WAVEFORM TESTING

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Abstract

Existing subjective and frequency domain testing procedures are shown to have major weaknesses in ensuring the delivery of acceptable television pictures to cable subscribers. Recommended, instead, are waveform test techniques using VIT signals as generated by the networks. Applications of measurement procedures and performance objectives are discussed for echoes, noise and chrominance/luminance gain and delay.

Waveform testing of television signals introduces a valuable concept to the performance testing and maintenance of R. F. distribution systems; including cable, satellite and fiber optics. Waveform techniques, as presently used by broadcast engineers to meet performance objectives for their video facilities, can also be used by cable engineers to meet performance objectives as to the picture quality of the television signals delivered to the subscribers. This is in contrast to present procedures that are primarily designed to provide information on quality and performance of cable equipment and distribution system.

Monitoring picture quality to ascertain that the delivered signals meet minimum acceptable level of impairment to the TV picture also ensures that the distribution system performs satisfactorily: the converse is not true. Knowing that the distribution system meets minimum standards does not ensure the delivery of satisfactory pictures. Maintenance procedures, based on distribution system characteristics, have resulted in many complaints by broadcasters, of excessive degradation of their local channels when carried by a cable system. This is especially true of local UHF signals where interference is often introduced at the head end by the mixing of harmonics of the local oscillator from the converter with other UHF. Distribution system testing has little value in resolving these complaints.

Waveform test procedures have had little application in the past to the cable industry as it was expensive to introduce these test signals at the head end. In addition, they provided no information as to the quality of incoming television signals. Equipment was necessary to demodulate each channel, insert these diagnostic signals and then remodulate them; all of which added degradation to the desired TV signal.

Today, waveform test procedures are applicable to the cable industry as these diagnostic signals are already injected into the four major network transmissions; ABC, CBS, NBC, and PBS. This eliminates the need for a cable operator to own expensive equipment to introduce these signals. Most important, in a report published in 1975 by the Network Transmission Committee 1/ there are recommended test procedures to meet picture impairment performance objectives. Granted these objectives for network transmission are more stringent than required for viewer reception, the signals still provide an excellent reference of quality and the measurement procedures are valuable and easy to use. There need only be reduced, reasonable standards for subscriber reception.

This paper compares linear waveform distortion analysis with presently used methods of subjective testing and frequency domain measurements. It also endeavors to show that waveform analysis merits consideration by the cable industry to improve subscriber penetration in existing systems and as an aid to gaining entry into urban markets. Before going into waveform analysis, this paper discusses the procedures we are using now, including subjective and frequency domain testing, and points out their present weaknesses.

Subjective testing can be defined as evaluation by observation of the television picture and is a valuable technique in the hands of qualified viewers in detecting visible degradation of the picture. In some respects, it is superior to measurements of impairments as it deals directly with the end result rather than causative factors that correlate with picture quality. All distortions are simultaneously visible and are diagnosed by the eye/brain complex for their acceptability. Other advantages include high sensitivity to some observable factors, the use of the TV set as test device and the lack of need to disrupt the system. Subjective testing has many advantages.

Subjective testing also has many limitations; one is the dependence for results on the viewer's competence or motivation. The viewer may be a cable technician without knowledge of the type or magnitude of the distortion observed or may be more concerned with concealing defects. A major weakness of subjective testing lies in the field of maintenance; some factors such as hum modulation can be difficult to see depending on the TV picture content, brightness, contrast and ambient light. Other distortions cannot be detected or measured until they are definitely visible; therefore they cannot be corrected until they reach this relatively high level. An example is an amplifier in the early part of a system which may be introducing an excessible amount of distortion, using up most of the system tolerance. Still the picture at that location may not appear degraded. Therefore the cable industry and the FCC requires that these procedures be supplemented with other techniques that include frequency domain measurements.

Frequency domain techniques involve introducing equal amplitude sine wave signals at various frequencies into equipment, cable or a system; and then measuring the amplitude or phase response variations that result. These techniques are valuable for maintenance of equipment, cable or detecting gross distortions in the cable distribution system since amplitude variations can affect other noise and overload factors. An important plus is that cable technicians generally have the test equipment and the know how to make frequency domain measurements whether using a standard sweep generator or a simultaneous sweep technique. The latter permits analysis of a cable system response during daytime hours while creating a minimum amount of distortion to the television picture.

Unfortunately frequency domain testing provides little information concerning the quality of the TV pictures delivered for the following reasons:

-(1) Faithful reproduction of the television signal, or minimum distortion of the waveform, requires that delay be considered as well as amplitude. The cable industry techniques do not include delay versus frequency measurements.

-(2) As pointed out by Osborne 2/ even "full knowledge of the amplitude/frequency and delay/frequency characteristics does not give a direct indication of the consequent deterioration of picture quality, save in certain extreme cases, and involves a great deal of unnecessary effort."

-(3) This same viewpoint is emphasized by Thiele 3/ "the deviation in frequency response (in dB) to produce a given subjective impairment in transient response, i.e. a minimum error in waveform shape, -----will be different at different frequencies. In a particular case the same picture impairment was produced by a deviation of 0.4dB at 5Mc/s as by a deviation of 0.5dB at 100Kc/s." Although these measurements were made using Australian TV standards, the fact remains that there could be a differential of more than 20dB in amplitude/frequency response, to produce equivalent impairment.

-(4) MacDiarmid 4/ discusses frequency domain in terms of picture impairment tolerances. He states "What is perhaps the most important objection to the use of sine-waves arises in considering the question of tolerances" and then "where the amount of distortion to be tolerated is modest, the only economical method is to specify and measure the waveform response and to abandon sine-wave ideas."

These are but a few examples from the published literature that encourage the use of waveform analysis for television signal measurement, and which show that existing methods do not ensure acceptable pictures to the viewers. I will now discuss waveform analysis and then its application to the cable industry.

Waveform analysis techniques involve measurement of the wave shape or the amplitude versus time response of a test signal of a specified waveform to determine the amount of distortion introduced. The test signals are selected to provide maximum information as to the desired parameters, in a manner that is easily evaluated, permits rapid testing and is accurate. These signals conform to the television picture which are of waveforms with similar energy distribution.

Waveform analysis signals as used by broadcast engineers fall into two categories: the first, Vertical Interval Reference (VIR) and the second, Vertical Interval Test (VIT) Signals. Because these signals are helpful to the broadcast engineer in adjusting electronic equipment, cameras, lighting, ect., they are incorporated into the programs in specified horizontal lines during the vertical blanking interval.

The VIR signals are valuable to broadcasters in referencing the program content to reduce undesired variations in color. They assist television producers and operators in adjusting various signal parameters so that different programs will have similar amplitude and phase characteristics. The VIR's are not applicable to cable systems as they reference program content factors that deal with video rather than transmission factors that also include R.F. Therefore this paper will not deal with these signals but for those desiring more information see the article by C. Bailey Neal on their history, in Communications/Engineering Digest 5/ or the EIA Television System Bulletins Nos. 1 and 3. 6, 7/

This article has covered some weaknesses of subjective and frequency domain testing. Now it will touch on my recommendation to the cable industry for the use of VIT waveform signals. This includes not only their advantages but also applications, measurement procedures and performance objectives.

The VIT signals are diagnostic tools used by the broadcast industry and intended to measure the characteristics of a transmission facility and to reduce picture impairments that occur on local or intercity transmission facilities. They are also used by remote control and test functions. Although these signals are designed to cope with video distortions, many of these same distortions can be introduced at RF by a broadcast transmitter, a microwave link, propagation, a cable headend or distribution system. A major feature of VIT signals is that they are very sensitive and can measure relatively small picture impairments. They can, therefore be used to pinpoint errors occuring in the various links of the transmission path and to allocate maximum acceptable levels of distortion for each link. The use of performance objectives for each link is not only helpful in determining responsibility for excessive total degradations but is also desirable for trouble shooting purposes.

These VIT signals are generally available to the cable engineer since they are transmitted by the four major networks and AT&T in accordance with the Network Transmission Committee (NTC) Report No. 7. 8/ These are: the Composite Test Signal (see figure 1a) which is inserted on line 17, field 1, and the Combination Test Signal (see figure 1b) which is inserted on line 17, field 2. This NTC report is especially valuable in that it defines transmission parameters, test signals, measuring methods and performance objectives for major network facilities. It is published by the Public Broadcasting Service.

A major advantage to the use of these signals is that the information they provide about linear distortions can be directly converted to impairments to the television signal and that these in turn can be correlated with subjective evaluation of picture quality. For CTAC Panel 2, the chairman Archer Taylor compiled some Bell Telephone Laboratory studies that provide this type of correlation. 9/

This paper will discuss the merits of those VIT signals pertinent to RF transmission systems that are important for the delivery of improved TV on locally broadcast channels. This includes factors such as echoes for which the broadcasters have no performance objectives, but it excludes many factors over which the cable operator has little control, such as luminance or chrominance non-linearity. However, first it is worthwhile touching on some of the history of VIT signals.

The history of waveform techniques dates back at least to 1935 when Puckle dealt with signal transients and later wrote a text suggesting the use of various waveforms for an oscilloscope time base. 10/ This analysis was expanded to television by Bedford and Fredenhall in 1939. 11/ In 1954, N.W. Lewis did a detailed study on Waveform Responses of Television Links based on sine squared bar and pulses plus a square wave. 12/ A few years later I.F. MacDiarmid did a two part tutorial analysis of waveform distortion: its derivation, choice of waveforms and examples of various types of distortion. 13/

In the early 60s, there were increasing applications of these techniques: Osborne 14/ did a paper on assessing picture quality by means of the K-rating and suggested the use of Wheeler's 15/ proposal that pairs of echoes of adjustable amplitude and polarity could be used to correct for amplitude/frequency and delay/ frequency distortions.

In 1963, AT&T 16/ published a valuable tutorial manual (as revised by the Network

Transmission Committee) dealing with an analysis of television signals. Siocos 17/ published a paper in 1966 evaluating CBS network transmissions with slight variations of VIT signals. Also about this time Peter Wolf 18/ proposed the addition of a special 20T pulse for measuring short-time distortions with and without a graticule; Everett 19/ derived means for correcting waveform errors; and Rhodes 20/ and Schmid 21/ contributed excellent analytical papers dealing with the modulated 12.5 sine-Squared Pulse.

The IEEE 22/ published a Video Signal Trial-Use Standard in 1974 that precisely defined the various terms, discussed measurement and included, in the appendices, a detailed description, derivation and measurement of the Sin^2 Pulse, Sin^2 Step, T Step and the Mod 12.5T Pulse.

A major step forward in terms of applications came in June of 1975 with NTC Report #7 23/ which introduced non-regulatory standards or "Performance Objectives" for network transmissions of video links. This report also defines the transmission parameters, test signals and measuring methods to be used. It also replaced the IEEE use of the sin^2 T pulse with the sin^2 2T pulse as the latter introduces less irrelevant distortions. Furthermore, these NTC recommended test signals are the ones presently transmitted by the four major networks, ABC, CBS, NBC and PBS.

This is an abridged history of the many important papers and texts that have dealt with waveform testing. Now I return to the present to discuss the advantages of VIT signals for cable systems.

There are some important advantages that are worth summarizing:

-1) Most important; tests can be made of parameters that greatly affect the picture reception, but which have not been feasible using present test procudures. This includes measurement of echoes, color saturation, color delay and impulse noise.

-2) Tests can be made without disrupting subscriber service, at any system location and on those channels for which the cable operator has responsibility for quality.

-3) There is no need to purchase equipment to interject these signals; for reception the only test equipment needed is a demodulator with several input modules plus a waveform monitor. This could total about $4000.

-4) There are major savings in labor which will soon exceed the above equipment cost. These savings will result from reduced system maintenance and especially from the minimization of conflicts with subscribers and TV service companies.

-5) The performance objectives for network transmission are more stringent than needed for subscriber reception. For these less sensitive objectives, the measurements are well within the capability of a system technician.

The advantages of using VIT signals for cable systems apply to many factors. However, this paper is being limited to just a few of these that are extremely difficult or costly to measure in any other way; noticably affect subscriber reception and for which the cable engineer has some control. In the future additional parameters will also be useful.

-1) Echoes: whether leading, due to direct pickup or lagging, for many other reasons. The cable industry often specifies the Paul Mertz 24/ curve without knowing how to measure compliance. Often, Time Domain Reflectometers or other techniques are used that merely measure the reflective characteristics of a component.

For the echo test, the 2T sin^2 pulse or the T bar from the Composite Test Signal can be used. (see figures 2, 3) This 2T pulse is an excellent test signal as its energy spectrum is similar to the waveform of the television signal; approaching zero at the video cutoff frequency.

These signals are also used by broadcasters to measure transients, high frequency amplitude and phase delay; e.g. waveform distortions from 125 ns to 1us. For the cable industry it may be wise to ignore short time echoes of less than 500 ns as the broadcast signal or the test demodulator can also introduce transients. Measurements are made of the amplitude and delay of the undesired pulses. Where difficulty exists in identifying echoes down 30 dB or more, because of noise levels at the end of a system, the use of photographs are helpful since the pulse is constant and the noise random.

The echoes of most concern are from 0.5 to 2 u seconds which can be correlated with its displacement on a TV set. For example, the video part of a TV line is 53 u sec; for a 20" wide screen this would be a displacement of 0.38 inches for 1 us.

Alternate methods of measuring echoes are through the examination of the first few microseconds of the T bar which has a rise time of 125 ns. or the horizontal sync pulse with a rise time of 250 ns. between 10 and 90%.

It is far easier during antenna surveys to observe waveform echoes than to attempt to minimize echoes by observing the television picture. For example, it can be very difficult in an urban area to pinpoint an antenna location with minimum echoes by subjective testing. The picture content varies, background light changes and the eye/brain cannot remember slight variations of quality while taking in changes of color and noise. Using VIT signals, a far better job can be done in much reduced time in measuring and locating the source of echoes.

-2) Chrominance/Luminance Gain and Delay Inequalities produce noticable effects on the quality of a color picture.

Chrominance/Luminance gain refers to the amplitude ratio of frequencies, between the low frequencies near the video carrier and the high frequencies near the color sub carriers. Improper ratios result in degraded color saturation of the TV picture.

Chrominance/Luminance delay refers to the additional time involved in the path of the color energy with respect to the low frequency energy near the video carrier. Additional time results in delayed chrominance which can show on the TV screen as funny picture effect; for example, the red color of the lips of a persons face can be displaced from the monochrome detail of the lips. In spite of their importance, these factors are rarely measured by cable engineers. This is due to the excessive cost of equipment and time, using other techniques.

The key to delivering satisfactory color is the ability to measure and correct chrominance inequalities. Color saturation inequalities are easily correctible by slight amplitude/frequency response alignment of a headend channel processor or preferably by correcting the source of distortion which could be antenna site location, a narrow band antenna array, incorrectly aligned trap etc.

For these tests a modulated 12.5T Chrominance Pulse Test Signal is used (see figure 4) which is also part of the Composite Test Signal. Relative Chrominance Level (RCL) - where there is no delay - is equal to the sum in percent of the peak and base displacements of the pulse or RCL = ± 2a percent.

Relative Chrominance Time (RCT), where there is no gain distortion, is equal to ten times the total base displacements in nanoseconds or RCT = ± 10 b nanoseconds (figure 4) where b is the total base displacement.

Where both gain and delay distortions exist, the equations are more complicated and it is easier to use one of the nomographs as developed by Charles Rhodes of Tektronix 25/ (see figure 5). This nomograph not only gives the delay in nanoseconds but also converts the gain to decibels.

Reasonable performance objectives for a viewer for Chrominance Gain would be ± 2dB* and for Chrominance Delay would be ± 477 nanoseconds, 26/ based on a study by A. Lessman of Bell Laboratories. The ± 2dB compares with the broadcast network gain performance objective of ± 0.5 dB and the ± 477 ns. compares with the network objective of ± 75 ns. These are standards that can be measured and met by the cable industry. The ± 477 ns. may seem too permissive, however it involves shaped delay which is less objectionable than the broadcasters flat delay. 27/

Some sources of degraded RCL and RCT in cable systems are the filters for two-way in amplifiers and traps, bandpass filters and signal processors at the head end.

-3) Random Impulse and Periodic Noise are also parameters of importance to the quality of a TV picture. and unfortunately are not generally measured in a cable system. Most procedures measure the random noise as introduced by head end and distribution equipment. This ignores Impulse noise caused by automobiles, industrial plants, cosmic sources, power lines and video tape or film program sources. Likewise Periodic noise can be introduced in the broadcast transmission and also at a cable head end from defective equipment or interfering signals.

A very simple method for measuring the summation of these noises or for identifying them independently is by the use of the 18 us. flat part of the line bar. For low frequency periodic noise, use can be made of the television

* The basis for ± 2 dB is past experiments showing noticeably degraded pictures on some TV sets resulting from a chrominance level reduced by 3 dB.

signal itself, observing it at a verticle sync rate.

This procedure is helpful in locating a cable antenna site or isolating noise sources as measurements are made during the actual signal transmission. This technique provides a means of comparing the total Signal-to-Noise with that introduced by the system.

There are other distortion measurements that can be made just as easily using VIT signals. However, time permits discussing only these few. Some others, such as differential gain and phase, are not presently serious sources of picture impairment although they become more important with the use of cable ancillary services such as satellites or terrestrial microwave. Another VIT signal, the multiburst, could supplement present amplitude/frequency response techniques in providing information as to total variations. In short this paper has just begun to scratch the surface in describing ways that tests using the VIT signals can contribute to the efficient operation of a cable system with a reduction in cost and time over current measuring procedures.

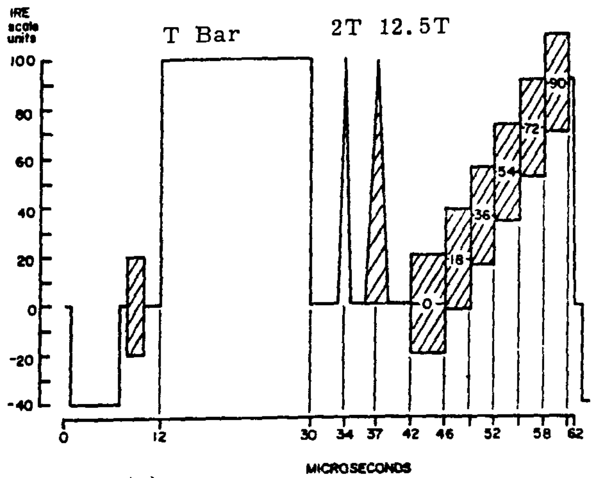
The measurement techniques discussed in this paper should help ensure that the quality of subscriber service is raised to its full potential. High quality subscriber service is necessary to open up urban markets and reduce broadcaster complaints. In addition high quality subscriber service will improve relations with subscribers, and therefore franchise officials. These points are elaborated in a previous paper. 27/

While the desireability of measuring picture impairment has often been acknowledged, the difficulties of measuring these parameters with traditional techniques has been a deterrent. As this paper demonstrates the test procedures using the VIT signals are not difficult, nor are they new or untried, having been used by broadcasters for years. The VIT signals are generally available for those channels over which the cable operator has some control. Finally the amounts of impairment measured can be compared with the television network performance objectives or be correlated with the Bell Telephone Lab picture quality ratings.

The parameters are important and there is no longer any reason not to measure them. For the future; there will be a need to use waveform analysis not only for measuring other parameters affecting picture quality, but also for isolating sources of problems, automating test procedures and correlating analog and digital TV reception.

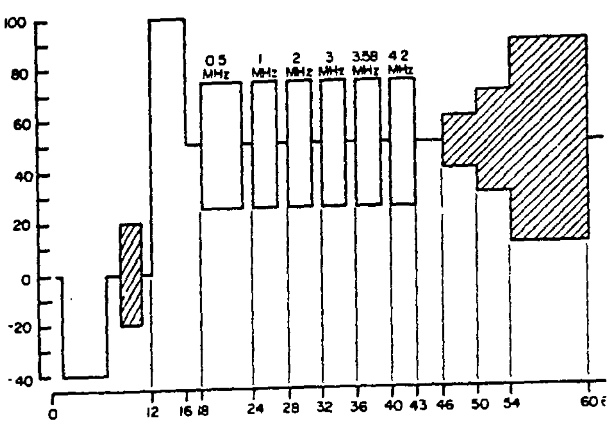
FIGURE 1

The Composite Test Signal



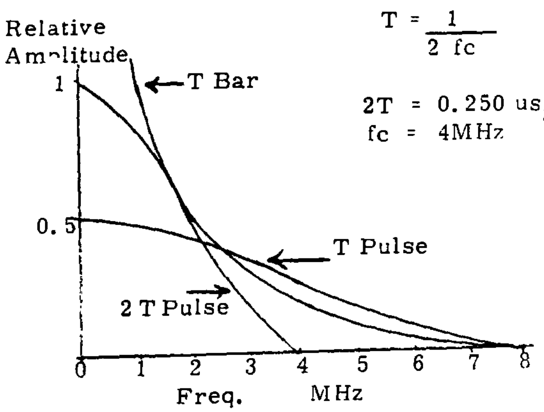
(a)

The Combination Test Signal



(b)

FIGURE 2

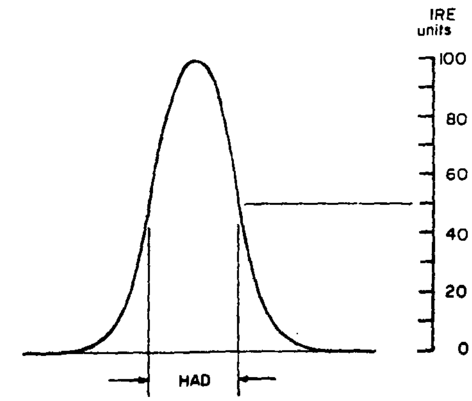


$T = \frac{1}{2\ fc}$

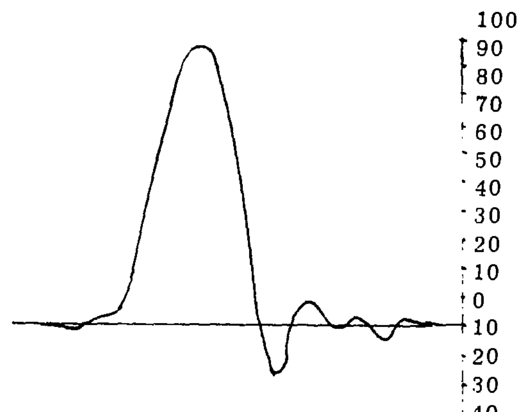
2T = 0.250 us, where
fc = 4MHz

FIGURE 3

2T Pulse Test Signal



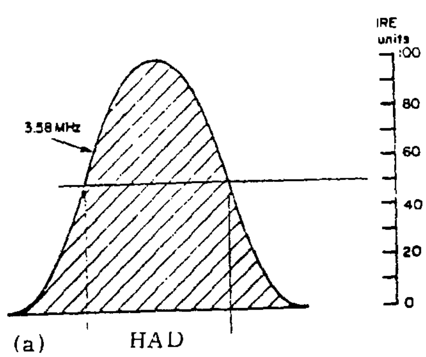
2t HALF-AMPLITUDE DURATION = 250ns



2T Sin[2] Signal with severe
Phase Delay

FIGURE 4

Chrominance Pulse Test Signal



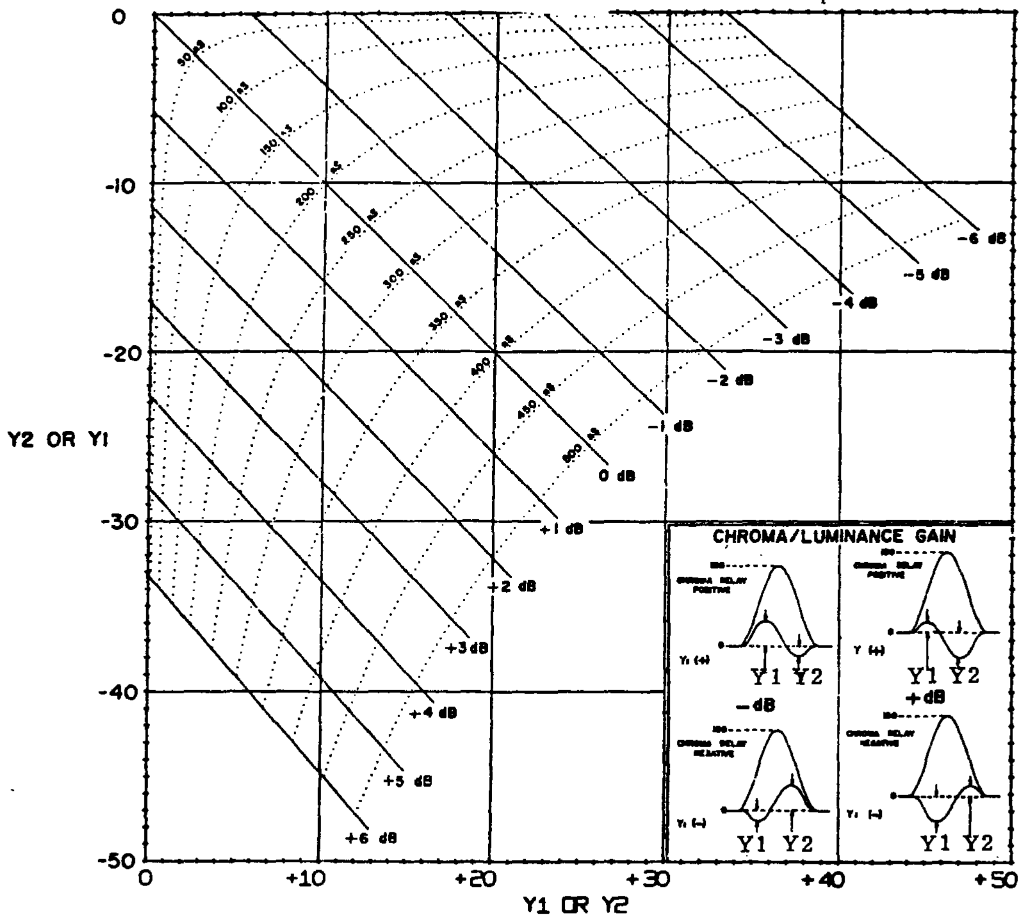
(a)

12.5T HAD = 1570 nanoseconds

FIGURE 4 (b)

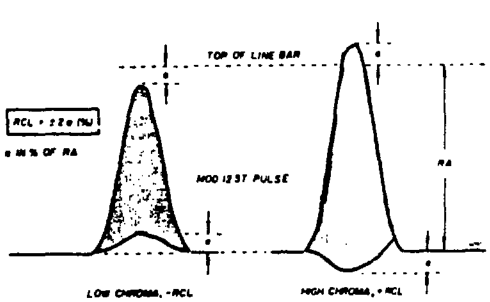
Nomograph 12.5T Modulated Sine-Squared Pulse for NTSC

CHARLES W. RHODES, Tektronix Corp.

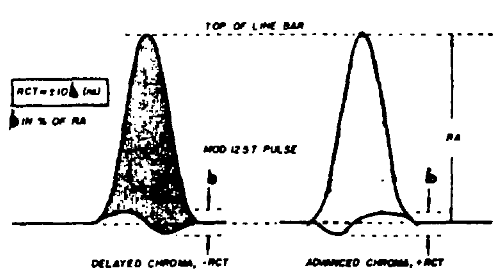


The Measurement of Linear Chroma Distortion in NTSC TV Facilities

HANS SCHMID



Relative chroma level.



Relative chroma time.

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