NTSC AND BEYOND

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ABSTRACT

Two recent technological developments of considerable significance have led to the critical reevaluation of the NTSC standard as an adequate public television service. These two developments were: (a) the rapid proliferation of a variety of HDTV proposals, and (b) the emergence of low-cost frame memories for home receivers. This critical reevaluation, which the author conducted in the course of his own research work, led him to the unavoidable conclusion that NTSC is indeed capable of rivalling HDTV image quality under certain conditions, and these are:

1. That today's much better understanding of the fundamental principles of color television be put to optimal use, and

2. That the advanced technology tools developed primarily for HDTV systems be applied in an equally innovative manner to the NTSC environment.

The proposal being made by the author is that this improved NTSC which he calls SuperNTSC (Trademark pending) can fulfill the need for a superior television system that does not require extra bandwidth for transmission, a new subcarrier for additional information, or any new signals "buried" or interleaved in the existing NTSC spectrum. What is even more important, this system is fully forward and reverse compatible with NTSC today and tomorrow.

The author also recommends that other HDTV proposals that do use wider transmission channels and/or extra subcarriers be considered for broadcasting only after all of the potential improvement options for a compatible NTSC have been fully examined and exploited, especially those that take into account emerging "smart" receivers with built-in flexible architecture which can greatly enhance the home display side of the NTSC of the future.

This paper deals with some of the more important details of this proposal for a SuperNTSC system that goes well beyond current NTSC performance characteristics.

INTRODUCTION

The major technical impact of the frequent demonstrations of various high definition systems at television conferences and equipment shows, all over the world, has been to motivate research and development engineers to more critically reexamine the existing color television systems now serving the public. In the NTSC areas of the world, where over 200 million home receivers represent almost 60% of the global color receiver population, the widespread adoption of an incompatible high definition television system is inconceivable, and fully precluded by social constraints.

That fact alone has led to a variety of research efforts to explore the ways in which the basic NTSC system can be improved to its maximum potential, particularly when some of the new technology developed for HDTV has a beneficial effect when it is tailored to NTSC requirements.

NTSC has indeed been both a commercial and technical success when one looks at it in a historical perspective. It has, and continues to provide the least costly color receivers for the largest number of users, and that with the the smallest transmission spectrum (6 MHz) of all existing color systems.

While a number of new techniques have sprung up for handling TV signals within the studio or production center (analog component, digital, etc.), the final product that goes on air or over cable is still the classical encoded NTSC. Continued international adherence to a set of well defined rules about the NTSC signal, in a manner that maintains full reverse compatibility with the existing NTSC receivers, should be the first goal of any future system dedicated to delivering better pictures into the home.

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STRENGTHS & WEAKNESSES OF THE NTSC STANDARD

The basic NTSC standard that we have been using for more than three decades has three fundamental advantages:

1. **There is a vast distribution network already in place covering 32 countries with over 200 million receivers.**

2. **It uses the least of our most precious resource, spectrum space, needing only a 6 MHz channel.**

3. **The basic benefits of the NTSC encoding process are almost self-evident.**

It makes the most efficient use of the available spectrum through the interleaving of the luminance and chrominance signals (Figs. 1 and 2). It was, and continues to be, fully compatible with monochrome television. It is the simplest of the three color television systems (NTSC, PAL and SECAM) in use today, because it does not use phase-line alternation or multiple subcarriers. This inherent simplicity makes it the most cost-effective system in use as well. Hundreds of millions of viewers, who live in those countries where NTSC is the national color standard, already receive acceptable quality color images in their homes via NTSC transmissions.

However, the present NTSC system also has 3 basic weaknesses which must be corrected, if an image quality comparable to HDTV is to be achieved. These deficiencies are:

1. **Monochrome limitations, visible line structure (525 lines, 2:1 interlace), and poor vertical and horizontal resolutions,**

2. **NTSC encoding limitations, especially those relating to intermodulation between luminance and chrominance,**

3. **Gamma problems that usurp the constant luminance principle for perfect image rendition.**

The techniques described in this article greatly reduce the impact of these problems, to the extent that the final NTSC image will appear on an improved home-viewer set as a full bandwidth, 1050 lines RGB image, emulating an HDTV display.

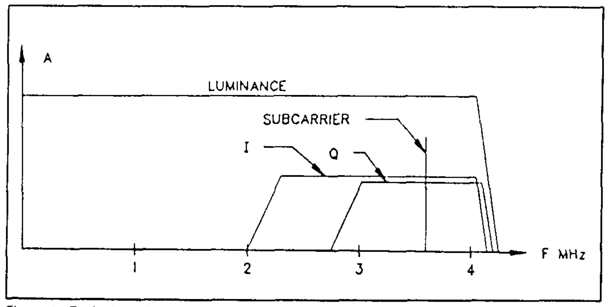

Figure 1. Typical quadrature modulated color television spectrum (NTSC).

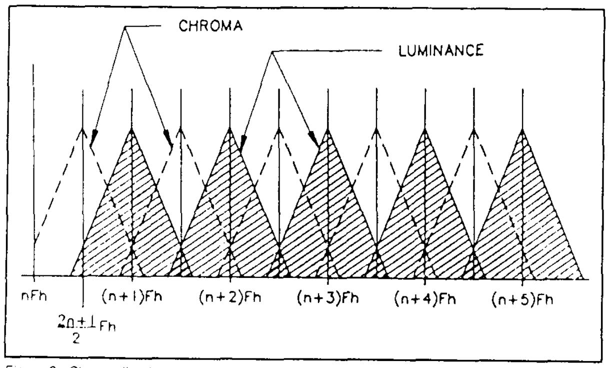

Figure 2. Chroma/luminance spectrum in the vicinity of the subcarrier.

1. LINE STRUCTURE VISIBILITY & RESOLUTION

The inherent weakness of a 525 line, 2:1 interlace television system is the line structure visibility. Many other researchers have proposed means to alleviate this problem, while improving the vertical resolution as well, and these proposals can be found in the literature (Ref. 11, 17, 21, 22).

The combination of some of the processes listed below can lead to a practical compromise where line structure and vertical aliases are no longer detectable. These are:

1. **525 lines, 30 Hz progressive scan at the camera,**

2. **30 Hz progressive scan to 2:1 interlace, 60 Hz conversion,**

3. **Use of a frame store in the receiver to transcode a 525 line, 2:1 interlaced image into a 60 Hz display with 1050 lines and 2:1 interlace.**

If progressive scan is used in the camera, vertical interpolation is made easier in the line doubler, and an apparent vertical resolution of the order of 440 lines is observed without visible artifacts (ragged or "stepped" diagonal transition). The subjective results are close to those obtained with HDTV systems.

In the horizontal domain a frequency response of 4.2 MHz is certainly not satisfactory. The subjective sharpness, however, may be significantly improved by the combination of 2 techniques: detail processing in the encoder luminance path, and spectrum expansion in the decoder.

Detail Processing

If small detail levels are increased (Ref. 25) without modifying large transitions, the broadcast information will appear to be of a wider bandwidth than 4.2 MHz, even though measurements at 0 to 100% transitional levels will not exhibit an increase in resolution.

Bandwidth Expansion

In the receiver, it is desirable to shorten the rise time of large horizontal transitions without introducing pre-shoots and overshoots in order to simulate a wider bandwidth. This is accomplished through multiplicative enhancement (Ref. 4).

The combined result of these 2 techniques leads to an apparent bandwidth increase in a ratio of 1.8, as has been proven by numerous subjective tests. This is equivalent to a 7.5 MHz bandwidth at 525 lines, or 15 MHz at 1050 lines, and is not too far from results obtained with wideband HDTV systems, particularly if one takes into consideration the different aspect ratios involved.

2. NTSC LIMITATIONS

A modern broadcast-quality color camera, properly balanced and registered, looking at a well-lit scene, will produce an excellent RGB image essentially matching all of the psychophysical attributes of the human eye. Fine detail, precise colorimetry, and low noise make these studio pictures a highly satisfactory rendition of the original image.

The passive matrixing of these RGB signals into the luminance and baseband color difference chrominance components also imposes no burden of spurious contamination between these two channels, and, in fact, if the signals are kept in analog component form for distribution and dematrixed for display, the results would look virtually identical to the RGB source.

However, to accommodate the need for a single-channel transmission path, conventional NTSC makes use of the band-sharing principle in which the luminance and chrominance components are multiplexed or encoded into a single signal, and where the separation of the two principal components is maintained by the frequency interleaving process (Fig. 2). The NTSC composite signal, which emerges from a standard encoder (Fig. 3), has three distinct deficiencies in descending order of importance, as follows:

1. Cross color

2. Cross luminance

3. Limited chroma bandwidth

If all signal transitions in the image were either horizontal or vertical, the interleaving process would adequately avoid any unwanted interference between the two components. Vertical-domain transitions have no high-frequency luminance information in them, so they do not interfere with the chrominance spectrum. Horizontal-domain transitions can be easily separated on a monitor with a comb filter, because the luminance information is at even multiples of half the line frequency, while the chrominance

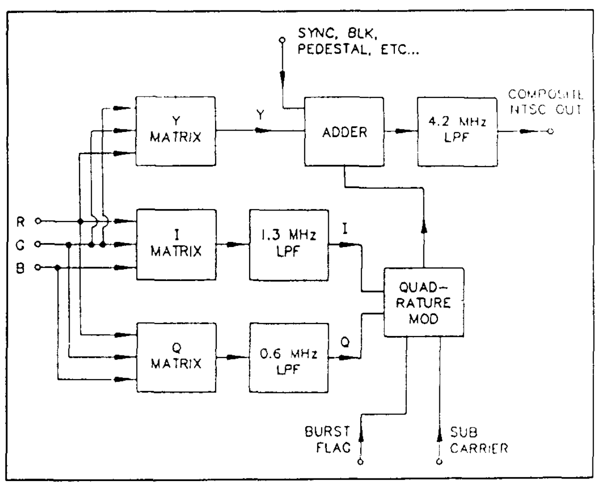

Figure 3. Typical NTSC encoder

information is at odd multiples. (Vertical-domain transitions appear on the screen as horizontal border lines between zones of difference brightness, and horizontal-domain transitions appear as vertical lines.) However, on real images there are diagonal transitions where the chroma and luminance signals share some spectrum, and this interference creates some unwanted artifacts.

Cross Color

The major deficiency produced by this spectral overlapping of chroma and luminance is cross color, which is perhaps the worst degradation of the NTSC signal. Its visual effect on the viewed image can best be described as a disturbing rainbow pattern in parts of the image where diagonal high-frequency luminance information is present. Johnny Carson's striped shirt, or his houndstooth sports jacket, is a good example of this annoying NTSC phenomenon.

The subliminal effect of this NTSC deficiency is also a factor in the psychophysical domain. Since NTSC is a four-field sequence, the phase of cross-color interference switches 180 degrees every other frame. Stationary objects in the image will therefore flicker at half the frame rate (15 Hz), a frequency which is well above the threshold of human eye comfort. As a result this flicker will contribute to long-term viewing fatigue.

Ironically, cross color in NTSC has been getting worse over the years, mainly because color cameras have been much improved. Early cameras produced "softer" color images because they did not have the modulation transfer function (MTF) capability at high-luminance frequencies that modern cameras have today. As a result, the effects of cross color were not then as noticeable as they are today.

Today, with cameras having a frequency response extending beyond 7 MHz and computer-generated images which generate very fast rise-time transitions at all angles, the results of the cross color produced are both highly visible and very disturbing to the viewer. Since cross color is generally perceived to be the most detrimental subjective aspect of NTSC, reducing or eliminating it will contribute greatly to improving the overall image performance of the system.

Cross Luminance

The second level of unwanted NTSC artifacts is cross luminance, previously referred to as the "hanging dot" pattern. This is only visible with a comb filter decoder, which mistakes the chroma at vertical domain transitions to be luminance information, and displays it as one or two lines of dots at 3.58 MHz. While cross luminance is visually much less objectionable than cross color, it is nevertheless an indication, to a trained observer, that the reproduced image is not RGB, and every effort to minimize or eliminate it is warranted.

Chroma Bandwidth

The third level of NTSC degradation, which is the least objectionable because of the limitations of the eye, is the result of the limited bandwidth imposed by the system in the chroma channels, namely, 1.3 MHz in the I channel, and 0.6 MHz in the Q channel. These purposely narrow chroma channels produce a visible loss of resolution for highly saturated chroma transitions. The effect can be masked by a clean luminance transition at the same point. However, the effect is very noticeable at a sharp vertical juncture between highly dissimilar colors. The transition from the green to the magenta bar in a standard color-bar pattern will vividly show the effect of the slow decay of green and the even slower rise of magenta. During the transition the subcarrier modulation dot pattern is also quite noticeable.

In summary, the three successive degradations of conventional NTSC, which are easily detected by television engineers, have in fact been tolerated by viewers. The human brain tends to adapt to these visual deficiencies as being "normal," and over repeated long-term exposure will psychologically suppress any conscious antipathy to such images. However, the brain has to work subconsciously to do this, and that creates fatigue in watching NTSC, as compared to watching an artifact-free RGB image.

The aim, therefore, is to eliminate the NTSC disturbances that cause a high level of subconscious activity for subliminal suppression by the viewer, and to achieve a high-quality, noise-free image that closely approximates the RGB original in the studio. Modern components and innovative circuitry now make that goal possible.

Removing NTSC Limitations

While much can be done in the NTSC system with the use of complex decoders to eliminate some of the artifacts generated in a conventional encoder, there are some practical limits to that process. Even a complex decoder cannot fully separate two spectra which have been superimposed in the multiplexing process; therefore, the solution must lie in modifying the encoding process. NTSC parameters, as defined by the original developers, do not restrict the processing of the encoder input component signals in any way that might make them easier to separate at the decoding processing.

A "two-wire" NTSC system, in which luminance and chroma are kept separate, does in fact produce an artifact-free image. We therefore propose to treat the three dimensions (horizontal, vertical, and time domain) of the video signal in such a manner as to prepare the NTSC-encoded signal, so that the subsequent decoding process will produce a result equivalent to the "two-wire" approach. Laboratory experiments to date have shown that the method described below can come very close to the desired ideal.

We will deal first with what is currently practical and concern ourselves only with the horizontal and vertical domains of NTSC that can be improved by intelligent signal manipulation.

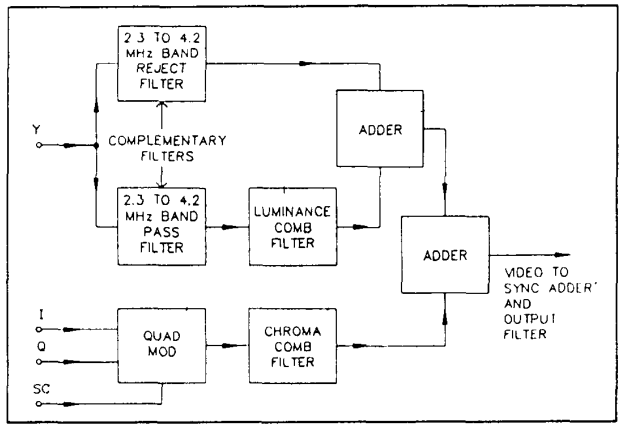

Figure 4. Improved encoder.

THE 2H ENCODER

The key to an improved encoder is to prevent the spectral overlap produced in a conventional encoder (Fig. 3) by prefiltering the luminance and chrominance information through comb filters prior to addition (Fig. 4). This bidimensional manipulation in both the horizontal and vertical domain significantly reduces the overlap area between the interleaved signals (Fig. 5). The luminance information is precombed between 2.3 MHz and 4.2 MHz so that it will not interfere with chrominance frequencies resident in that spectrum. The chrominance is also combed by a filter that averages it over a number of lines, thus reducing the "hanging dot" pattern.

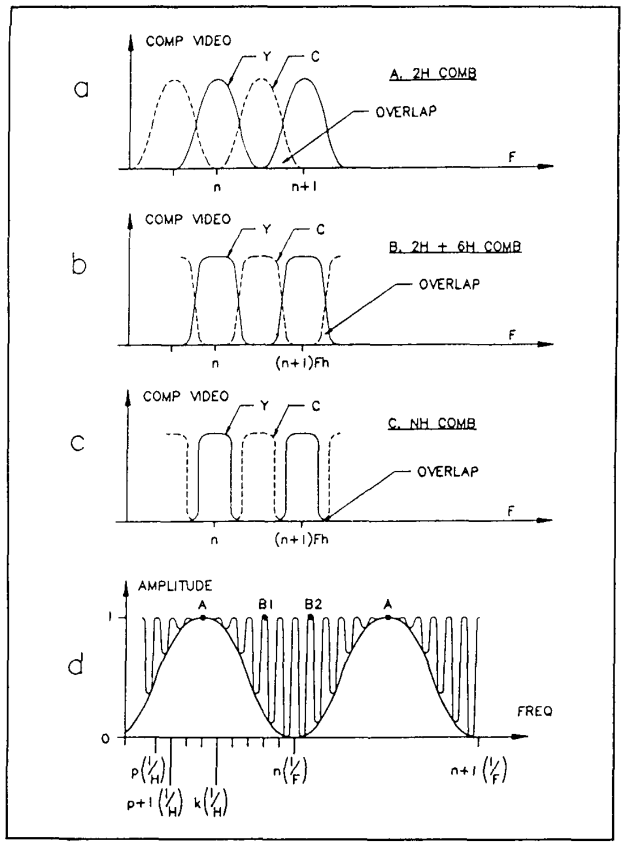

Figure 5. Different comb filter and Y/C spectral overlap configurations in encoder.

These comb filters can be of different complexities (Fig. 5a) starting with 2H structures and increasing the number of delay paths to achieve greater intermodulation rejection. In practice the trade-off between a 2H comb and one with more delay lines is a matter of cost-effectiveness, circuit complexity, and marginally-improved performance.

The present system uses 2H combs throughout so as to adequately meet economic constraints, even though some residual cross color could be further reduced by a more complex, multiline comb filter. Figure 6 shows an experimental 2H+6H comb filter where the luminance and chroma component signals are made to look more like square waves (Fig. 5b), thus greatly diminishing the overlap area where the undesirable intermodulation is generated in the encoder. The process can even be carried beyond 6H, as shown in Fig. 5c, where 11 and 13 line delays have been simulated to totally separate luminance and chroma signals going into the encoder's adder and quadrature modulation circuits. Note that both NTSC and PAL color systems use similar encoding techniques, therefore the principles described in this paper for NTSC can apply with some modification to PAL. However, for the sake of simplicity, this article will deal only with the NTSC improvements that have been achieved.

The current encoder, using 2H comb filtering and precise passband for the luminance and chrominance information, produces an output NTSC composite signal in which the cross-color and cross-luminance artifacts have been greatly reduced. Coupled with symmetrical 2H comb filter decoding in the monitor or home receiver, the results can come very close to the original RGB input.

NTSC SYSTEM IMPROVEMENT

The degree of overall improvement for the home viewer achieved by this new approach to NTSC encoding will depend to some degree on the type of decoder in the home receiver. The new encoder is completely compatible with existing NTSC, and even a low-cost TV set employing a simple notch filter or subcarrier trap at the color frequency of 3.58 MHz will show some improvement in the transmitted image. Cross-color artifacts will still be visible on vertical luminance lines, but the encoder comb filtering process will virtually eliminate them at 45 degrees, thus reducing greatly the 15-Hz flicker. The overall impact on picture "quietness" is quite significant, and this improvement in existing minimal-performance TV sets is a welcome one, at no cost to the viewer.

High-quality, large-screen home receivers

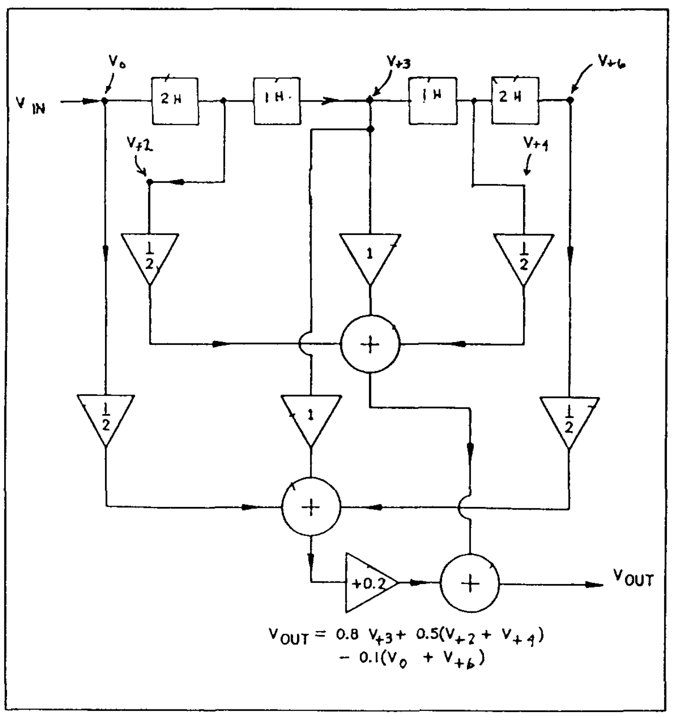

Figure 6. A 6H comb-filter structure.

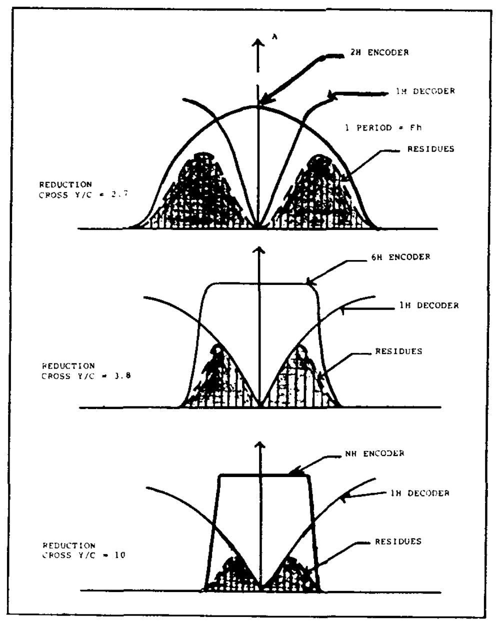

Figure 7. Cross-Y and cross-C levels reductions at the outset of a 1H comb decoder with different encoder comb-filter configurations.

now come equipped with one-line glass delay comb filters to show a better image on conventional NTSC. The combination effect of a 2H encoder and a 1H decoder is shown at the top of Fig. 7, and gives the cross-color reduction factor as 2.7. Increasing the encoder to 6H, or even more, as shown in the lower diagrams on Fig. 7, can improve the cross-color reduction factor to 3.8 for 6H and 10 for 11H.

Even with only a one-line comb filter in the decoder, the measurable reduction of cross color is very significant, and subjectively it is quite visible. High-quality broadcast decoders already use 2H comb filters, and there is no doubt that future NTSC home receivers will also adopt them.

In the 2H decoder the cross-color reduction factor is substantially improved, as shown in Fig. 8. This time the symmetrical combination of 2H combing in the encoder and decoder yields a factor of 6.0, and increased filtering in the encoder further raises this to 10 and 16 respectively.

It should be pointed out that all of these processes are nonadaptive, and since nothing is done in the time domain, there are no motion problems. Further improvements in the system could be achieved by employing adaptive techniques compensating for residual artifacts.

CHROMINANCE NOISE

One of the unexpected benefits that came out of this new encoding technique was the considerable improvement of the chrominance signal-to-noise ratio (SNR), particularly in low-luminance-level scenes. In a conventional encoder without prefiltering, what appears as chrominance noise is actually a combination of high-frequency luminance noise injected into the chrominance channel. The triangular noise spectrum shown in Fig. 9 illustrates the typical rising noise characteristic in color cameras for the matrixed luminance signal. The luminance noise contribution is substantial around the color subcarrier frequency. By contrast, color noise is inherently limited by the narrow bandwidth of the chrominance channels.

The degree of improvement in the chrominance noise figure is related to the noise level in luminance and therefore can range from a high of 15 dB, with really poorly lit images, to very little when a clean luminance signal is coming from a high-brightness scene. Between these extremes the more typical result, when using the 2H encoder and 2H decoder on any dark scenes,

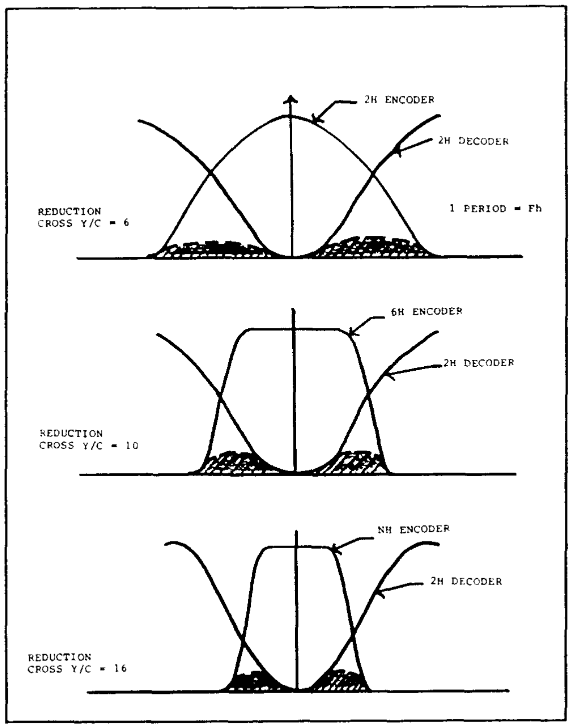

Figure 8. Reduction in cross-color and cross-luminance levels at the output of a 2H comb decoder with different encoder comb-filter configurations.

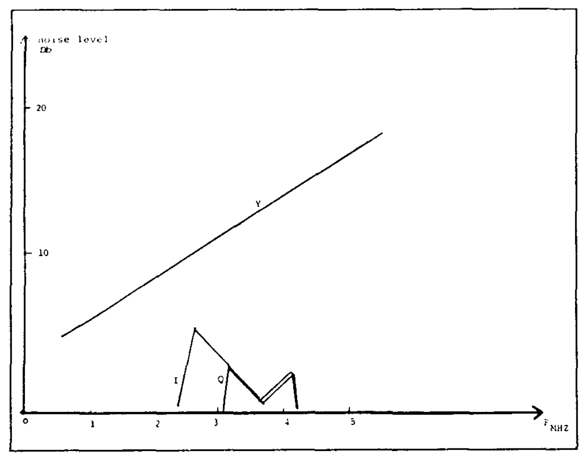

Figure 9. Contribution of luminance and chroma channels to overall chroma noise figures.

is a very substantial 12-dB chrominance SNR improvement. It is interesting to note that this was not a goal of the original experiments in the improvement of NTSC encoding, and when first noticed was regarded as some unexplained "serendipity" in the system. Later, more critical analysis of the effect with live color cameras showed repeatedly that the chrominance SNR did indeed improve when the luminance noise was filtered out of it. The total effect is that noise coming from dark scenes in the luminance channel is prevented from modulating the chrominance channel by the special filters in this encoder, while conventional encoders allow the noise to pass through.

LIMITATIONS OF NEW ENCODING PROCESS

While the overall performance of the new encoder is substantially better than that of a conventional encoder, there are some limitations that should be explained. There is a small loss of diagonal resolution in the luminance path because the information above 2.3 MHz is averaged over three lines. However, for receivers using notch-filter decoders, there is little useful information above 2.3 MHz, so there will be no loss of diagonal information and no visible effect of this limitation. If a 2H comb filter decoder is used, the rise time of diagonal transitions will be degraded by 16%, giving a small reduction of modulation depth at 45 degrees, which works out to be the spatial equivalent of a 3.5-MHz bandwidth as compared to a normal 4.2 MHz. This limitation can be diminished if the 6H or NH delay-line systems are used, but the economic trade-off is not adequate to offset this small, highly selective loss of resolution. Adaptive approaches in the 2H encoder are more practical than the use of multiple delay lines.

Of course, time domain (Fig. 5d) processing in the encoder would also eliminate artifacts if a corresponding symmetrical process was taking place in the decoder as well, but would be of no use with present day decoders using only space-domain manipulation.

It is therefore not practical, in the present technical context, to use time-domain processing in the encoder, and another solution has to be found.

Purely passive encoding and decoding techniques reduce the cross-luminance effect, but do not eliminate it. The computation for this suppression characteristic of cross luminance for a 2H encoder and 2H decoder shows a reduction of 12 dB. This renders the "hanging dots" hardly visible on the screen. It is rare to have a color transition in program material that accentuates the effect of cross luminance, therefore for all intentional purposes the 12-dB reduction is adequate. There are some instances where matting or other video processing is being done, where the 12-dB reduction may not be adequate. Other small limitations in the chroma path with nonadaptive approaches include some loss of vertical chroma resolution due to the averaging process (3H or more) and a small loss of chroma horizontal resolution due to basic NTSC characteristics.

Therefore, the decoder has adaptive characteristics which include four distinct logic levels that eliminate some of the remaining lower-order deficiencies. To understand this processing in the 2H decoder requires that the decoder architecture be described in detail.

The basic diagram of the decoder is represented in Fig. 10 and is very simple. The chroma is comb-filtered, then subtracted from video to provide luminance. Demodulated I and Q components are matrixed with the Y signal to provide RGB and YIQ outputs (or Y, R-Y, B-Y).

THE 2H DECODER

The chroma processing includes a 2H comb filter and four layers of adaptive logic circuitry responding to those residual defects which cannot be fully processed by purely passive circuitry. The four levels of adaptive logic include:

1. A means of further reducing the "hanging dot" pattern,
2. Variable bandwidth control in relation to picture changes,
3. Non-linear processing with 45 degree logic circuitry,
4. Chroma bandwidth expansion to sharpen chroma transitions.

To reduce the effect of the cross-luminance "hanging dot" effect, the decoder circuitry for the luminance path includes a vertical logic circuit which detects the presence of a chrominance transition and changes the combing coef-

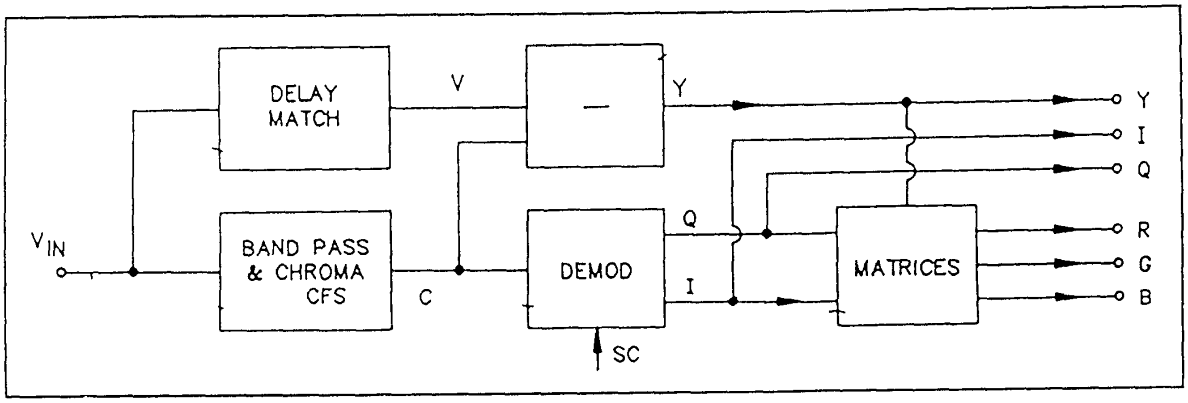

Figure 10. Improved decoder.

ficients in the decoder in a continuous fashion so as to optimize the combing action at all times. The decoder does not switch to a notch filter or static comb under these conditions, but applies continuous dynamic combing as a function of a varying signal.

The second logic function applied in the horizontal domain of the 2H decoder involves the constant manipulation of the bandwidth of the chrominance circuit. There are two basically contradictory requirements for the bandwidth of the decoder: a wideband channel to allow for clean, sharp chrominance transitions and a narrow bandwidth to reduce both chroma noise and cross color. Of course, these requirements change in relation to the actual picture material, so this logic in the decoder selects a wider bandwidth when there is a high-level chrominance transition. Obviously when these large chroma transitions occur, maximum bandpass is a first-order need, and noise and cross color are only second-order effects. The logic therefore caters to the primary need. When chroma levels are low and there are no large transitions in the signal, the logic imposes a narrowband condition. Low chroma with minor transitional activity is easily polluted by crosstalk, and limiting their visibility improves the overall image.

There is also a beneficial effect to this process, which comes from the fact that the combed chroma is used to generate combed luminance by subtracting the combed chroma from the composite video signal. A precise subtractive process at this point produces the best possible luminance signal. By directing the circuit to its maximum wideband mode at transitions, there will be no dot crawl in the horizontal domain, as well as in the vertical. This adds one more positive step toward making the system approach RGB performance.

The third level of nonlinear processing is a form of cross-color suppression using 45-degree logic that can be applied in the case where a conventional rather than a 2H encoder is used. The cross color coming from a standard encoder, where the luminance and chrominance spectra are already overlapping, limits the degree of improvement the 2H decoder can apply. However, this 45-degree logic circuit detects the first luminance transition and applies corrective action by replacing polluted chrominance information by the average of adjacent chroma pixels which are free of cross color. Such a process is limited in scope and is effective only for cross color generated by single luminance transitions. Large areas of cross-color effects are not modified.

The fourth logic circuit, which is called chrominance bandwidth expansion, uses a unique method of positioning and sharpening the chrominance transition, by using its luminance counterpart as a reference for such action. The underlying principle is that luminance and chrominance transitions are normally congruent. However, the chroma transition gets degraded or "smeared" by the narrower bandwidth of the chroma channel. This circuit analyzes the coincident luminance transition, and synthesizes a chroma transition with a frequency characteristic far above 1.3 MHz for both R-Y and B-Y (or

I and Q) channels. After matrixing the Y, enhanced R-Y, and B-Y signals to obtain RGB, the screen appearance of a short transition between different colors will be virtually indistinguishable from direct RGB transition, without any of the usual blurring associated with NTSC. The combination of 2H encoding, 2H decoding, and four levels of adaptive logic in the decoder produces a near-perfect result, with the one minor deficiency that resolution at 45 degrees is somewhat reduced. This loss can also be compensated for by using external "crispening" circuits designed to be effective only at 45 degrees.

The decoder also has vertical chrominance enhancement, which compensates for the loss in chrominance resolution in the 2H encoder. This is a switchable circuit that is actuated when the 2H encoder is being used and is turned off when a conventional encoder is used. The purpose of this circuit is to avoid sacrificing cross-luminance elimination in exchange for an excessive vertical blurring for chrominance. This system provides excellent vertical chrominance bandwidth on the 2H encoder.

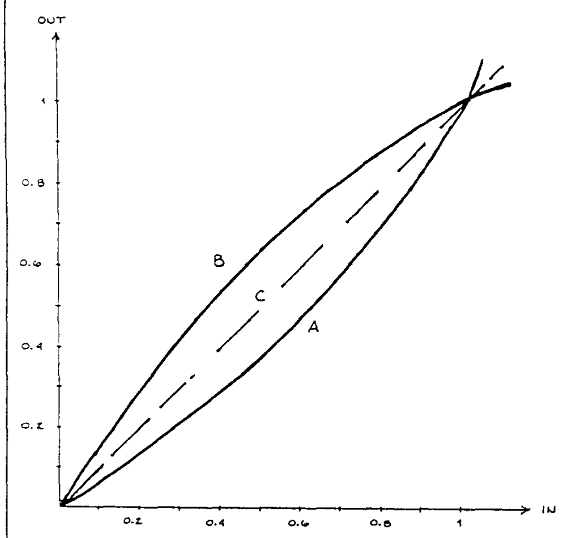

Fig.11 Gamma characteristics.

3. GAMMA PROBLEMS

The gamma characteristics of the NTSC standard have never been defined by a set of enforceable regulations. Through the years, the practice has slowly evolved, in a rather uncoordinated fashion, and present day cameras have a gamma of 0.45 (an average) while color monitors or sets have a gamma of 2.8 to 3.1. As a result, the overall transfer curve (light in, to camera - light out, from monitor) <u>is not linear</u> and the overall displayed gamma is, in practice, in the vicinity of <u>1.35</u> (Fig. 11a).

The consequences of this state of affairs is that blacks are often compressed, and details disappear in dark areas, while the whites are excessively amplified to the point of reaching CRT saturation and blooming.

Very significant improvements in the overall pricture quality are therefore observed if the red, green and blue output of the NTSC decoder are submitted to a gamma correction of 0.74 (Fig. 11b), thus reestablishing proper grey scale and more natural, "film like," blacks, without white saturation.

Another problem caused by gamma correction is the nonadherence of the NTSC standard to the constant luminance principle, as matrixing, in the encoder, is performed on gamma-corrected components to obtain luminance instead of the highly desirable linear matrixing.

As pointed out by many authors (Ref. 9, 12, 21), the result of this improper manipulation in relation with chrominance-band limiting is an increase in luminance rise-time for saturated colors. Different approaches (Ref. 12) have been proposed to correct the problem. It is our experience that a <u>limited</u> amount of luminance transition gamma precorrection in the encoder is practical, if it is made effective only for highly saturated colors, and if, in particular, red/black transitions are favored. This process, combined with chrominance bandwidth expansion in the decoder, delivers NTSC pictures which do not appear to be bandwidth-limited in the chroma channels.

SUMMARY SuperNTSC

The optimum NTSC processing, herein described as "SuperNTSC," includes the following steps:

1. At the transmission end:

   -525 lines, 30 Hz progressive scan

   -525 lines progressive to 2:1 interlace conversion

   -Luminance transitional gamma correction

   -Luminance detail processing

   -2H precombing of luminance and chrominance information prior to addition in the encoder

   -Transmission in a 6 MHz channel of a compatible NTSC signal in agreement with FCC specifications.

2. At the receiving end:

   -2H decoding of the NTSC signal

   -Horizontal, vertical and diagonal logic for adaptive combing

   -Chrominance bandwidth expansion by use of luminance information

   -Luminance multiplicative enhancement

   -Line doubling.

The resulting image has the following characteristics:

-1050 lines, 2:1 interlace, 60 Hz

-Apparent horizontal bandwidth: 15.1 MHz

-Aspect ratio: 3:4

-No visible cross color

-No visible cross luminance

-No visible vertical aliasing

-No apparent chroma bandwidth loss

It is against this yardstick that HDTV schemes are to be compared. Compatible schemes (Ref. 11, 13, 18, 19, 22), making use of wider transmission channels, or of extra subcarrier, have to exhibit a significant superiority over this system in terms of picture quality. It appears difficult to justify the introduction of a noncompatible scheme in the immediate future, as its advantages in terms of picture quality over SuperNTSC may not be sufficient to counter-balance the inconveniences of noncompatibility and wider transmission bandwidth requirements. As far as aspect ratio is concerned an aesthetic choice has to be made, and should be considered as a separate question.

Perhaps the introduction of a "smart receiver," as proposed by Professor Schreiber (Ref. 23), would allow a smooth transition during the next 15 years between the NTSC of today, the SuperNTSC of tomorrow, and the HDTV of the future.

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BIOGRAPHY

Yves C. Faroudja is founder and president of Faroudja Laboratories, Inc., Sunnyvale, Calif., where his current technical work focuses on optimizing NTSC signal performance at all stages to approach performance of high-definition television without a change in stardard or bandwidth.

Faroudja graduated from the Ecole Superieure d'Electricite, Paris, with an M.S. degree in electrical engineering. He worked at ITT Research Laboratoires in France and at NATO in Italy as a research engineer until 1965, when he moved to the U.S. While working in Europe, Faroudja participated in three engineering "firsts": the development and implementation of the first tide-power plant in the Rance estuary, the first transistorized Doppler radar, and the first laser activated on that continent.

After arriving in the Bay Area 20 years ago, Faroudja worked in the area of color television, both as an engineer and as a consultant. In 1981 he founded Faroudja Laboratories, Inc. The company has been instrumental in improving noise-reduction and enhancement technologies, and more recently, in developing NTSC encoders and decoders. Faroudja has developed and patented a number of significant new techniques for the improvement of color television images on professional and consumer VTRs, VCRs, cameras, and monitors.

Faroudja is a Fellow of the SMPTE, a member of the Institution of Electrical and Electronics Engineers (IEEE), Association des Anciens Eleves (ESE), National Association of Broadcasters (NAB), and Advanced Television Systems Committee (ATSC), in addition to his acting as a technical consultant to various U.S. and foreign companies. This year he was also honored with the 1987 Monitor Award for excellence in engineering, and the David Sarnoff Gold Medal Award from the Society of Motion Picture and Television Engineers for his contributions in optimizing NTSC signal performance by developing techniques presently used in video processing equipment.