The Influence of Carrier-to-Noise Ratio and Stylus Life on the RCA VideoDisc System Parameters

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Abstract—In the RCA VideoDisc System, the video and audio information is stored in depressions recorded in grooves that are pressed into plastic discs. During playback of the disc, a capacitive pickup system converts these depressions into electrical signals. The carrier-to-noise ratio obtainable from these signals during the useful life of the pickup stylus influences the choice of many of the system parameters, such as minimum recorded wavelength, groove pitch, playing time, inner recorded radius, rotational velocity, FM deviation, maximum carrier frequency, and video signal-to-noise ratio.

It is shown that the carrier-to-noise ratio data can be used to make trade-offs between the minimum recorded wavelength, maximum carrier frequency, and rotational velocity to obtain a desired value of the weighted video signal-to-noise ratio. For maximum stylus life, the rotational velocity should be chosen as low as possible consistent with desired signal-to-noise ratio and manufacturing margins.

1. Introduction

In the RCA VideoDisc System, the video and audio information is stored in depressions recorded in grooves that are pressed into plastic discs. During playback of the disc a capacitive pickup system converts these depressions into electrical signals as described in Ref. [1]. The carrier-to-noise ratio obtainable from these signals during the useful life of the pickup stylus influences the choice of many of the system parameters, such as minimum recorded wavelength, groove pitch, playing time, inner recorded radius, rotational velocity, FM deviation, maximum carrier frequency and video signal-to-noise ratio.

The RCA Capacitance Electronic Disc (CED) System in its present form evolved over many years[2] with substantial changes occurring in such basic techniques as pickups, recording instruments, mastering, and disc materials. Each of these changes affected the carrier-to-noise ratio of the signal channel whereby information is stored and reproduced in the VideoDisc system. As these changes occurred, it was necessary to make appropriate tradeoffs of the system parameters in order to obtain our basic goal of good picture quality, long playing time, and low cost of both player and disc.

2. Relationship Between Parameters

The mean signal-to-noise power ratio, S/N, for an FM system with de-emphasis is given by Schwartz[3] as

$$\frac{S}{N} = \frac{3\beta^2}{D}\frac{S_c}{N_c}, \qquad [1]$$

where β is the modulation index, D is the de-emphasis factor, and S_c/N_c is the carrier-to-noise ratio of an AM system with the same maximum modulating frequency, carrier power, and noise power spectral density. The modulation index is given by

$$\beta = \frac{\Delta\omega}{\omega_m} = \frac{\Delta f}{f_m}, \qquad [2]$$

where $\Delta f = \Delta\omega/2\pi$ is the peak frequency deviation and f_m is the maximum bandwidth of the modulation signal. Therefore, for a fixed maximum modulation frequency and de-emphasis factor, the signal-to-noise ratio obtainable from an FM system is directly proportional to both the carrier-to-noise ratio at the input to the system and the square of the peak frequency deviation.

In the VideoDisc System, if the lowest carrier frequency is fixed, the peak frequency deviation is proportional to the maximum carrier frequency, f_{max}, and the carrier-to-noise ratio obtainable at that frequency influences the choice of other system parameters. For a constant number of disc rotations per minute, RPM, the minimum groove velocity, ν_{min}, will occur at the inner recorded radius, R_i, and is given by

$$\nu_{min} = 2\pi R_i \cdot \mathrm{RPM}. \qquad [3]$$

Units conversion factors are not shown in these equations but are included in all calculations. The minimum recorded wavelength, λ_{min}, is related to the minimum groove velocity by

$$\lambda_{min} = \frac{\nu_{min}}{f_{max}} = \frac{2\pi R_i \cdot \mathrm{RPM}}{f_{max}}. \qquad [4]$$

In the VideoDisc System, recording, replication, and pickup apertures cause a reduction in the carrier-to-noise ratio as the wavelengths become smaller. From Eq. [4] it appears desirable to increase the RPM and reduce f_{max} to increase the minimum wavelength and, thus, the carrier-to-noise ratio. However, from Eq. [1] the signal-to-noise ratio increases linearly with carrier-to-noise ratio but increases as the square of the peak frequency deviation, which is proportional to f_{max}. In general, a trade-off must be made between RPM and f_{max} to keep the carrier-to-noisie ratio at the minimum wavelength from falling below the threshold of the FM system,[3] which would cause undesirable defects in the picture, and to obtain a signal-to-noise ratio that is high enough to be consistent with good picture quality. Of course, sufficient margin must be maintained above threshold to allow for manufacturing tolerances. Longer wavelengths are easier to record and replicate and cause less problems in the player from signal loss due to stylus lifting from either debris or severe disc warp.[1]

The stylus tip geometry used in the RCA VideoDisc System is referred to as keel-shaped. The sides of this stylus are relatively straight and the width remains essentially constant with wear. If a stylus is designed to fit a given groove width, its life will be determined by the volumetric wear rate and the length and height of the keel. In the RCA VideoDisc System, the width of the groove is essentially equal to the distance between the grooves or the groove pitch, P_G, which for a constant RPM disc is given by

$$P_G = \frac{R_0 - R_i}{T_p \cdot \mathrm{RPM}}, \qquad [5]$$

where R_0 is the outer recorded radius, R_i is the inner recorded radius, and T_p is the playing time per side. For a fixed recorded area and playing time, the groove pitch will increase as the RPM is lowered. The larger groove width will result in increased stylus life. Also with lower RPM the stylus travels less distance per hour of play which results in less wear.

In general, it is desirable to keep the RPM as low as possible to increase stylus life. However, Eq. [4] shows that for a fixed f_{max}, reducing the RPM causes a reduction in λ_{min}, which results in a reduction of the carrier-to-noise ratio due to aperture effects and a reduction in manufacturing tolerances. Of course, f_{max} could be reduced to increase λ_{min}, but Eq. [1] shows that this would reduce the signal-to-noise ratio obtainable from the disc, since β is proportional to f_{max}. Thus, a trade-off between RPM, λ_{min}, and f_{max} is required to obtain maximum stylus life at a desired level of signal-to-noise ratio and manufacturing margins.

3. Impetus for Development of Buried Subcarrier System

The desire both to keep the RPM as low as possible to increase stylus life and to make λ_{min} as large as possible to provide manufacturing margins led to the development of the buried-subcarrier signal encoding and decoding system for the RCA VideoDisc.[1,4] While λ_{min} occurs at f_{max} (Equation [4]), the lowest carrier frequency that can be used is also an important consideration in FM systems where the carrier is located close to the maximum modulating frequency. These systems typically use a low modulation index such that only the first-order sidebands are significant.[3] They also typically use an FM demodulator that employs frequency doubling to reject carrier frequencies, f_c, close to the maximum modulating frequency, f_m. The frequency doubler output will contain both the desired frequency f_m plus the doubled carrier and sideband frequencies $2f_c \pm nf_m$. The amplitude at the frequency $2f_c - 2f_m$ is generally large enough to cause a disturbance in the picture and must be removed by the video filter. If this frequency is set equal to or higher than the maximum modulating frequency, then

$$2f_c - 2f_m \geq f_m \quad \text{or} \quad f_c \geq (3/2)\, f_m.$$

This is for the ideal case. If second harmonic or baseband components are present as in the VideoDisc channel, then distortion components will appear at $f_c - f_m$ in the video domain.[1,4] If $f_c \geq 2f_m$ the distortion components will fall outside the video filter. Thus the lowest carrier frequency should be higher than $(3/2)f_m$ for the ideal case and higher than $2f_m$ when distortions are present.

In the RCA VideoDisc System, the luminance bandwidth was chosen to be 3 MHz to be consistent with good resolution in a home TV receiver. If only the luminance information were recorded, then the lowest carrier frequency could be 4.5 MHz in the ideal case and 6 MHz if distortions are considered. If color information were recorded using the standard NTSC format with the color subcarrier at 3.58 MHz and an overall bandwidth of 4.2 MHz, then the lowest carrier frequency would be 6.1 MHz in the ideal case and 8.4 MHz if distortions are considered. In addition to the reduced wavelengths required to record the NTSC color subcarrier, a second disadvantage is that in an FM system the signal-to-noise ratio available at the color subcarrier frequency decreases as the subcarrier frequency moves further away from the main luminance carrier. These disadvantages led to the investigation of many methods of recording color information in the RCA VideoDisc System.

The buried-subcarrier composite color signal encoding and decoding system developed for the RCA VideoDisc uses comb-filter techniques to place the color subcarrier at a frequency of 1.53 MHz with modulation sidebands extending from 1 to 2 MHz. The advantages of this approach are that it can be recorded in a 3 MHz bandwidth, which results in a low minimum FM carrier frequency, and the reduced subcarrier frequency provides improved signal-to-noise ratio of the chrominance over the standard NTSC composite system.

Extensive viewing tests using the buried subcarrier system in the FM domain have shown that with the baseband distortions present in the VideoDisc, the lowest black-level frequency, f_{black}, can be placed such that the highest chrominance modulating frequency, f_{mc}, of the lower sideband color subcarrier, f_{sc}, is greater than the maximum video baseband component, f_m, or

$$\begin{aligned} f_{black} - f_{sc} - f_{mc} &\geq f_m \\ f_{black} &\geq f_m + f_{sc} + f_{mc} \end{aligned} \qquad [6]$$

For f_m = 3 MHz, f_{sc} = 1.53 MHz, and f_{mc} = 0.5 MHz, this results in a black-level frequency of 5 MHz. Placing the black-level frequency at 5 MHz instead of at 6 MHz as required by the baseband distortions causes an overlap between the baseband luminance interference from 2 to 3 MHz and the lower sideband luminance information that is 2 to 3 MHz from the black-level carrier. Interference in this frequency range is hardly noticeable in the picture partly because the signal energy is low and partly because it is almost exclusively caused by the edge information in the picture. Note, however, that this would not be the case if the color subcarrier appeared in this range. Since the subcarrier and its sidebands are not necessarily related to the luminance information, these signals would cause unacceptable beats to appear in flat areas of the picture. Applying Eq. [6] to the standard NTSC system with f_m = 4.2 MHz, f_{sc} = 3.6 MHz and f_{mc} = 0.5 MHz would result in a black-level frequency of 8.3 MHz. The reduced black-level frequency obtained by using the buried subcarrier composite color system results in a proportional reduction in the maximum modulating frequency required, thus making λ_{min} as large as possible and allowing the use of a low RPM to increase stylus life.

4. Signal-to-Noise Ratio Definitions

Eqs. 1 and 2 show that for a fixed maximum modulation frequency, f_m, the signal-to-noise power ratio obtainable from an FM system is directly proportional to both the carrier-to-noise ratio and the square of the peak frequency deviation and inversely proportional to the de-emphasis factor. To make the proper trade-offs between these variables, it is desirable to know the value of signal-to-noise ratio required. In an FM system, the noise power at the output of the detector increases as the square of the frequency and is modified by the de-emphasis factor and other system components, such as filter responses. In comparing a system that has a non-flat noise response with test results that in general are for systems with a flat noise response, it is common pratice to use a noise weighting function. The weighting function attempts to make equal measured values denote equal visual interfering effects regardless of the shape of the noise spectrum being measured. The noise weighting function used for the RCA VideoDisc is that adopted by the CCIR in 1974.[5]

The definition of signal-to-noise ratio used for the RCA VideoDisc is the peak-to-peak signal amplitude measured from blanking to white level versus the rms noise weighted with the CCIR function in a 4.2-MHz bandwidth. This definition is different from the CCIR definition in that a 4.2-MHz bandwidth is used instead of the specified 5-MHz bandwidth. 4.2 MHz is chosen because most of the noise measuring equipment for NTSC systems uses this bandwidth. The CCIR noise weighting factor for flat noise is 7.4 dB in a 5-MHz bandwidth and 6.8 dB in a 4.2-MHz bandwidth.

Extensive subjective tests have been performed using experienced viewers to determine the effect of a flat noise spectrum on the impairment to television pictures.[6] These tests showed that for a viewing distance equal to eight times the picture height, a signal-to-noise ratio equal to or greater than 39 dB resulted in a picture in which 50% of the viewers said the noise was just perceptible and more than 90% of the viewers said the noise was not objectionable. In these tests, the peak-to-peak signal was measured from sync tip to white level and the rms noise was unweighted in a 4.2-MHz bandwidth. Subtracting 3 dB to convert the signal from sync tip to blanking level and adding 6.8 dB for noise weighting converts this data to a weighted signal-to-noise ratio of 42.8 dB. Similar tests conducted at a viewing distance equal to four times the picture height resulted in a weighted signal-to-noise ratio of 45 dB to give the same 50% and 90% viewer responses.[7] Later tests at a viewing distance of four times the picture height resulted in a weighted signal-to-noise ratio of 50 dB to obtain the same viewer responses.[8]

While noise weighting attempts to denote equal impairments due to the presence of noise, the effects of the signal-to-noise measured at the output of the RCA VideoDisc player cannot be directly compared with the previously determined signal-to-noise ratio standards. Since the buried subcarrier system employs comb-filtering techniques for video processing, two additional factors must be considered. First, the chrominance signal is converted from 1.53 MHz to 3.58 MHz in the player. The noise in the chrominance signal is the sum of the chrominance noise from midband and any luminance noise at 3.58 MHz. Since the previous noise shapes do not account for this type of processing, viewing test and measurements were conducted to determine a comparison with flat noise data. Secondly, comb filtering a video signal with a 1-H delay line improves the measured signal-to-noise ratio by 3 dB if consecutive scanning lines carry identical picture information. This is because the delayed and undelayed random noise add only on a power basis. While combing improves the measured signal-to-noise ratio by 3 dB, the visibility of combed noise is not reduced by the same amount. Viewing test and measurements were conducted to show that the visible signal-to-noise ratio improvement due to combing is approximately 1.25 dB. Also, the luminance signal is not completely combed due to the addition of the vertical detail signal.[1,4]

The net effect of the previous considerations is that the equivalent visible signal-to-noise ratio of the RCA VideoDisc Player is approximately 2.5 dB less than the measured signal-to-noise ratio at the output of the player. In other words, it would be necessary to measure a signal-to-noise ratio of approximately 45.5 dB at the output of the player in order to obtain performance equivalent to a weighted signal-to-noise ratio of 42.8 dB. As noted previously, this latter value is such that 50% of the viewers at a distance of eight times the picture height would say the noise was just perceptible and more than 90% would say the noise was not objectionable. The worst-case weighted signal-to-noise ratio acceptable at the innermost radius of the disc has been specified to be 46 dB.

5. Relationship between Carrier-to-Noise Ratio and Signal-to-Noise Ratio

As stated in Sec. 2, a trade-off between RPM, λ_{min}, and f_{max} is required to obtain maximum stylus life at a desired level of signal-to-noise ratio. Combining Eqs. [1] and [2] gives

$$S/N = \frac{3}{D}\left(\frac{\Delta f}{f_m}\right)^2 \frac{S_c}{N_c}. \qquad [7]$$

The worst case weighted signal-to-noise ratio acceptable at the innermost radius of the disc has been established at 46 dB, the maximum luminance bandwidth (f_m) has been established at 3 MHz and from Eq. [6] the black-level frequency is established at 5 MHz. The de-emphasis factor, D in Eq. [7] involves a trade-off between picture quality and improved signal-to-noise ratio that will be discussed later. For a fixed black-level frequency, the peak frequency deviation, Δf in [7] is proportional to the frequency chosen for the white level, f_{max}. From Eq. [4] for a given f_{max}, the minimum wavelength, λ_{min}, is proportional to the RPM for a given inner recording radius, R_i. Due to recording, replicating, and pickup apertures a reduction occurs in the carrier-to-noise ratio, S_C/N_C, in Eq. [7] as the wavelength, λ_{min}, is reduced. Thus the trade-offs involved in the solution of Eq. [7] are the selection of D and f_{max}, and also an RPM that is high enough to meet the signal-to-noise ratio requirement but is as low as possible to obtain maximum stylus life.

The choice of the de-emphasis factor, D, affects not only the signal-to-noise ratio but also distortions of the luminance signal caused by pre-emphasis and clipping in the encoder.[4] In general, more spacing between the lower and upper breakpoint frequencies in the pre-emphasis network results in a large improvement in the signal-to-noise ratio. For given values of the pre-emphasis factor, D, and clipping levels, the weighted signal-to-noise ratio can be traded for low-frequency distortions by shifting the breakpoint frequencies up or down. Lowering the breakpoint frequencies improves the weighted signal-to-noise ratio by reducing low-frequency noise, but increases smear in the picture. Increased smear occurs because the lower-frequency components with relatively high signal amplitudes become more pre-emphasized and clipped causing a loss of rise time. Increasing the breakpoint frequencies reduces the smear but also reduces the weighted signal-to-noise ratio. Similarly, for a fixed low-frequency breakpoint and clipping levels, the weighted signal-to-noise ratio can be traded for high-frequency distortions by shifting the upper breakpoint frequency up or down. Raising the upper breakpoint frequency improves the weighted signal-to-noise ratio but reduces the contrast of small details in the picture, since the higher frequency components become more pre-emphasized and clipped causing a deterioration in rise time.

The choice of the de-emphasis factor, D, in Eq. [7] involves a compromise between weighted signal-to-noise ratio and both low-frequency and high-frequency distortions in the picture. In the RCA VideoDisc system, the luminance signal is pre-emphasized approximately 12 dB using a double breakpoint network with R-L time constants of 0.64 microseconds and 0.16 microseconds, respectively. In addition, a linear pre-emphasis of approximately 9 dB is used between 1.0 and 3.0 MHz. The luminance clipping levels are set at −66 IRE units in the direction of sync and +140 IRE units in the white direction. The calculated de-emphasis improvement factor, D, for these choices is 14.8 dB.

Fig. 1 shows the reduction in carrier-to-noise ratio, S_C/N_C, in Eq. [7] as the wavelength, λ_{min}, is reduced. The carrier-to-noise ratio was measured using a spectrum analyzer with a 30-kHz bandwidth. The data were taken from noncoated discs[9] recorded with an electromechanical recorder.[10] Note that the carrier-to-noise ratio is essentially flat from 1.5 to 1 μm and decreases about 6 dB per octave from 1 to 0.5 μm. The

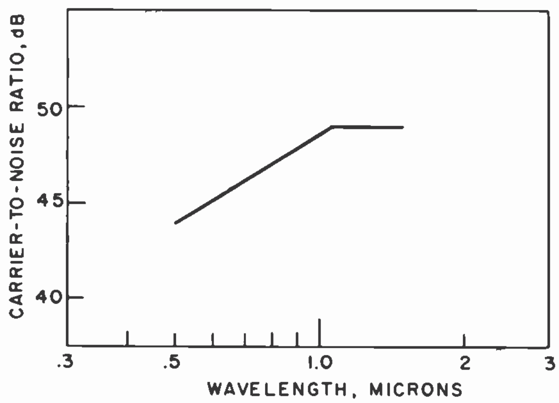

Fig. 1—Carrier-to-noise ratio versus wavelength at 2.9-inch radius for noncoated discs measured with a spectrum analyzer in a 30-kHz bandwidth.

data have been corrected to show the carrier-to-noise ratio that would be measured at the inside radius of a disc. The carrier-to-noise ratio measured at the outside radius of the disc would be approximately 3 dB higher due to the doubling of the stylus-to-disc velocity caused by the doubling of the radius, as can be seen from Eq. [3].

At a given radius, for both fixed playing time and recorded area, the carrier-to-noise ratio measured in a given bandwidth is independent of the RPM assuming the groove pitch is adjusted according to Eq. [5]. For example, assume that under these conditions the RPM of a disc is doubled. From Eq. [5] the groove pitch would be reduced by one-half. In order to play the narrower groove, the stylus width would have to be reduced by one-half. The decrease in the detected signal amplitude due to the narrower groove and stylus would be 6 dB. Since the noise is incoherent across the groove, the decrease in the noise under these same conditions is 3 dB. However, since RPM and thus the velocity have been doubled, disc noise per unit bandwidth is further reduced 3 dB resulting in no change in the carrier-to-noise ratio apart from aperture effects. While the carrier-to-noise has not changed, it can be seen from Eq. [4] that doubling the RPM will double the wavelength for a given frequency at a given radius. As shown in Fig. 1, if the wavelength change is in the range from 0.5 to 1.0 μm the carrier-to-noise ratio will increase due to the increased wavelength. One further note on this example is that doubling the RPM causes the stylus width to be reduced by one-half, which will reduce the life of the stylus as determined by the volumetric wear rate and make the stylus more susceptible to damage by disc imperfections.

From the previous example, it can be seen that the carrier-to-noise ratio data shown in Fig. 1 can be used to make the trade-offs involved in the solution of Eq. [7] at various values of RPM, and that the desire to maximize stylus life will affect the choice of other system parameters. In general, the calculations involved in the solution of Eq. [7] are lengthy. However, if the simplifying assumption is made that the noise into the FM demodulator is white, then it is possible to make some relatively simple calculations. In general, these calculations have shown reasonably good agreement with measurements from noncoated discs.

The noise in the video signal from a disc is normally measured in the vertical blanking interval at black level. Using a black-level frequency of 5 MHz, an inside radius of 2.9 inches, a RPM of 450, and the proper conversion constants, Eq. (4) gives a wavelength of approximately 0.69 μm. From Fig. 1 the carrier-to-noise ratio measured in a 30-kHz bandwidth using a spectrum analyzer is approximately 46.2 dB. Table 1 summarizes the calculations leading to the unweighted luminance only peak-to-peak signal-to-rms noise ratio. Line 2 represents a spectrum analyzer correction factor to account for the fact that the noise bandwidth of the analyzer is wider than the 3-dB bandwidth and for an inherent error in log amplifiers when measuring noise. Line 5 is the FM improvement factor where $\Delta f = (f_{white} - f_{sync})/2 = (6.3 - 4.3)/2 = 1$ MHz. Line 7 represents the solution to Eq. [7]. Lines 8 and 9 convert line 7 to the ratio of peak-to-peak signal to rms noise as measured from blanking to white definition of signal-to-noise ratio. Line 10 represents the improvement in the measured signal-to-noise ratio due to combing, which is less than 3 dB due to the addition of the vertical detail signal to the combed luminance signal as previously discussed. Line 11 may appear to be a low value for the unweighted luminance signal-to-noise ratio, but it should be noted that the noise distribution of the RCA VideoDisc System is such that the CCIR weighting factor is higher than that for a system with this same value that has a flat noise spectrum.

Table 1—Unweighted Luminance Calculations

Line No.	C/N and S/N Calculations	Description
1	46.2 dB	C/N ratio in 30 kHz BW
2	−1.7 dB	Spectrum analyzer error
3	−23.0 dB	Conversion to 6 MHz BW
4	21.5 dB	10 log S_c/N_c Eq. [7]
5	−4.8 dB	10 log 3 $(\Delta f/f_m)^2$ Eq. [7]
6	14.8 dB	10 log $1/D$ Eq. [7]
7	31.5 dB	rms S/N ratio, 10 log S/N Eq. [7]
8	+9.0 dB	Conversion from RMS to p-p
9	−3.0 dB	Conversion to blank to white
10	+2.2 dB	Combing improvement
11	39.7 dB	Unweighted luminance only p-p signal to rms noise

However, before a value for the weighted signal-to-noise ratio at the output of the player can be obtained, it is necessary to consider the noise contribution from the chrominance signal.

It can be shown that the signal-to-noise power ratio, $(S/N)_{sc}$, for a subcarrier measured in a narrow bandwidth (i.e., 30 kHz) is given by[3]

$$(S/N)_{SC} = \frac{1}{2}\left(\frac{\Delta f}{f_{sc}}\right)^2 \frac{S_c}{N_c}, \qquad [8]$$

where S_c/N_c is the video carrier-to-noise power in a 30-kHz bandwidth, Δf is the peak chrominance deviation, and f_{sc} is the chrominance subcarrier frequency of 1.53 MHz. Table 2 shows the calculations for the unweighted chrominance signal-to-noise ratio. The first two lines are similar to the luminance calculations in that the carrier-to-noise ratio is obtained from Fig. 1 for a 0.69 μm wavelength and corrected for noise measurement errors in the spectrum analyzer. Line three is the video carrier-to-noise power, S_c/N_c, shown in Eq. [8]. Line 4 is the FM improvement factor. In the buried-subcarrier system the chrominance subcarrier is increased 2.7 times the NTSC value to improve the final signal-to-noise ratio. In the encoder, this enhanced chrominance signal is added to the pre-emphasized luminance signal to form the composite buried-subcarrier signal. The composite signal is then clipped at +144 IRE units and −70 IRE units to prevent over deviation of the FM modulator.[4] In order to calculate the FM improvement factor, a chrominance signal within this linear range will be considered (e.g., 50 IRE units peak-to-peak). Increasing this signal 2.7 times results in an enhanced chrominance of 135 IRE units, which corresponds to a peak-to-peak FM deviation of approximately 1.92 MHz. Substituting a peak deviation, Δf, of 0.96 MHz and a subcarrier frequency, f_{sc}, of 1.53 MHz into Eq. [8] results in an FM improvement factor of −7 dB for the 50 IRE peak-to-peak chrominance signal. However, the definition of signal-to-noise ratio is based on a measurement from blanking to white level,

Table 2—Unweighted Chrominance Calculations

Line No.	C/N and S/N Calculations	Description
1	46.2 dB	C/N ratio in 30 kHz BW
2	−1.7 dB	Spectrum analyzer error
3	44.5 dB	Actual video C/N in 30 kHz BW
4	−1.0 dB	10 log ½ $(\Delta f/f_{sc})^2$ Eq. [8]
5	43.5 dB	10 log $(S/N)_{sc}$ Eq. [8]
6	−15.2 dB	Conversion to 1 MHz BW
7	28.3 dB	rms chroma S/N ratio
8	+9.0 dB	Conversion from rms to p-p
9	+3.0 dB	Combing improvement
10	40.3 dB	Unweighted chroma only p-p signal to rms noise

which corresponds to 100 IRE units. Thus, a correction factor of 6 dB is added to this calculated value, which results in the −1 dB value shown in line 4 of Table 2. Line 5 represents the solution to Eq. [8]. The remaining conversion factors are similar to those explained for the luminance calculation and result in the unweighted chrominance-only signal-to-noise ratio shown in line 10.

The unweighted composite signal-to-noise ratio is obtained by adding the unweighted noise power of the luminance in Table 1, −39.7 dB, to the unweighted noise power of the chrominance in Table 2, −40.3 dB, resulting in a value of −36.9 dB. Applying the CCIR weighting function to the noise spectrum of the RCA VideoDisc results in a 9.1 dB improvement. Thus, the worse-case weighted signal-to-noise ratio measured at the inside of the disc would be 46 dB. Note that this is the value established by the specification and is equivalent to being 0.5 dB above the value where over 90% of the experienced viewers said the noise in the picture was not objectionable.

If the calculations shown in Tables 1 and 2 are repeated for various f_{max} and RPM while maintaining the black level fixed at 5 MHz, then the results shown in Fig. 2 are obtained. The values of RPM shown result in an even number of TV fields being recorded on the disc. It appears from Fig. 2 that both increased stylus life and the desired weighted sig-

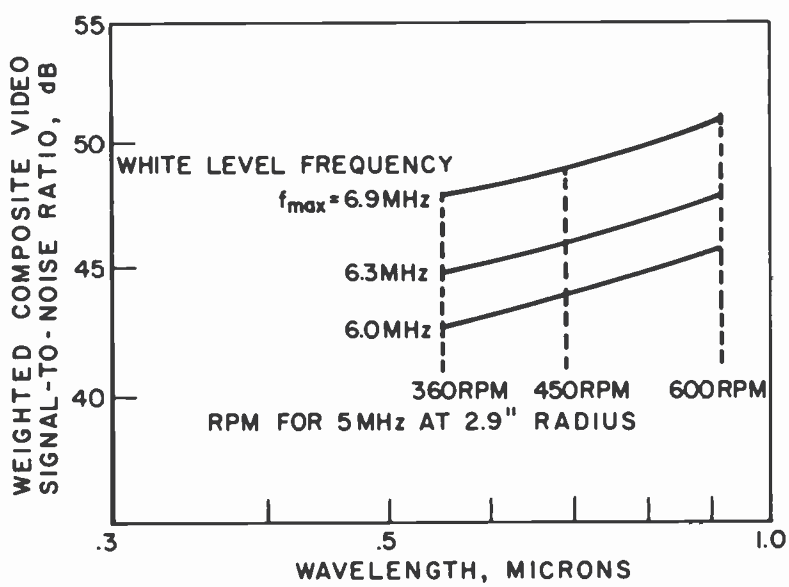

Fig. 2—Calculated weighted composite video signal-to-noise ratio at black level frequency versus wavelength at 2.9-inch radius for various white-level frequencies and RPM.

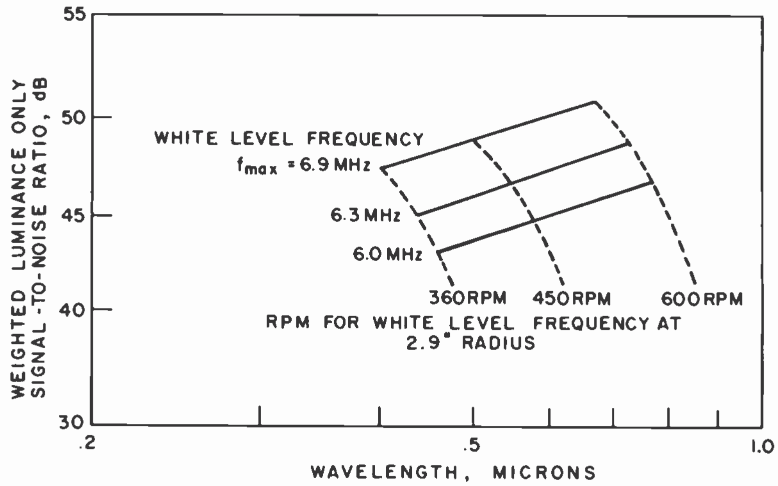

Fig. 3—Calculated weighted luminance-only signal-to-noise ratio at white-level frequencies versus wavelength at 2.9-inch radius for various RPM and white-level frequencies.

nal-to-noise ratio of 46 dB could be obtained by choosing the parameters of 360 RPM and a white level of approximately 6.9 MHz. This is somewhat misleading, however, since the wavelengths shown were calculated for the black-level frequency. Fig. 3 shows the effect of calculations made for the luminance-only weighted signal-to-noise ratio for wavelengths at the white-level frequencies. No specification exists for this ratio, but the calculations are useful in showing some of the tradeoffs involved in the choice of the system parameters. A luminance-only-weighted signal-to-noise ratio of 47 dB approximately corresponds to the previously specified composite value of 46 dB. The figure shows the reduction in minimum wavelength, λ_{min}, that would occur at 360 RPM in order to achieve a weighted luminance signal-to-noise ratio of 47 dB. Tests have shown that signal loss in a player increases and that disc manufacturing margins are reduced as the wavelength is reduced below approximately 0.5 μm, which makes the choice of 360 RPM undesirable.

Fig. 3 shows that a luminance-only weighted signal-to-noise ratio of 47 dB could also be obtained with a white-level frequency of 6.0 MHz and 600 RPM. While this would result in larger wavelengths, the increased number of grooves to obtain the same playing time as the lower RPM systems would result in reduced stylus width and a costly reduction in stylus life.

Fig. 3 also shows that with the present parameters of 450 RPM and a white level of 6.3 MHz, the weighted luminance-only signal-to-noise ratio is approximately equal to the 47 dB level. It may appear desirable to increase the white level to 6.9 MHz in order to provide more margin; however, there are several considerations involved in such a decision. From Fig. 3 it can be seen that for 450 RPM, raising the white level to 6.9 MHz will decrease the wavelengths at the inner radius to approximately 0.5 μm which will increase the risk of signal loss in the player and reduce the disc manufacturing margins. In addition, wavelengths are further reduced due to pre-emphasis which extends approximately 0.6 MHz above white level. As stated previously, it is expected that the carrier-to-noise ratio shown in Fig. 1 will improve with production, so that the present parameters provide sufficient margin.

6. Conclusions

The carrier-to-noise ratio data shown in Fig. 1 can be used to make trade-offs between f_{max}, λ_{min}, and RPM to obtain a desired value of the weighted video signal-to-noise ratio as shown in Figs. 2 and 3. For maximum stylus life, the RPM should be chosen as low as possible consistent with manufacturing margins and loss of signal performance in the player caused by wavelengths smaller than approximately 0.5 μm. It appears that the existing system parameters are compatible with the present state of the art in noncoated disc materials, recording, mastering, and manufacturing.

Acknowledgment

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