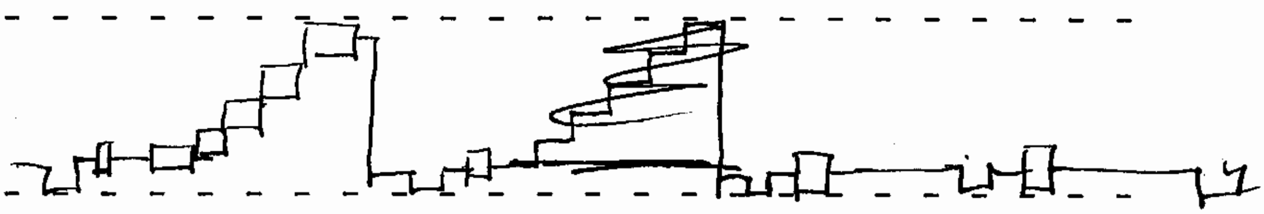


Figure 4: Black Staircase waveform

NON-LINEAR DISTORTION MEASUREMENTS

Switch BAR to 'ON', and sketch the waveform below.

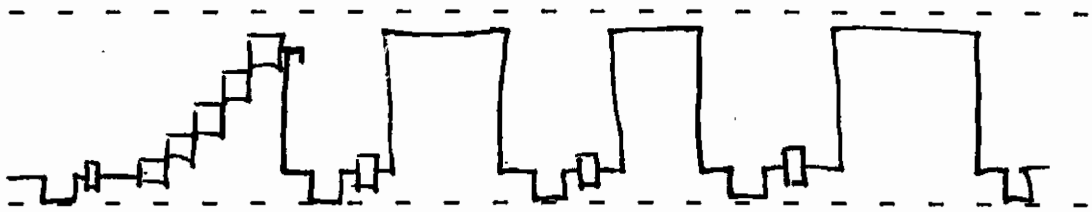


Figure 5: White Staircase waveform

3.4 Examination of the mean levels of the two CCIR waveforms

With the oscilloscope input d.c. coupled, switch the generator between bar on and bar off. Observe the effect.

Now a.c. couple the oscilloscope input and switch between bar on and bar off.

These two waveforms represent signals having high and low mean levels. Measure the difference in mean level of these two waveforms, by noting on the a.c. coupled oscilloscope display the change in voltage of back porch when the bar on/off switch is toggled.

Difference in mean level of black and white staircase waveforms = ..480....mV.

What is the mean level of each waveform? Ground the oscilloscope input, set the trace against a horizontal scale line, and measure the difference between this ground reference and blanking level of the a.c. coupled waveform.

Mean level of black staircase .....40.......mV above blanking
Mean level of white staircase ....500.......mV " "

4. NON-LINEAR DISTORTION MEASUREMENTS

This section covers the measurement techniques and tests on a distorting amplifier.

4.1 Luminance non-linearity

The height of each step of the staircase is a measure of the gain in the luminance channel at each step.

The FL1/509B filter removes the colour subcarrier and differentiaties the waveform to give a series of spikes corresponding to the height of each transition of the input waveform.

Connect the test signal to the D.A. input, and connect the outputs to the oscilloscope inputs, one of them passing through the FL1/509B.

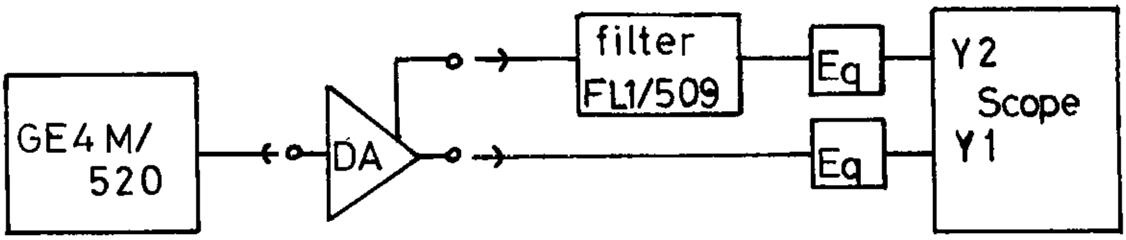


Figure 6: Connections for Luminance Non-Linearity Measurement

Sketch the part of the filtered waveform corresponding to the staircase.

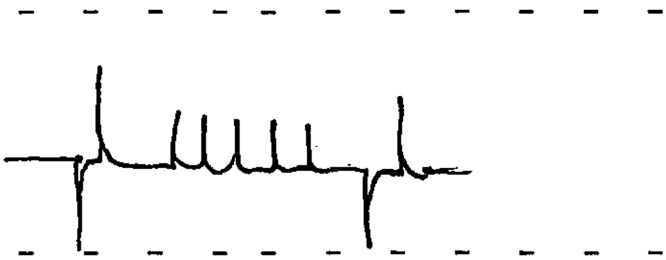


Figure 7: Filtered Staircase

NOW, connect the 'Distort Amp' between the test generator and the D.A. The relative heights of the 5 risers are affected by Luminance Non-Linearity.

The distortion is expressed as:-

$$\text{Luminance Non-Linearity} = \frac{a - b}{a} \times 100\%$$

where a is the largest spike

b is the smallest spike of the five.

Typical practice is to adjust the oscilloscope until the largest spike fills five divisions, say, equal to 100%. The difference in the spike heights can then be read off directly, as in figure 8.

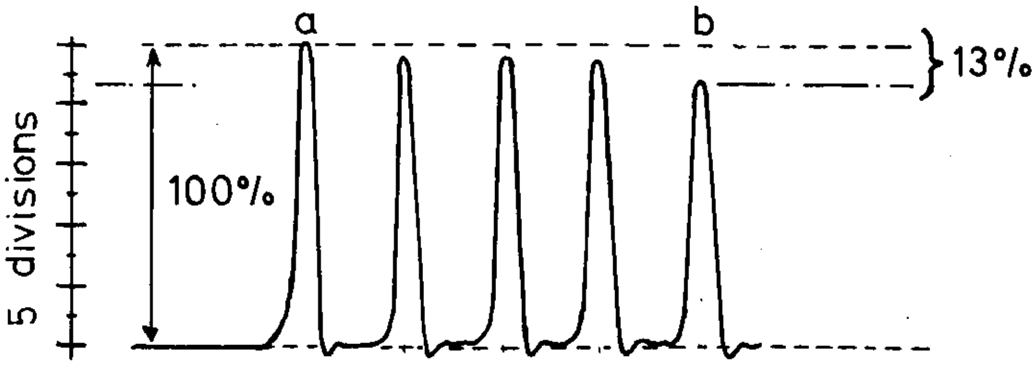


Figure 8: Measurement display for luminance non-linearity

NON-LINEAR DISTORTION MEASUREMENTS

Measurements should be made on both 'black' and 'white' staircases, first at 'NORMAL' level (0dB), then at '+ 3dB' to assess overload capability.

	0dB	+ 3dB
Black Staircase	16%	[illegible] 12%
White Staircase	18%	[illegible] 16%

4.2 Differential Gain Distortion

Measurement of the variation in chrominance amplitude, caused by a change of luminance level.
The 'staircase + subcarrier' waveform is passed through the Distortion Amplifier, (simulating a system under test).

The luminance staircase ensures that the subcarrier on each step is on a different part of the amplifier (system) transfer characteristic. However, when the signal is to be analysed for differential gain, the staircase is first filtered off, (measurement is easier and more accurate).
The 'Remote Signal Analyser' contains a 4.43 MHz band-pass filter and a gate to blank out the burst. (Proc. unit switched to CHROMA).
Its input is from the distortion amplifier (output 3).
The oscilloscope should be connected to display the distorted signal on one trace and the subcarrier only, from the 'Remote Signal Analyser' 'CHROMA OUT' socket, on the other trace. The connections are shown in figure 9.

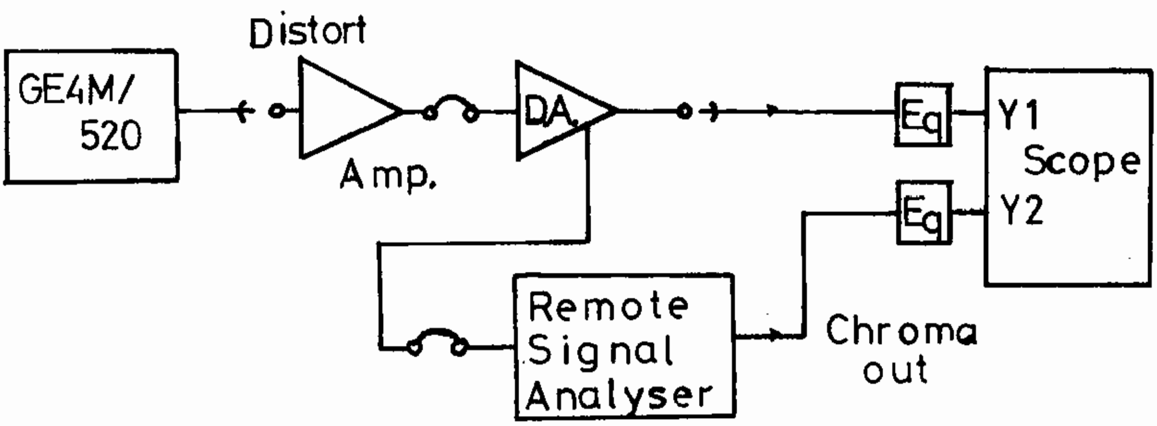


Figure 9: Connections for Differential Gain measurements

Compare the 'CHROMA OUT' waveforms with, and without, the distort amp. in circuit and sketch a distorted waveform over.

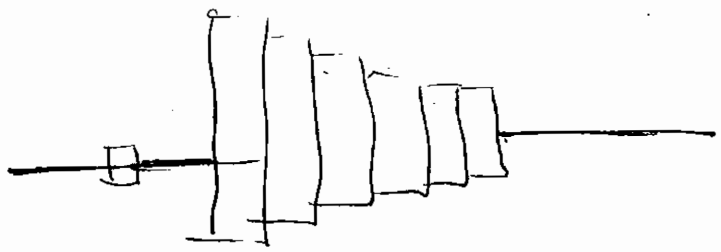


Figure 10: Sketch:- Differential gain waveform of .5 riser....... Staircase

The gain at 4.43 MHz may vary, dependent on staircase amplitude, by a positive or negative amount relative to the gain at black level.

For each waveform, only the worst case of the positive or negative gain variation and its sign are recorded.

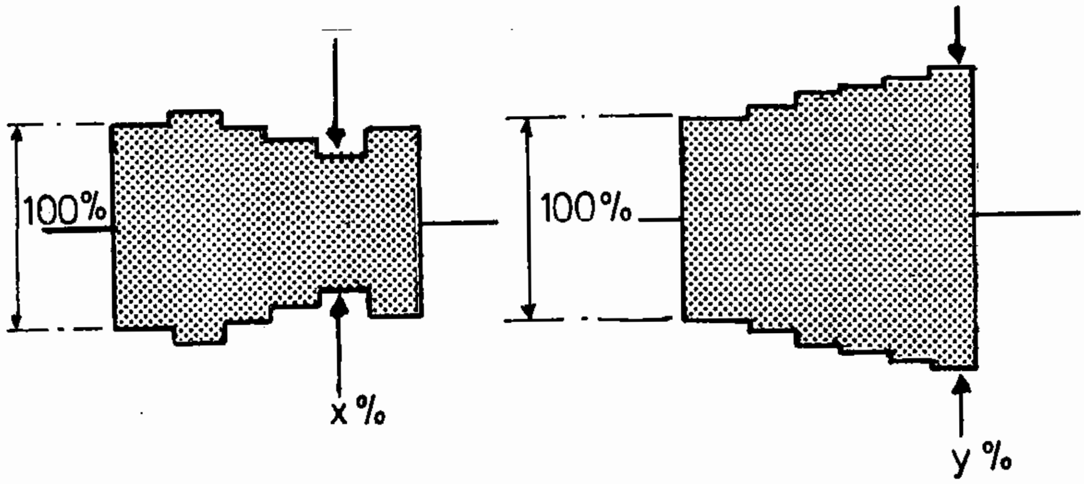


Figure 11: Two typical differential gain displays

The measurement is taken by expanding the oscilloscope display until the CSC corresponding to black level fills chosen 0 - 100% marks on the graticule. (eg 5 divisions). The worst % error, +ve or -ve, is read off directly.

In figure 11.1, the distortion would be (x - 100)%, a -ve quantity

In figure 11.2, the distortion would be (y - 100)%, a +ve quantity

Switch the generator between bar 'ON', and bar 'OFF', and note the effect produced by a change in mean level of the picture.

Measure the distortions on black and white staircases, at 0dB and at +3dB sending level.

NON-LINEAR DISTORTION MEASUREMENTS

Black Staircase	..−22....%	......−22......%	include the sign.
White Staircase	..+24....%	+..32......%	
	0dB	+3dB	

4.3 Differential Phase Distortion

The subcarrier added to the staircase has the same phase, relative to the black level step, on each step. Variation of the circuit delay with luminance amplitude will cause a phase change on one or more of the steps.

The Remote Signal Analyser contains a phase detector, which gives a null (zero) output when its inputs are 90° apart.

Its inputs are a steady subcarrier, 4.43 MHz, locked to the mean phase of the burst (at black level); and the 'Chroma' separated from its luminance staircase, (differential gain waveform).

Connect the oscilloscope to monitor at 'Demod. Out', (differential Phase).

The demodulator (phase detector) will give a null at 90° and also at 270°, between its 4.43 MHz inputs. To assess the sign of the distortion, +ve or −ve delay, the display must be set to the correct null point.

Adjust the calibrated phase shift controls to give a display similar to the drawing of figure 12. Increase the setting of the 1° control and note the result. If the display moves upwards, add or subtract 180° on the 90° phase shift control. Increase the 1° control again, when the display should move down for an increase on the 1° control.

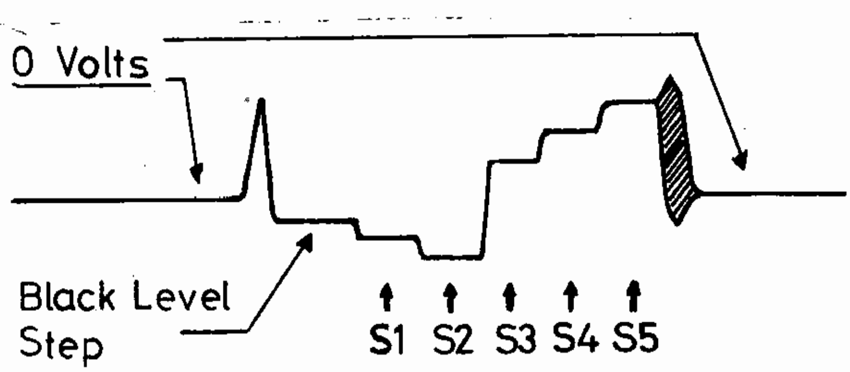


Figure 12: Typical differential phase display

To make the measurement, adjust the controls until the black level step is level with the blanking line on either side of the display. Read and record the settings over.

Next adjust the controls for the most +ve step to read zero, and finally the most -ve step, recording the results below.
Measure both black and white staircase, at 0dB and at +3dB.

NOTE. The 90° and 10° controls are not accurate to 0.1°. DO NOT ADJUST THESE BETWEEN BLACK LEVEL AND PEAK ERROR MEASUREMENTS.

3° 5°

Ø-Shifter reading	Black 0dB	Black +3dB	White 0dB	White +3dB
Black level step				
most +ve step				
most -ve step				
Larger error	3°		5°	

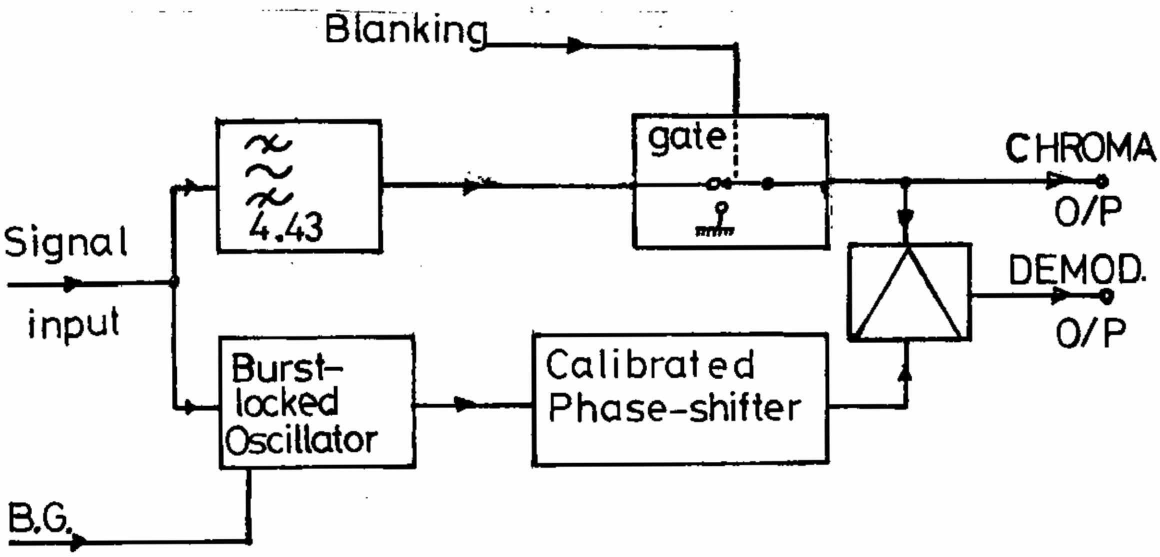


Figure 13: Block diagram of the Remote Signal Analyser

The test signal used so far has been a 'full-field', or 'line-by-line' waveform; which occupies all of the information space of the television format. It can only be used when the circuit is not carrying programme.

Interval test signals (ITS) can be added to the normal programme signals to enable measurements to be taken whilst the circuit is working for its living.

NON-LINEAR DISTORTION MEASUREMENTS

5. MEASUREMENT OF INTERVAL TEST SIGNALS.

BBC 1 and 2 carry test signals on lines 19 and 20 (332 & 333) in the field blanking period.
Connect the Off-air receiver (Rx) outlet of the wallbox directly to the D.A. input, as below.

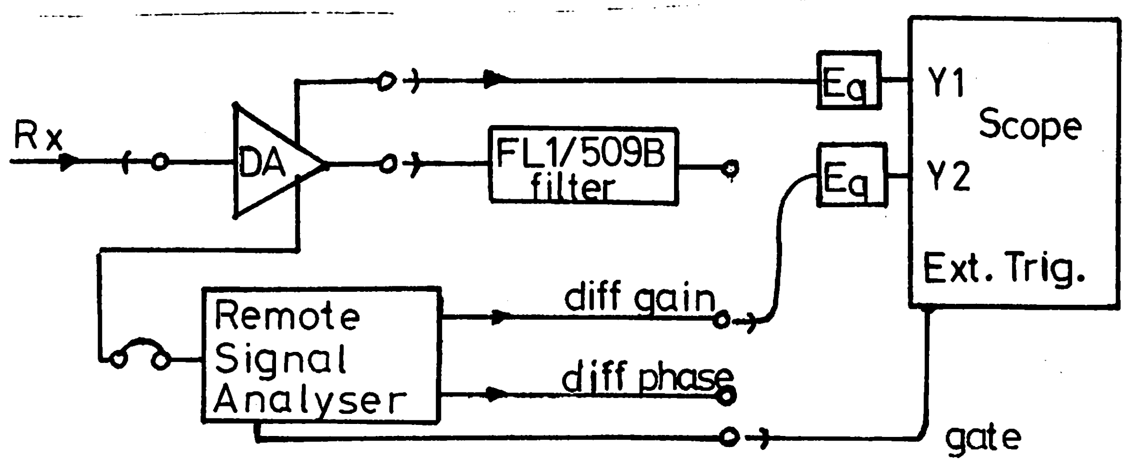
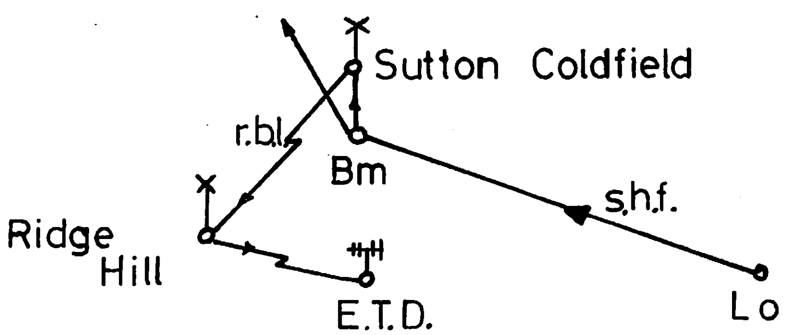


Figure 14: Connection for ITS measurements

The 'GATE' output of the Remote Signal Analyser is a +ve edge on the line selected, to be used as an oscilloscope trigger.
Measure luminance non-linearity, differential gain and differential phase for the path London - ETD.



Luminance non-linearity .....%, Differential gain .....%,
Differential phase .....°

P.J. Harris/VC
15th March 1978