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RESEARCH DEPARTMENT

Visibility of sound/chrominance pattern with the PAL system:

dependence upon offset of intercarrier frequency and upon sound modulation

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THE BRITISH BROADCASTING CORPORATION

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RESEARCH DEPARTMENT

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SUMMARY

In order to minimize the visibility of the sound/chrominance beat pattern in compatible reception of PAL colour transmissions, an optimum sound/vision intercarrier frequency may be specified, together with a frequency tolerance. For the U.K. Standard I the results of subjective assessments of the pattern show that an appreciable improvement, over the existing specification of 6 MHz ± 1 kHz, would be obtained by using 6 MHz - 400 Hz ± 500 Hz. A more precisely controlled offset would have little advantage in practical conditions.

1. INTRODUCTION

In compatible reception of a colour television transmission using Standard I, a coarse pattern may become visible (in some conditions of receiver tuning) caused by interaction of the chrominance subcarrier signal at about 4·4 MHz with the sound intercarrier signal at about 6·0 MHz. The visibility of the fine pattern caused by the chrominance signal itself is minimized by a very careful and precise choice of subcarrier frequency in terms of the line and picture frequencies. No such precision is specified for the sound/vision intercarrier frequency; the usual choice is to make this an integral multiple of the line frequency so that the coarse pattern and the fine pattern have similar structures. At the same time, a tolerance of 1 kHz is usually considered permissible for the intercarrier frequency since the latter is frequency-modulated up to ± 50 kHz deviation by the sound programme.

The purpose of this report is to give a brief explanation for the choice of the chrominance subcarrier frequency for the PAL system, to question the assumptions made about the optimum sound/vision intercarrier frequency and to indicate the best compromise for its mean value and the tolerance, based on observations of the sound/chrominance pattern on PAL colour bars with various degrees of sound modulation.

2. THE CHOICE OF A COLOUR SUBCARRIER FREQUENCY

For Standard I (625 lines, 50 fields/second, 5·5 MHz video bandwidth) a colour subcarrier frequency of about 4·4 MHz is chosen. This frequency is low enough to allow sufficient bandwidth for the colour sidebands and high enough to reduce the visibility of the beat pattern (which may limit compatibility on a monochrome receiver) to a sufficient extent.

The subcarrier pattern will be most visible when the subcarrier has a constant phase and a frequency, f_{sc}, which is an integral multiple of the line-scan frequency (f_L = 15625 Hz) since the phase of the brightness distribution will then be the same on each line of the picture, giving a pattern of vertical lines. A gradual offset of the subcarrier frequency will cause the lines of the pattern to slope away from the vertical and therefore become less visible. At an offset of one half of the line-frequency, the phase of the pattern will be displaced by 180° on successive lines giving minimum visibility. For example, the NTSC subcarrier frequency is chosen to be $f_{sc} = 283\frac{1}{2} f_L$, resulting in a subcarrier pattern having the appearance of a mass of upwards-moving dots rather than a series of sloping lines.

The PAL system transmits saturation and hue in a similar way to the NTSC system with one important difference. The phase and amplitude of the subcarrier of either system may be resolved into two components in quadrature as shown by the following expressions for the total video modulating voltage in each system:

$$\text{NTSC} \qquad E_M = E'_Y + E'_Q \sin(2\pi f_{sc} t + \phi) + E'_I \cos(2\pi f_{sc} t + \phi)$$

$$\text{PAL*} \qquad E_M = E'_Y + E'_U \sin 2\pi f_{sc} t \pm E'_V \cos 2\pi f_{sc} t$$

where E'_Y is the luminance voltage and E'_Q, E'_I, E'_U, E'_V are the chrominance voltages, all of which are derived from the original red, green and blue voltages; ϕ is a phase constant for the NTSC system. The phase reference for the subcarrier, frequency f_{sc}, is supplied by a burst of subcarrier signal during the line-blanking interval.

The important difference between the two systems is that the sign of E'_V is reversed on alternate line-scans in the PAL system. A half-line-offset subcarrier frequency would therefore be unsuitable for PAL since hues giving a predominance of the E'_V signal will again show a vertical beat pattern through cancellation of the phase shift caused by the offset.

The best compromise for PAL is clearly to choose some intermediate offset, say, plus or minus ¼ f_L, in order to make the patterns slope equally in opposite directions for the E'_U and E'_V signals, even though they will still be closer to the vertical than in the NTSC pattern. It can be shown[1] that, for a 625-line system, the optimum subcarrier frequency for PAL is:

$$f_{sc} = (n - \tfrac{1}{4})f_L + f_P$$

where n is usually chosen to be 284 and f_P is the picture frequency, 25 Hz. The additional offset of 25 Hz results in the pattern most nearly interlacing on alternate field-scans.

The subjective appearance of the PAL subcarrier pattern, unlike that of the NTSC pattern, depends on the hue, being one or other set of diagonal lines for hues which have only one chrominance component and a combination of these two predominant patterns for hues with comparable amounts of both the E'_U and E'_V signals.

3. THE CHOICE OF SOUND CARRIER FREQUENCY

The above discussion on the visibility of the PAL system subcarrier is equally applicable to the sound/chrominance beat pattern and the general requirement for minimum visibility still applies.

If, therefore, the sound carrier were unmodulated and had a frequency equal to an exact multiple of the line frequency (e.g. 6 MHz or 384 f_L, U.K. Standard I) the sound/chrominance beat would have a minimum visibility automatically since the fractional offset of the beat frequency would be the same as that of the subcarrier itself. However, the practical situation, in which the sound carrier is modulated and the two colour components may not be present to an equal extent, warrants experimental investigation.

* Revised specification agreed by EBU Ad-Hoc Group on Colour Television, 1966.

4. ASSESSMENT OF PATTERN VISIBILITY WITH SOUND CARRIER OFFSET

4.1. Experimental Procedure

PAL Colour Bars were observed by viewing a commercial u.h.f. television receiver at a distance of eight times the picture height. The observer (an experienced engineer) adjusted the sound carrier level at each frequency offset so that the sound/chrominance pattern was at the threshold of perceptibility (grade 1½).* The receiver was detuned slightly towards the sound carrier-frequency so that it was never necessary to use a sound carrier level exceeding the normal value (-7 dB relative to peak vision signal). For this latter reason the results may be taken to show only the variation in pattern visibility near to the threshold of perception, not the absolute susceptibility of a properly tuned receiver. At the time of the experiment, the available PAL equipment produced alternation of the E'_I component of the colour signal according to an earlier standard[2] for the system, but it is not considered that results for the new standards would be significantly different.

4.2. Discussion of Experimental Results

The visibility of the pattern depends upon its coarseness of structure, its rate of apparent motion and the degree to which it is made indistinct by the frequency-modulation of the sound-carrier. Fig. 1 shows the dependence of visibility on the structure of the pattern as a function of the sound carrier offset over a line-frequency interval; Fig. 2 shows the dependence of visibility upon the movement of the pattern as a function of the sound carrier offset over a picture-frequency interval. Because of the effect of small closely-controlled offsets shown in Fig. 2, Fig. 1 includes two curves for an unmodulated carrier, one for the most visible condition

* This refers to the six-point impairment scale of the EBU; grade 1½ corresponds to the condition, which an experienced engineer can assess, when about 50% of ordinary observers would find it "imperceptible" (grade 1) and 50% would find it "just perceptible" (grade 2).

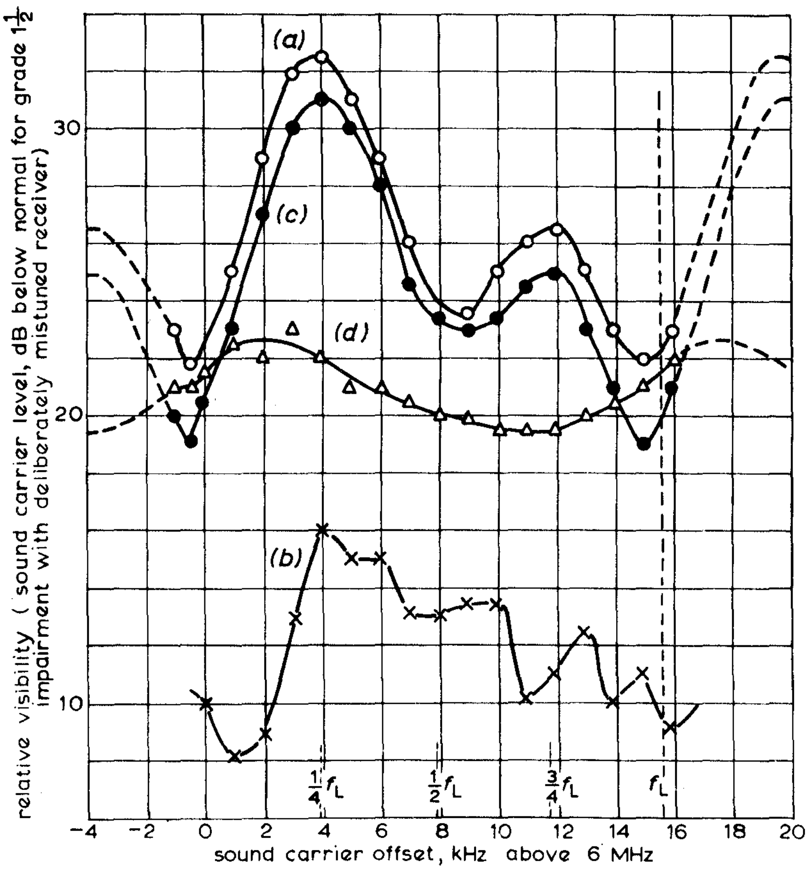

Fig. 1 - Visibility of sound/chrominance pattern on PAL colour bars as a function of sound carrier offset

(*a*) Unmodulated c.w. source; most visible pattern
(*b*) Unmodulated c.w. source; least visible pattern
(*c*) Frequency-modulated source; peak deviation ± 100 Hz (l.f. noise)
(*d*) Frequency-modulated source; nominal peak deviation ± 50 kHz (continuous light music)

(pattern almost stationary) and one for the least visible condition (pattern moving rapidly or interlaced on successive fields).

Considering first an unmodulated carrier, the pattern becomes coarsest when it contains nearly vertical bars. The bars are vertical on colours of constant phase when the sound carrier is offset from an integral multiple of f_L by approximately -¼ f_L (a similar offset to that of the colour subcarrier) but they are also vertical at an offset of approximately +¼ f_L on colours whose phase is alternated line by line, as this switching process completely cancels the effect of pattern interlacing on successive lines that would normally occur at a relative offset of ½ f_L. There are therefore two peaks in the curve of maximum visibility given in Fig. 1 curve (*a*), one at about 4 kHz offset and another at about 12 kHz offset. The difference in the height of these two peaks is explained by considering the relative amplitude of the colour signal on which the vertical pattern is most marked. It was found that the patterns were always most easily observed on the cyan and/or green colour bars; the cyan signal has a large component of alternating phase and the green signal has a large component of constant phase but, of the two, the cyan signal has the larger effective amplitude and gives rise to the more marked pattern. The complementary colours, magenta and red, have lower values of luminance and give rise to much less noticeable patterns.

Fig. 1 curve (*a*) shows that the visibility of a near-stationary pattern has its lowest value for an unmodulated sound signal at an offset very close to zero (6·0 MHz being the reference value for Standard I) but, in fact, slightly negative (about -400 Hz) where the best compromise is reached between the visibility of the patterns on the cyan and green bars. Owing to the same effect, the minimum at half-line offset is displaced in a positive sense. It might be expected that the two minima (at half-line offset and whole-line offset) would have the same value, the only difference being a reversal of the slope of the pattern lines. The small disparity is thought to be caused by interference between the sound/chrominance beat-pattern and the chrominance pattern itself; these have the same fractional line offset (approximately $-\frac{1}{4} f_L$) when the sound carrier offset is near $\frac{1}{2} f_L$ so that both patterns slope in the same direction, giving a somewhat coarser and more visible secondary interference pattern.

Fig. 1 curve (*b*) shows the lowest visibility of the pattern when, by means of a small additional offset, it is made to appear to move most rapidly. An additional offset of about 25 Hz (f_P) is required to change from the most visible to the least visible pattern, that is, between curves (*a*) and (*b*) in Fig. 1. The progressive change of pattern visibility as this small offset is changed is shown in Fig. 2 for a range of major offsets extending to f_L. For convenience Fig. 2 shows the visibility as a function of the fractional term $af_P (-1 < a < 1)$ when the sound/vision intercarrier frequency is expressed in the form:

$$f_S = pf_L + 2qf_P + af_P \tag{1}$$

where pf_L = 384 f_L represents 6 MHz and $2qf_P$ is

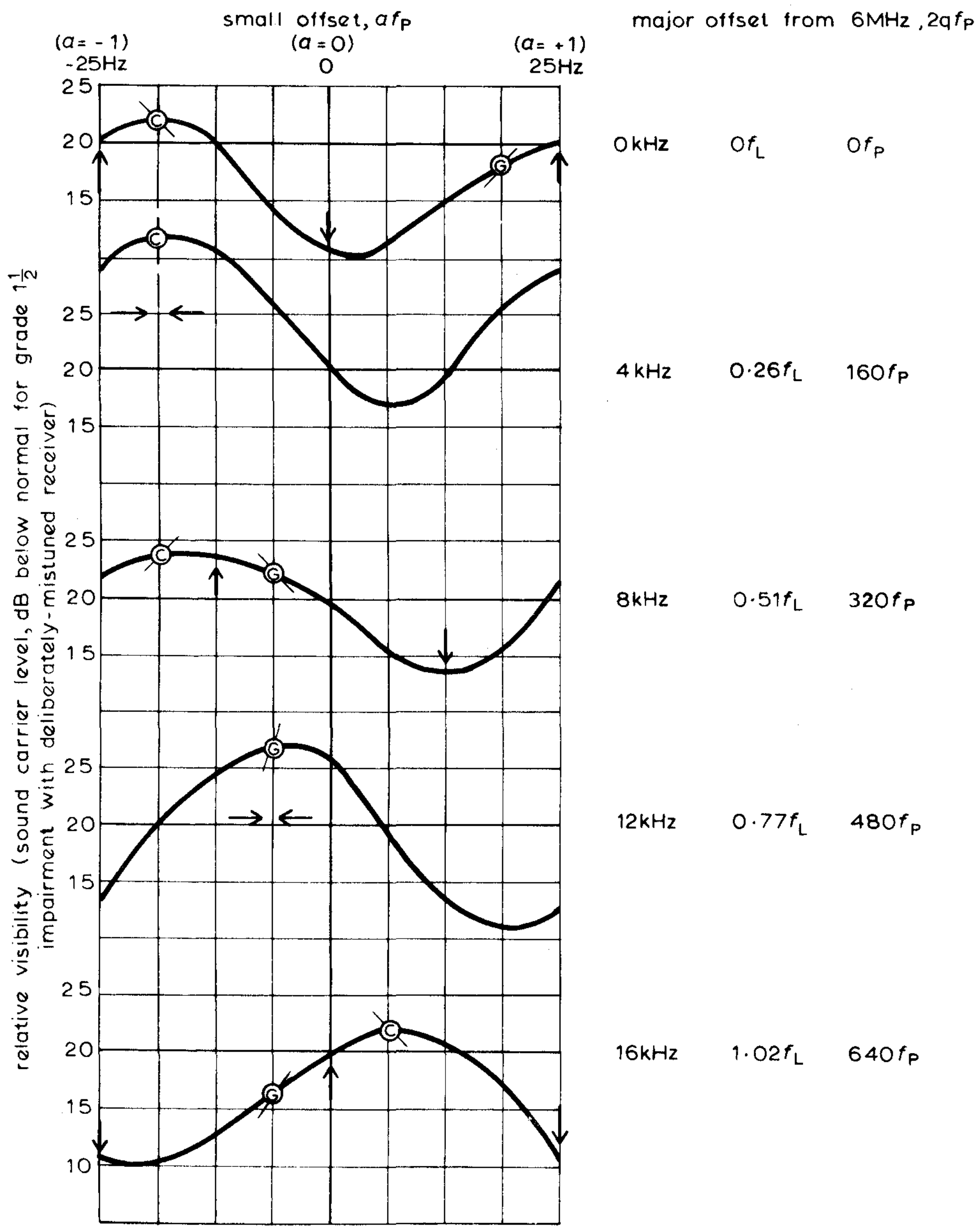

Fig. 2 - Visibility of sound/chrominance pattern on PAL colour bars as a function of small precisely-controlled sound carrier offsets

Angle of main pattern, stationary on cyan, Ⓒ, or green, Ⓖ

Direction of pattern motion

twice an integral multiple of the picture frequency f_P. The term $2qf_P$ is indicated opposite each curve in Fig. 2 and is also expressed in kHz and the corresponding fraction of the line frequency f_L.

The circles in the curves in Fig. 2 show when, in certain colours, the pattern becomes stationary. In the curves near the top, for example, the cyan signal pattern becomes stationary at $a = -\frac{3}{4}$, the fractional offset being -18·75 Hz. When the total offset is near f_L, however, the same pattern is stationary at $a = +\frac{1}{4}$. It might appear that this is a different condition, but if the intercarrier frequency is expressed in relation to the *nearest* line harmonic we have:

$$f_S = p'f_L + 2q'f_P + a'f_P \qquad (2)$$

where $p' = p + 1 = 385$. Since $f_L = 625f_P$, we must have either $q' = q - 312$ and $a' = a - 1$ or $q' = q - 313$ and $a' = a + 1$ for equivalence of expressions (1) and (2), so that condition $a = +\frac{1}{4}$ becomes $a' = -\frac{3}{4}$.

Considering next the effect of frequency-modulation of the sound carrier, it might be expected that audio-frequency carrier deviations of more than ± 25 Hz (66 dB below peak deviation) would make the pattern visibility become independent of the precise value of the mean carrier frequency as given in Fig. 2. This was confirmed by the observations and the results are given in Fig. 1 by the single curve (*c*) showing the visibility of the "shimmering" pattern when the carrier is deviated ± 100 Hz by low-frequency noise; the visibility is reduced by only about 2 dB compared with the nearly-stationary condition of curve (*a*).

Finally, the effect of normal sound carrier deviation which frequently reaches ± 12 kHz ($\pm\frac{3}{4}f_L$) for a programme such as continuous light music, is that the range of coarser variations in pattern visibility is smoothed out, giving the result shown by Fig. 1 curve (*d*), which has a shallow minimum in the region of + 11 kHz offset, roughly mid-way between the major peaks near + 4 kHz in curve (*a*).

5. DETERMINATION OF THE OPTIMUM INTER-CARRIER FREQUENCY AND ITS TOLERANCE

Although the measurements were carried out using colour bars, it was considered that they form a valid basis for recommending a most generally acceptable solution, since the amplitudes and phases of the colour subcarrier produced by all colour bars are equally representative of the maximum of which the system is capable in practice.

If the intercarrier frequency is maintained at 6 MHz with a tolerance of ± 1 kHz (the present U.K. specification), the pattern will be within 4 dB of the least visible condition for low values of modulation. Precision control of the mean frequency would give a 10 dB improvement only when there is no modulation at all; this improvement would vanish for modulation levels greater than about 66 dB below peak, a condition likely to be caused by noise even during "quiet" periods in programmes. From the results of tests on colour bars, there appears to be a slightly better choice of mean frequency at about - 400 Hz offset where a tolerance of ± 500 Hz would give 3 dB lower visibility than the ± 1 kHz tolerance mentioned above. At normal levels of sound modulation, the pattern visibility would increase by only 1 or 2 dB from the value during "quiet" periods.

Even if the sound carrier should become completely stable and reveal a near-stationary pattern, as may be possible for short periods, the pattern would become only 2 or 3 dB more visible than during nominally "quiet" periods.

6. CONCLUSIONS

A sound/vision intercarrier frequency of exactly 6 MHz is close to the optimum value for low sound/chrominance pattern visibility during pauses in sound modulation. A value of 6 MHz - 400 Hz ± 500 Hz is recommended as giving up to 3 dB improvement compared with the present U.K. specification of 6 MHz ± 1 kHz.

7. REFERENCES

1. BRUCH, W. 1964. Das PAL-Farbfernseh system - Prinzipielle Grundlagen der Modulation und Demodulation, Nachrtech. Z., 1964, **17**, 3, pp. 109 - 121.

2. Report of the EBU Ad-Hoc Group on Colour Television, 2nd Edition, Appendix I, February 1965.

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