BBC RD 1973/1

1969
THE QUEEN'S AWARD TO INDUSTRY

RESEARCH DEPARTMENT

REPORT

DIGITAL VIDEO: effect of PAL decoder alignment on the acceptable limits for timing jitter

V.G. Devereux, M.A.
G.C. Wilkinson

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION February 1973 (EL-74)

BBC RD 1973/1
UDC 621.376.56
621.397

DIGITAL VIDEO: EFFECT OF PAL DECODER ALIGNMENT ON THE ACCEPTABLE LIMITS FOR TIMING JITTER

V.G. Devereux, M.A.
G.C. Wilkinson

Summary

Tests have been performed to investigate the effect of alignment errors in PAL decoders on the acceptable limits for timing jitter in the decoded samples from a pulse modulation (p.c.m.) system carrying 625-line PAL colour television signals. It is shown that certain alignment errors in the PAL decoder such as incorrect adjustment of the static phase of the reference subcarrier, can considerably increase the impairment caused by timing jitter. Limits have been obtained for the amount of timing jitter which can be tolerated in a broadcast-quality television system allowing for a tolerance of ±15° on the static phase adjustment.

Issued under the authority of

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

(EL-74)

DIGITAL VIDEO: EFFECT OF PAL DECODER ALIGNMENT ON THE ACCEPTABLE LIMITS FOR TIMING JITTER

(EL-74)

February 1973

BBC RD 1973/1
UDC 621.376.56
621.397

DIGITAL VIDEO: EFFECT OF PAL DECODER ALIGNMENT ON THE ACCEPTABLE LIMITS FOR TIMING JITTER

V.G. Devereux, M.A.
G.C. Wilkinson

1. Introduction

In most pulse code modulation (p.c.m.) systems, it is important that the pulses should arrive at regular intervals at the p.c.m. decoder. Assuming that all timing information is derived from the p.c.m. pulse train, any timing jitter in these pulses causes pulse-position modulation of the samples forming the analogue signal, thus introducing unwanted components. A very large amount of timing jitter will also cause errors in the p.c.m. decoding process, i.e. 0's may be decoded as 1's and vice-versa, but this extreme condition will not be considered.

The subjective effect on a television display of timing jitter on the samples of a PAL 625-line video signal obtained from a p.c.m. decoder has already been considered in a previous report.[1] However, since that report was published, it has been discovered in connection with video tape recorder problems that certain alignment errors in PAL decoders, particularly dephasing of the reference subcarrier, can considerably increase the picture impairment caused by timing jitter although these same errors cause no significant degradation of jitter-free video signals.[2] The degree of such alignment errors in the previous tests[1] is not known since the PAL decoder was aligned on jitter-free signals and the question of precise adjustment of the alignment controls, as will be considered in this report, was not given special attention. Further subjective tests have therefore been carried out to determine acceptable limits for jitter both for accurately aligned PAL decoders and also for

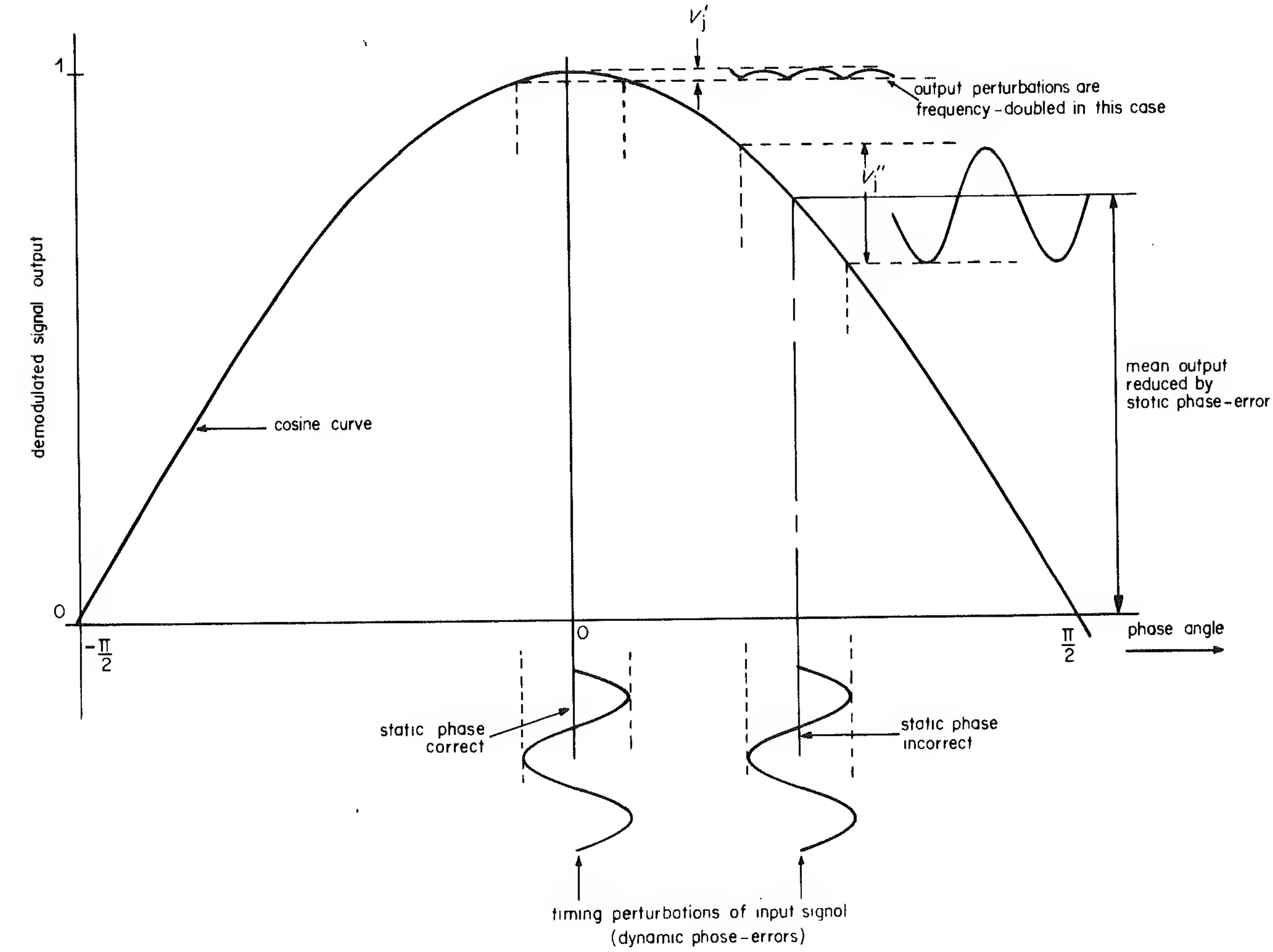

Fig. 1 - Synchronous demodulation: the combined effects of static and dynamic phase errors

decoders in which the alignment is incorrect by an amount likely to occur through long term drifts.

A similar series of tests have been carried out in relation to timing jitter introduced by analogue processing equipment,[2] e.g. video-tape recorders. These tests, however, were concerned with a somewhat lower jitter-frequency range (0 – 7·5 kHz) than is of interest in relation to jitter introduced by p.c.m. links.

2. Properties of PAL_D decoding circuits affecting picture impairment caused by jitter

The most important error likely to occur in practice in the alignment of delay-line (PAL_D) decoders is an incorrect adjustment of the static phase of the reference subcarrier applied to the colour difference demodulators. With jitter-free video signals the only effect of such an error is to cause a reduction in the output level of the demodulators according to a cosine law as shown in Fig. 1; this can easily be compensated for by an increase in the chrominance gain. However, if the chrominance signals fed to the demodulators are jittering in phase with respect to the reference subcarrier, the magnitude of the resulting variations in the demodulated colour-difference signals (V_j' and V_j'' in Fig. 1) are increased in the presence of a static phase error. Moreover, re-adjustment of the chrominance gain to compensate for the static phase error causes a further increase in the magnitude of these variations. It can be seen from Fig. 1 that when the static phase adjustment is correct, the output variations caused by jitter are at a minimum and, also, that a frequency doubling effect occurs which reduces the coarseness of the resulting impairment pattern on a television display, thereby further reducing its visibility.

With a delay-line PAL_D decoder, the situation is complicated since timing jitter in the video signal can cause perturbations in both the amplitude and the phase of the chrominance signals fed to the two colour difference demodulators; it is shown in the appendix (Section 7) that the relative proportions of these two types of perturbation depend on the repetition frequency of the jitter. If the repetition frequency is close to nf_L where f_L is the line frequency of the video signal and n = 0, 1, 2 etc., the overall effect of jitter is to cause variations only in the saturation of the colour as discussed in relation to Fig. 1, no hue variations being obtained. On the other hand, if the repetition frequency is close to $(n + ½)f_L$, the jitter then causes variations in hue but no variations in saturation; in this case, the magnitude of the hue variations is nearly independent of the setting of the static phase of the reference subcarrier.

Other decoding errors which increase the impairment resulting from jitter include:—

1. Decoding axes at the two colour difference demodulators not in quadrature.
2. Error in chrominance delay-line length.
3. Gain error in delay-line adder/subtractor.

These three types of error are generally less important than an error in the static phase of reference subcarrier and were not examined in the subjective tests; details of their effects are discussed elsewhere.[2]

3. Picture impairment produced by jitter

The impairment caused by jitter is far more noticeable in coloured areas than in monochrome areas of a picture. Also, the magnitude of the unwanted components in the colour difference signals is directly proportional to the amplitude of the colour subcarrier and therefore the picture degradation is most noticeable in 100% saturated colours.

With random forms of jitter, the resulting impairment looks similar to that produced by noise in the chrominance

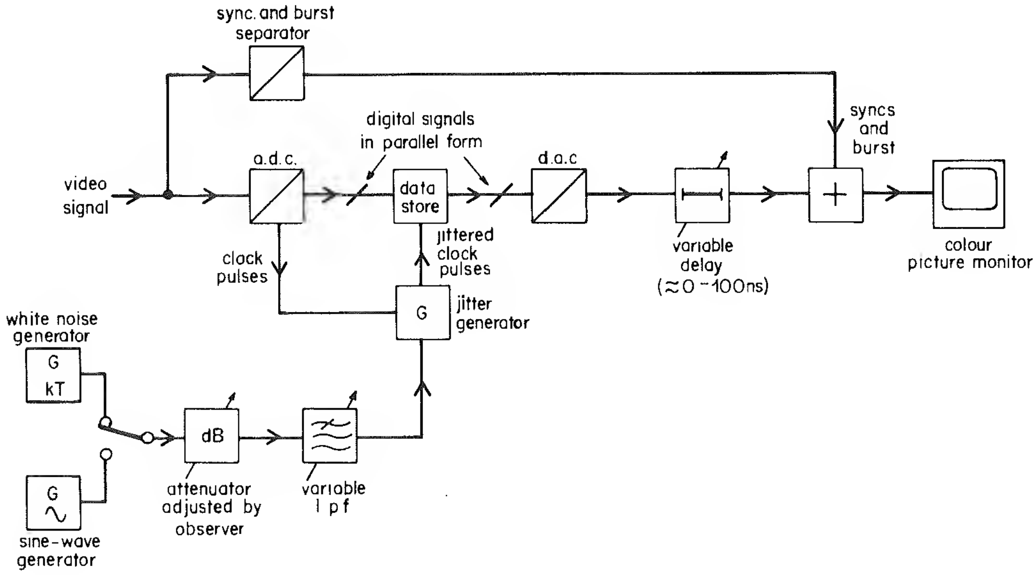

Fig. 2 - Block diagram of test equipment

channel, while sinusoidal jitter produces regular patterning similar to that produced by co-channel interference.

For jitter frequencies below about 50 Hz, the sub-carrier reference oscillator in the colour decoder is able to follow the jitter and no picture impairment is obtained.

4. Subjective tests

4.1. Equipment

A block diagram of the equipment is shown in Fig. 2. The video analogue-to-digital converter (a.d.c.) and digital-to-analogue converter (d.a.c.) have been described in an earlier report.[3] In the a.d.c. the video signal was sampled at approximately 13·3 MHz and each sample was coded into an 8-digit binary number; these 8 digits were then fed to the d.a.c. in parallel along separate wires.

The jitter on the analogue samples was produced by retiming the digital signals in a store controlled by jittered clock pulses. All eight digits described by a given sample were jittered by the same amount.

A block diagram of the jitter generator is shown in Fig. 3(*a*) and associated waveforms in Figs. 3(*b*) to (*f*). The

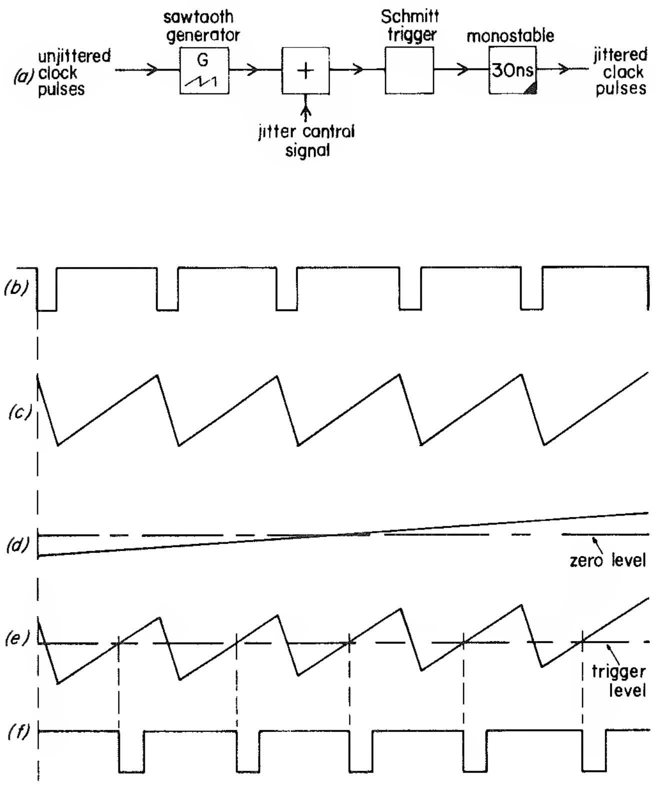

Fig. 3 - Method of obtaining jittered clock pulses
(*a*) Block diagram of jitter generator (*b*) Input clock pulses
(*c*) Output of sawtooth generator (*d*) Jitter control signal
(*e*) Output of adder (*f*) Jittered clock pulses from monostable

addition of the jitter control signal to the clock frequency sawtooth waveform varies the point on the sawtooth at which the Schmitt trigger operates, thus varying the clock pulse delay introduced by the unit.

For a constant amplitude of sinusoidal jitter signal, the amount of jitter produced was sensibly constant over the range of frequencies used in the subjective tests. Also, the amount of jitter was linearly related to the amplitude of a sinusoidal jitter signal up to at least 12·5 ns peak-to-peak.

Both random Gaussian and sinusoidal forms of jitter were used in the tests. The source of the white noise was a generator having a wide band output which was filtered as appropriate by low-pass filters. The sinusoidal control voltage was obtained from a frequency synthesiser giving a very stable frequency and the frequencies chosen were such as to give maximum visibility patterns on the display.

Variation of the static phase of the reference sub-carrier in the PAL decoder was obtained by adjusting the signal path delay, as shown in Fig. 2, at a point before adding in unjittered syncs and bursts to the reconstituted analogue signal. Subsidiary tests had shown that the absence of jitter on the syncs and burst in the signal fed to the PAL decoder had no noticeable effect on the degree of impairment caused by the forms of jitter used in the tests.

The video signals were displayed on a high quality 53 cm monitor having a peak brightness of 55 candelas/metre^2; with zero beam current the brightness of the monitor resulting from ambient illumination was 0·1 candelas/metre^2.

4.2. Test procedure

The video signal used in all the tests was obtained from a PAL 625-line colour bar generator at 100% saturation, this signal being the most critical for showing the effects of jitter.

Most of the tests carried out with jitter frequencies in the range 0 to 20 kHz since it is understood that jitter generated in long-distance p.c.m. links is likely to lie within this range. Moreover, it has been found that the impairment caused by a given amplitude of jitter in this frequency range is at least as great as that caused by jitter at higher frequencies.

Each test condition was shown to eight skilled observers seated in turn at a distance of about six times picture height from the display. Each observer was asked to adjust the variable attenuator controlling the amplitude of jitter until the picture impairment was judged to be at the threshold between grades 1 and 2 on the 6 point EBU impairment scale given in Table 1. This procedure has been found previously[1] to give a reliable indication of an impairment grade of 1·5 as determined from a curve of mean grade versus jitter amplitude when subjects are asked to grade various fixed amounts of jitter.

TABLE 1

EBU Impairment Scale

Grade	Degree of Impairment
1	Imperceptible
2	Just perceptible
3	Definitely perceptible but not disturbing
4	Somewhat objectionable
5	Definitely objectionable
6	Unusable

4.3. Results

The results of the tests for three different settings of the static phase of reference subcarrier are shown in Figs. 4 and 5. Fig. 4 shows the r.m.s. magnitude of random jitter giving grade 1·5 impairment plotted as a function of the cut-off frequency of the low-pass filter limiting the bandwidth of the random noise jitter signal. Fig. 5 shows the r.m.s. magnitude of sinusoidal jitter which causes grade 1·5 impairment plotted as a function of jitter frequency.

It will be seen that irrespective of the bandwidth of random jitter, with zero offset of the static phase of the reference subcarrier in the PAL decoder, a jitter amplitude of less than 0·6 ns r.m.s. will result in a grading of 1·5 or less. However, from discussions with manufacturers, it would seem that the long term drift of the static phase in commercial receivers could not be guaranteed to be better than about ±15° even if special precautions were taken in this direction; until very recently, the alignment of the static phase was not thought to be a critical adjustment and in present day receivers, errors of up to ±15° are not uncommon.

Assuming that errors in the static phase will not be greater than ±15°, the results of the tests show that the impairment caused by random jitter will be within acceptable limits for r.m.s. amplitudes less than 0·3 ns. For sinusoidal jitter, the r.m.s. amplitude should not be greater than 0·15 ns at the most critical jitter frequencies. These figures are similar to those given in the previous report[1]

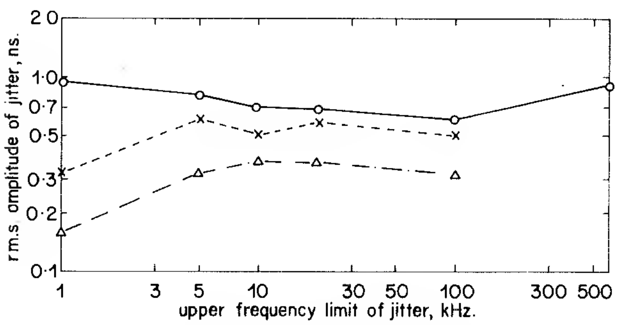

Fig. 4 - Amplitude of random jitter causing just perceptible picture impairment for different errors in the phase of the reference subcarrier

—o— Phase Error = 0° – –x– – Phase Error = 16°

— △— Phase Error = 32°

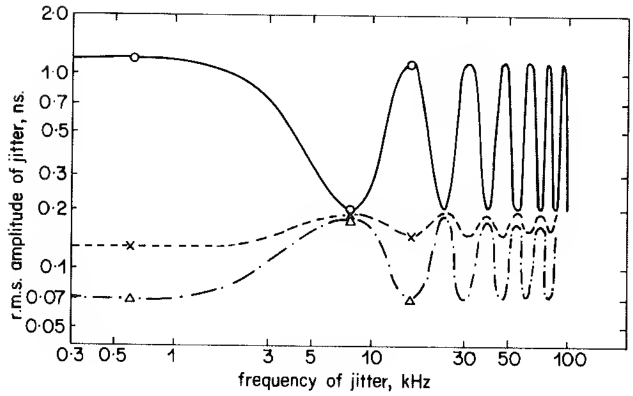

Fig. 5 - Amplitude of sinusoidal jitter causing just perceptible picture impairment for different errors in the phase of the reference subcarrier

—o— Phase Error = 0° – – –x– – – Phase Error = 61°

— △—· Phase Error = 32°

Points O X △ are results from tests using 8 observers; lines indicate general form of variations at other frequencies obtained by one observer

indicating that alignment errors were present during the earlier tests.

The results given here are also substantially in agreement with those given in Reference 2 over the frequency range common to both series of tests.

5. Conclusions

It has been found that the picture impairment resulting from timing jitter in the decoded analogue samples from a p.c.m. system carrying PAL video signals is significantly affected by errors in the adjustment of the static phase of the reference subcarrier in the PAL decoder used in displaying these signals.

Assuming that errors in this static phase adjustment are not greater than ±15°, the impairment caused by random jitter will be within acceptable limits for broadcast quality pictures if the amplitude of the jitter is less than 0·3 ns r.m.s. Although this figure of 0·3 ns r.m.s. is the same as that given in a previous report,[1] the conditions for which this limit applies have now been qualified.

More specific limits for random jitter of a given bandwidth or for sinusoidal jitter of a given frequency are shown in Figs. 4 and 5 for 0°, 16° and 32° of static phase error of the reference subcarrier; limits applicable to other phase errors may be estimated by interpolation.

6. References

1. Pulse code modulation of video signals: subjective tests on acceptable limits for timing jitter in the decoded analogue samples. BBC Research Department Report No. 1971/42.

2. Specification of the timing stability of broadcast monochrome and PAL colour television signals. BBC Research Department Report in course of preparation.

3. Pulse code modulation of video signals: 8-bit coder and decoder. BBC Research Department Report No. 1970/25.

7. Appendix

Effect of repetition frequency of jitter on the form of the resulting picture impairment

In a delay-line PAL decoder, the two colour difference signals, V_{B-Y} and V_{R-Y} are first separated by adding and subtracting the input and output signals V_1 and V_2 of a one-line delay as shown in Fig. 6 where $|V_1| = |V_2|$ in areas of uniform chrominance.

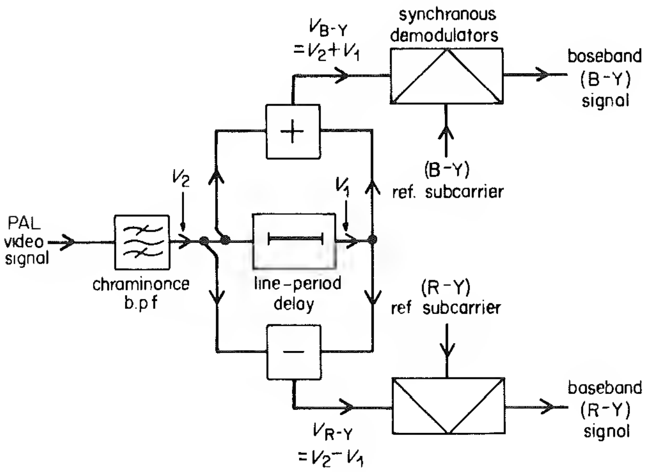

Fig. 6 - Block diagram of delay-line PAL decoder

Assuming no change in chrominance on successive lines and that no jitter is present, the relative phases of the subcarrier at the input and output of the delay line are symmetrical about the B–Y axis as shown in Fig. 7(*a*) and the phase of outputs of the adder and subtractor are as shown in Fig. 7(*b*).

In the presence of jitter which has a repetition frequency close to nf_L, where n = 0, 1, 2, etc. and f_L is the line frequency of the video signal, any phase shifts in V_1 and V_2 will be equal and in the same direction; this is shown in Fig. 7(*c*) where V_1 and V_2 are shifted by ϕ to become $V_1{}^1$ and $V_2{}^1$ and $|V_1| = |V_2| = |V_1{}^1| = |V_2{}^1|$. The resulting outputs from the adder and subtractor are now as given by V^1_{B-Y} and V^1_{R-Y} in Fig. 7(*d*) where the magnitude of these signals are equal to V_{B-Y} and V_{R-Y}. Assuming that the static phase of the reference subcarrier fed to the synchronous demodulators are correctly aligned along the R–Y and B–Y axes, the outputs from the demodulators will both be reduced by a factor of cos ϕ; as a result only the saturation of the colours is altered, the hue remaining unaltered; a similar but static effect is obtained if the reference subcarrier is misaligned providing that its components fed to the two demodulators are in quadrature. The combination of static and jitter effects will be as discussed in Section 2 and Fig. 1.

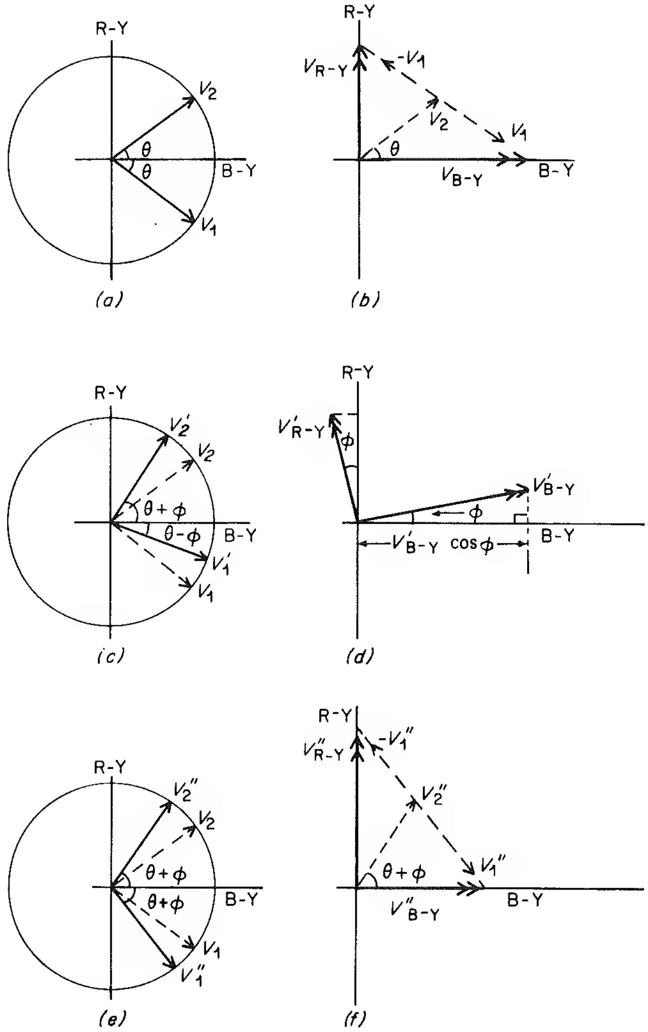

Fig. 7 - Effect of different jitter frequencies on the phase and amplitude of the chrominance signals at the inputs and outputs of the adder and subtractor in a delay-line PAL decoder

(*a*) Inputs of adder and subtractor) No jitter
(*b*) Outputs of adder and subtractor)
(*c*) Inputs of adder and subtractor) Jitter freq. = nf_L
(*d*) Outputs of adder and subtractor)
(*e*) Inputs of adder and subtractor) Jitter freq. = $(n + ½)f_L$
(*f*) Outputs of adder and subtractor)

In the presence of jitter which has a repetition frequency close to $(n + ½)f_L$, the instantaneous phase-shifts of V_1 and V_2 will be equal and opposite as indicated by V_1'' and V_2'', in Fig. 7(*e*). Since the angle between V_1'' and the B—Y axis is now equal and opposite to that between V_2'' and the B—Y axis and also $|V_1| = |V_1''| = |V_2| = |V_2''|$, it can be seen directly from Fig. 7(*e*) that only the hue of the chrominance signal has been changed to correspond to a subcarrier phase of $(\theta + \phi)$ instead of θ, the saturation remaining unaltered. For completeness, the form of the outputs from the adder and subtractor are indicated by V''_{R-Y} and V''_{B-Y} in Fig. 7(*f*).

SMW/JFS

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey