Choice of Chrominance Subcarrier Frequency in the NTSC Standards*

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Summary—There are a number of considerations which lead to the final choice of the chrominance subcarrier frequency in the NTSC signal. In addition to the considerations given elsewhere[1] it is also desirable to minimize the visibility of the beats between the sound carrier and the chrominance subcarrier. This requires a slight alteration of the nominal field and line rates over those used in monochrome television.

Introduction

There are a number of factors which influence the choice of the chrominance subcarrier frequency in the National Television System Committee Standards. They are governed primarily by interference effects by and to the chrominance signal in both existing monochrome, as well as color television receivers. In this paper are discussed the reasons for the final choice of the subcarrier frequency as well as its tolerances. In addition, the resulting choice of field and line frequencies as well as sound carrier-video carrier frequency separation are covered.

Approximate Choice of Subcarrier Frequency

It is desirable that the subcarrier frequency be chosen high enough to minimize interference with the luminance signal. Thus, in an existing monochrome receiver, any dot structure resulting from the subcarrier will not only be as fine as possible, but it will also be reduced by any attenuation in the receiver at the chrominance subcarrier frequency. On the other hand, the chrominance subcarrier frequency must be low enough so as to permit the upper side-bands of the carrier chrominance signal to fall within the useful video band. As explained by Brown and others,[2–5] the spectrum of the carrier chrominance signal needs to extend only to frequencies lying approximately 0.6 megacycle above the subcarrier. Since it is practical to obtain video bandwidths of approximately 4.2 mc in transmitters and receivers, the subcarrier frequency may be chosen as high as 3.6 mc.

Closer Selection of Subcarrier Frequency

The choice of a subcarrier frequency is also dictated by the "frequency interleaving" principle. This has been discussed at length elsewhere by the author.[1] It was shown in that paper that it is desirable to choose a frequency which is an odd multiple of one-half the line rate; further, that this multiple have small (odd) factors. Accordingly, it may be seen that if we choose the multiple 455, having the factors 13, 7, and 5, one would obtain a subcarrier frequency of 3.583125 mc.

Effect of Sound Carrier Interference

This frequency would prove quite satisfactory were it not for a further consideration, involving the presence of the sound carrier. In some monochrome receivers now in use, there may be insufficient attenuation of the sound carrier to prevent an objectionable 0.9-mc signal, resulting from the beat between the sound carrier and the chrominance subcarrier. Experiments have shown[6] that this beat signal is much less objectionable if it is an odd multiple of one-half the line rate, because of the "frequency interleaving" effect previously referred to. This requires that the sound and video carriers be separated by an amount approximately equal to a multiple of the line rate (i.e., an even multiple of one-half the line rate). This means that the beat between the visual and aural carriers is *not* interleaved. Its visibility, however, is so low anyway, because of 4.5-mc attenuation and the fine structure of the pattern, that no difficulty is encountered. Because of the frequency modulation of the sound carrier, the beat between it and the chrominance subcarrier will likewise be frequency modulated, and therefore, be "interleaved" only on the average. There is, nevertheless, a definite reduction in beat visibility.[6]

It is easily computed that there are harmonics of 15.75 kilocycles at 4.48875 and 4.5045 mc, corresponding to the *285th* and *286th* multiples, respectively. The latter figure is nearest to the proper nominal value;

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[1] I. C. Abrahams, "The 'Frequency Interleaving' Principle in the NTSC Standards," NTSC Technical Monograph No. 3; and Proc. I.R.E., pp. 81–83; this issue.

[2] G. H. Brown, "Choice of Axes and Bandwidths for the Chrominance Signals in NTSC Color Television," NTSC Technical Monograph No. 14; and Proc. I.R.E., pp. 58, 59; this issue.

[3] P. W. Howells, "A Proposal for a Modification of the Chrominance Signal Specification," NTSC Document P13-289, August, 1952.

[4] W. F. Bailey and C. J. Hirsch, "Quadrature Crosstalk in NTSC Color Television," NTSC Technical Monograph No. 2-A; and Proc. I.R.E., pp. 84–90; this issue.

[5] RCA Laboratories, "Tests Relating to the Choice of Narrow and Wide-band Components for a Balanced Color Gamut System," NTSC Document P-13-286, October 19, 1952.

[6] Report of Subcommittee No. 8, Panel 13, NTSC, on "Visibility of Beat-note between Sound and Color Subcarrier," August, 1952.

nevertheless, it would be unsatisfactory to move the sound carrier by the required 4,500 cycles, lest some of the existing monochrome sets be unable to obtain proper sound reception. The sound carrier has, therefore, been left at its monochrome value; i.e., separated from the video carrier by 4.5 mc. In order to obtain "frequency interleaving" with the chrominance subcarrier, it is, therefore, necessary to move the latter. This, in turn, necessitates moving the line and field rates by the same percentage, in order to maintain "frequency interleaving."

Choice of Exact Frequencies

The new frequencies were, therefore, chosen by defining the sound-carrier separation of 4.5 mc as being the 286*th* harmonic of the new line rate. This leads to a horizontal frequency of

$$f_l = \frac{4.5 \times 10^6}{286} \text{ cps} \qquad (1)$$

$$= 15{,}734.26 \text{ cps.}$$

Since there will still be 525 lines per frame, the new field frequency then becomes

$$f_f = \frac{f_l}{525/2}$$

$$= 59.94 \text{ cps.} \qquad (2)$$

The subcarrier frequency is given by

$$f_s = \frac{455}{2} \times f_l, \qquad (3)$$

as before. In view of (1),

$$f_s = \frac{455}{2} \times \frac{4.5 \times 10}{286} \text{ cps}$$

$$= 3.579545 \text{ mc.}$$

It should be noted that these values of f_l and f_f are only 0.1 per cent removed from the nominal values now used for monochrome, which is well within the tolerance of 1.0 per cent allowed for such operation.

The values of f_l and f_f given above do not permit synchronous operation with the power line. As will be seen later, the tolerances would not permit such operation anyway. With the advent of network and other remote operations, power-line synchronous operation is of little value or necessity, in any case.

It should be noted that in order to reduce further the beat between the sound carrier and the color subcarrier, the maximum aural power is limited to 70 per cent of the peak visual power. It has been found in monochrome practice that this is sufficient aural power for good reception.[6]

Tolerances

The tolerance on the subcarrier frequency has been set at ± 0.0003 per cent, or about ± 10 cps. The rate of change of frequency of the subcarrier has been set at not more than 1/10 cps per second. These tolerances have been chosen in order to facilitate synchronization of the subcarrier at the receiver. Thus, for example, the use of crystal oscillators or filters is made easier.

In addition, the sound-carrier–picture-carrier separation is required to be held to within $\pm 1{,}000$ cps. This is in order to maintain as much as possible the advantages of the "frequency interleaved" beat between the sound carrier and the chrominance subcarrier.