# MEASURING AND EVALUATING VIDEO SIGNALS IN THE HEADEND

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## ABSTRACT

The NCTA and the cities have recently agreed to, among other things, a set of basic measurements to be made on video signals. We'll show you how to make the new measurements, and tell you what they mean. We'll also discuss other basic measurements that should be made in order to provide good signals. The measurement emphasis is on practical things that can be done in the headend, using available equipment augmented with devices that can be built in the system. In looking at various cable systems, we have collected some prime examples of what good video does NOT look like. Baseband video and modulation are reviewed.

## INTRODUCTION

Consumer devices are adding features which emphasize the need for quality in the delivered signals. These added features include larger and sharper pictures viewed from a shorter distance, on-screen displays in VCRs and other equipment, and more recording options. In addition, as this is written, the FCC is about to formalize new rules aimed at providing the subscriber with better service. These new Rules are based on an agreement reached recently between the cities and the cable industry. These rules are good, but you can still do more to improve pictures. Complying with the rules will allow you to put out better pictures, yielding fewer subscriber complaints.

New to cable rules is the requirement to make certain baseband measurements on signals you carry. These measurements may not be familiar to some. We show you ways to make the required measurements, and why they are important. In additional, we will discuss some of the problems we have observed in cable systems.

## THE NEW MEASUREMENTS REQUIRED

The cable industry and the cities have recently reached agreement on, among other things, technical performance standards for cable systems. These are to be incorporated into the FCC Rules in the near future (they may even be in effect by the time this is published). Among the changes are that, for the first time, you will have to make certain basic baseband measurements in your headend. This section seeks to explain the measurements you must make. By no means does this represent a comprehensive set of measurements, and minimum compliance does not necessarily mean that you are supplying impeccable pictures. However, they are a starting point for improving pictures.

A remaining task associated with the agreement is to agree on measurement techniques for the governed parameters. This task is beginning as this is being written. Since we are writing this before the measuring techniques have been agreed, we are taking some risk that we will say something that is not exactly in accord with the final agreement. However, the techniques presented are all standard techniques in use in the broadcast industry, at CATV manufacturers and at some systems. Certainly the principles will remain valid.

## Frequency Response

No measurement on a TV channel is more basic than that of frequency response. Errors can cause picture softness, close ghosting, smearing, weak color and other nasty things that cable TV claims to improve. You are familiar with measuring the RF response of a channel. This is directly related to the baseband frequency response, but the relation is not always simple. In some parts of the spectrum, a big error at RF can translate to a small error at baseband, and at other frequencies a big error at RF can produce a big error at baseband. Since the RF carrier is only something we add to the baseband picture for part of its journey from studio to home, we are primarily interested in the baseband response of a system. Frequency response may be measured in many ways, and this article cannot cover all of them. Rather, we concentrate on one simple means of measuring frequency response. It is accurate enough for most everyday needs and should satisfy the needs of the agreement with the cities.

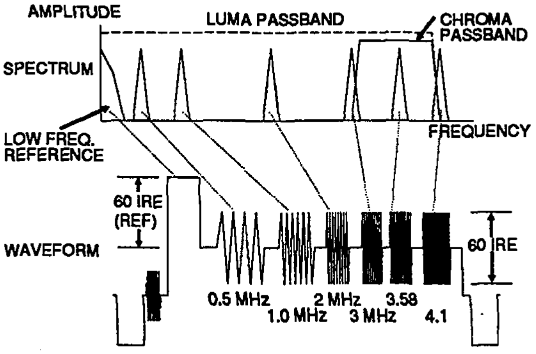


Figure 1. Multiburst Waveform

The technique uses the "multiburst" waveform. This is a simple signal composed of a pedestal (40 IRE in the example - you will see multiburst elements of other amplitudes) on which bursts of different frequencies have been added. By measuring the relative amplitude of each frequency burst, one can get a good idea of the channel response. Figure 1 shows a multiburst waveform. Above it is a spectrum diagram indicating the spectrum occupied by each burst. Intentionally, the spectrum is not shown exactly above the corresponding burst. The X-axis of the waveform is time. The X-axis of the spectrum diagram represents frequency. Each burst in the multiburst occupies a different part of the baseband spectrum, and will be affected by the amplitude response of the channel. By measuring the amplitude of each burst after demodulation, one can ascertain the response of the channel from the point of injection of the multiburst.

For example, suppose that we measure the 0.5 MHz burst amplitude to be 60 IRE (the nominal amplitude) and the 1 MHz burst to be 40 IRE. The frequency response of the channel at 1 MHz *compared with 0.5 MHz* is

$$20LOG(40/60) = -3.52 \text{ dB}.$$

We use 20LOG because we are measuring voltage. Frequency response is measured with respect to some reference frequency. Many times that reference frequency is taken to be 0.5 MHz, this being the frequency of the lowest burst. This is not a preferred way to evaluate the channel, however, because it leads us to ignore the channel response below 0.5 MHz. These lower frequencies constitute an important part of the channel, which contains most of the luminance energy. Errors in low frequency response can cause picture streaking, brightness variation from left to right in the picture, and synchronization problems, among others. A preferred measurement technique is to measure response with respect to the reference bar on the left of the figure 1 waveform. This bar also has an amplitude of 60 IRE, the same as that of each burst, measured between peak white and the 40 IRE pedestal on which the bursts are imposed. The energy in the bar occupies the lowest frequency part of the spectrum. We can use this as a reference and get a much more relevant picture of channel response. The easiest way to make the measurement is to set the gain of your oscilloscope to make the bar amplitude 60 IRE as shown, then measure the IRE amplitude of all the bursts, calculating frequency response as shown above.

Notice that we have drawn each burst as occupying a narrow band of frequencies rather than a single point (If we drew this accurately, we would spread out the spectrum even more). This is because each burst can be thought of as a carrier in its own right, 100% amplitude modulated by a rectangular wave that turns it on for a short time every so often. This modulation causes sidebands, as would any other modulation of a carrier. Thus, the spectrum spreads out. Is it difficult to think of the bursts as carriers? The 1 MHz burst is in the middle of the AM broadcast band and 3.58 MHz is near the lower edge of the amateur 80 meter C.W. band.

In practice, you will never see the last burst (between 4.0 and 4.2 MHz, depending upon the generator) look very good after a trip through a band limited channel. This is because the burst is at the very edge of the passband, which theoretically ends at 4.18 MHz in NTSC transmission, but which rarely extends this high (NCTA standards assume a video bandwidth of 4 MHz). The modulation sidebands associated with this burst extend past the channel edge. The result is often a trapezoidal envelope on the last burst, which may not have time to reach its C.W. amplitude. For this reason, frequency response is normally measured only to 3.58 MHz when using the multiburst. Interpretation of the last burst is dangerous and is best left to an expert (most of whom ignore it).

Notice that we show the chroma passband as occupying the spectrum about ±600 KHz from the 3.58 MHz carrier. (Technically, one component of the color extends 1.2 MHz below the color subcarrier, but this extended bandwidth is rarely used in consumer equipment.) The color bandwidth can be smaller than the luminance bandwidth due to the way our eyes perceive color. We perceive sharpness in the luminance signal much more than in the color information. The luminance bandwidth is shown overlapping the chrominance bandwidth. Lower cost TVs cannot recover this bandwidth, but higher cost sets with comb filters can separate the chrominance and luminance, as a result of the way information is interleaved in the spectrum. The details are beyond the scope of this paper.

Figures 2 and 3 show examples of deficient multibursts which we have found on cable systems. (The pictures were taken with a low cost oscilloscope and the clamp/sync separator shown in the appendix.) Figure 2 shows a frequency response roll-off of about 2.9 dB at 3 MHz. This part of the spectrum carries luminance detail information, so the picture will not be quite as sharp as it should be. By the way, we measured the baseband response by using a ruler to measure the heights of the bursts from the photo. We then took 20 LOG the ratio of heights in inches. Measuring in volts or IRE is not necessary: when you are making ratio measurements such as this, it is

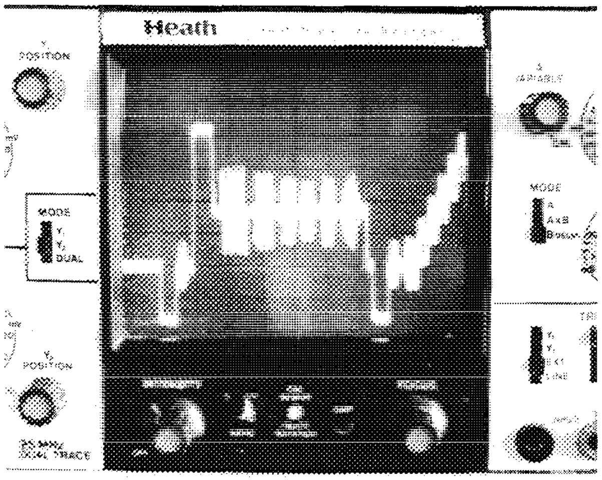


Figure 2. Multiburst With 2.9 dB Mid Frequency Rolloff

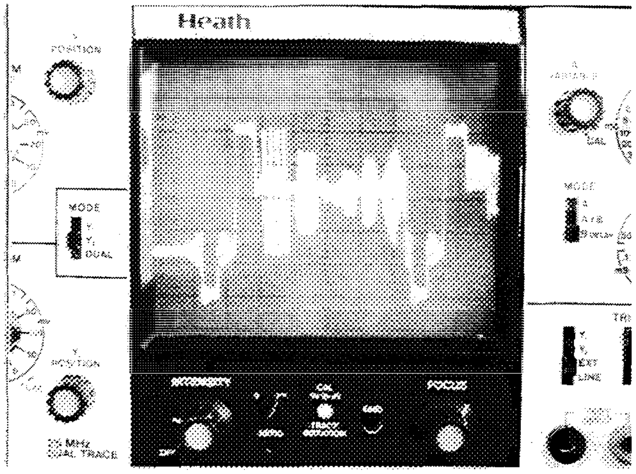


Figure 3. Multiburst on Channel Protected by Positive Trap

only necessary to make both measurements in the same units.

You can also see from figure 2, the effect of spectrum truncation of the last burst. It has a triangular shape due to the inability of the system to pass the high sideband.

Figure 3 shows the effect of a positive trap. The 2 MHz burst is missing and the higher bursts are grossly reduced in amplitude. This is the reason that channels protected by positive traps have the reputation of being "fuzzy." Also, note that the multiburst in figure 3 is a full amplitude multiburst, meaning that the amplitude of each burst is 100 IRE peak to peak, and so must be measured with respect to the leading edge of the bar rather than with respect to the trailing edge. Transmission of full amplitude bursts is not recommended but is permitted for cable programmers.

## Differential Gain

The amplitude of the color subcarrier determines the saturation, or "purity" of the color on the screen. Adjusting the "COLOR" control of a TV receiver effectively adjusts the amplitude of the chroma signal. One of the important parameters which you are asked to measure in the new FCC Rules, is differential gain. This is a measure of how much the chroma amplitude changes as the luminance level on which it rides changes. To appreciate the importance, consider a picture of a baseball stadium, with green grass on the playing field. Now consider that half of the stadium is in shade and the other half is in sunlight. The "greeness" of the grass is the same in sunlight or shade, but if we have differential gain in the system, the grass in one area will appear greener than in the other.

Figure 4 shows the idea behind measuring differential gain. A test signal is generated on one or more TV lines,

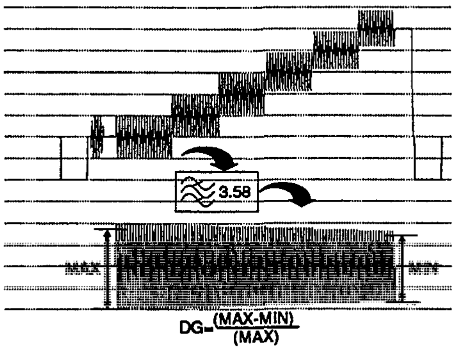


Figure 4. Measurement of Differential Gain

consisting of several (5 or 10) steps of luminance, from 0 to 100 IRE. A gradually rising ramp is also used. Each luminance step has superimposed on it a sample of the color subcarrier, 3.58 MHz. (OK, for those of you who take pleasure in examining things with a micrometer, you caught us: the subcarrier on this and the next figure is drawn as if it were 2 MHz. We just did this so the figure would be a little clearer. Most other figures are literally correct as far as frequencies and durations are concerned.) If the system has differential gain, the amplitude of the subcarrier component will change on different steps. The signal is passed through a 3.58 MHz bandpass filter to eliminate all but the color subcarrier. The change in peak-to-peak amplitude can be measured, and the differential gain computed as shown in the figure. The amount of differential gain shown is 20%, probably equal to the limit negotiated between the cities and the cable industry.[1] By the way, this is a LOT of differential gain: you should be ashamed to have this much in your headend. (Not that it will affect the picture that much, but modern equipment can do much better, and you are not to be forgiven for low quality in your headend. For cost reasons, most of the tolerable distortion must be allocated to the subscriber end.)

Differential gain may be measured on a waveform monitor using the method shown. Vector scopes pass the filtered signal to a detector, and display a line calibrated in percent differential gain.

## Differential Phase

The phase of the chroma subcarrier determines the actual color, or tint. Adjusting the "TINT" control of a TV receiver is analogous to changing the phase of the subcarrier with respect to the burst. The primary operative specification is differential phase. Differential phase is similar to differential gain. Indeed, by sheer coincidence, they often have about the same numerical value. Differential phase is a measure of how much the phase of the signal changes as the luminance changes. In our stadium example, if the system has differential phase, the grass could look green in the shade and blue in the sun! Obviously this is an extreme example, but the idea is that the color of the grass could change between light and dark areas if the system has differential phase.

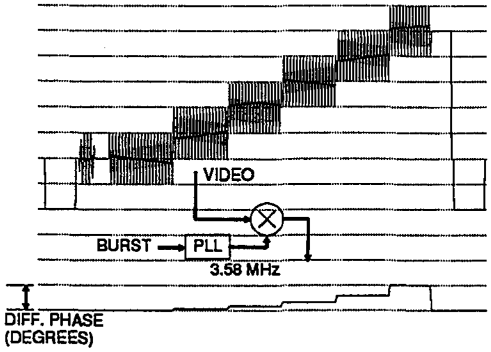


Figure 5. Measurement of Differential Phase

Figure 5 shows the idea behind measuring differential phase. A 3.58 MHz oscillator is phase locked to the burst, and supplies one input to a phase detector. The other input to the phase detector is the video signal itself. Output of the phase detector may be applied to a CRT, and will produce a plot as shown at the bottom of the figure. As the relative phase of the chroma subcarrier changes with different steps, the phase detector output changes. Note that this is not an absolute measurement: one measures the *change* in phase as luminance changes from 0 IRE to 100 IRE. The calibration shown is not absolute, but if one division on the lower part of the scale represents 10 degrees, the differential phase shown is at the agreement limit. Again, you should be able to do better in a headend.

Differential gain must be measured with a vector scope: a waveform monitor cannot measure it.

## Chrominance to Luminance Delay

The final baseband specification to be measured according to the agreement, is chrominance to luminance delay.$^2$ Refer again to figure 5, which includes the baseband spectrum. Delay is a nasty side effect of filtering which must be done to the RF and baseband signals. Some frequency components in the TV spectrum go through a filter faster than do other components. This can cause what is often termed the "funny paper effect." The name comes from the tendency in funny paper printing, to misalign the three primary colors, each of which requires the paper to pass under a different press. If the paper is not positioned precisely at each pass, the colors are not properly registered. The corresponding situation in a television signal is group delay, a consequence of the picture spectral components at different frequencies getting through at different times. The most obvious problem (and a very practical one) is that the color information will not make it through as quickly as will most of the luminance information. This is often due to the sound trap, which is located only 300 KHz above the theoretical edge of the video passband.

Figure 6 shows a modulated 12.5T pulse used to measure group delay, after the signal has passed through a system having

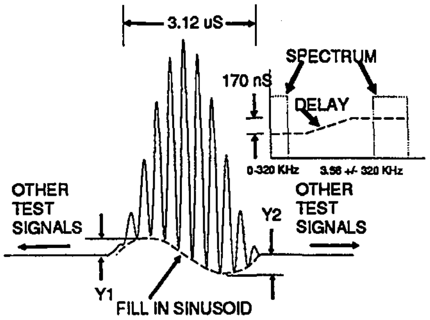


Figure 6. Modulated 12.5T Pulse Showing about 170 nS Delay

about 170 nS of group delay, the limit specified in the agreement. Later you will compare this with an ideal modulated 12.5T pulse. Of interest in figure 6 is the small spectrum diagram to the right, which shows the situation modelled in developing the figure. The lower frequency video components get through the system faster than do the chrominance components, which are "delayed." By measuring the deviation from a flat baseline, of the bottom of the modulated 12.5T pulse, we can compute both delay and amplitude differences between the luma and chroma components. The modulated 12.5T pulse is on a line of video which also includes a bar, which is set to 100 IRE. Then the positive and negative deviations of the baseline, Y1 and Y2, are measured in IRE units. A nomograph may then be used to read both the amplitude and group delay. The nomograph has been published many places, including the video waveform chart that appeared in Communications Technology magazine in November 1991.

## A Somewhat Intuitive Approach to Group Delay

The other measurements with which we have dealt have been rather more intuitive than is group delay. It will be profitable for us to take a few moments to develop the group delay concept and measurement further.

Chroma to luma delay is usually measured using a modulated 12.5T pulse. "T" is a constant measured in microseconds, related to the bandwidth of the TV system. It is the shortest pulse that can theoretically pass through the system. The NTSC system has a maximum channel frequency response of 4 MHz (more accurately 4.18 MHz, but good luck getting this). Thus, the maximum frequency that can pass is 4 MHz. Now consider the width of the minimum pulse that can produce a white vertical line on the screen. A 4 MHz wave will, in one cycle, produce a white and black line pair. The minimum pulse that can produce a luminance level is thus half of this 4 MHz period.[3] This is the period we call "T." It is equal to one half the reciprocal of the maximum passband frequency of the system. For NTSC, this is

$$T = 1/(2(4\text{MHz})) = 125\text{ nS}.$$

The *unmodulated* 12.5T pulse has a half amplitude duration (from 50% rising edge to 50% falling edge) of 12.5 times this minimum, and a total duration of twice this. Mathematically, the 12.5T pulse is expressed as

$$v(t) = \sin^2(t/\tau),$$

where:

$v(t)$ = voltage waveform

$t$ = time

$\tau = 2(12.5)T/\pi$, and

$T = 125$ nS for NTSC.

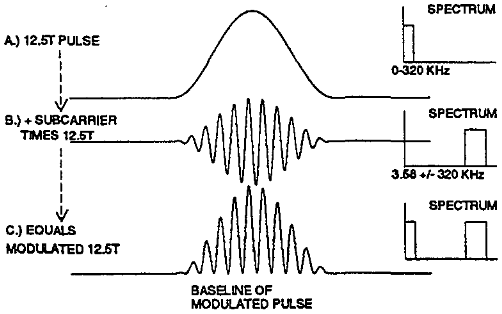


Figure 7. Composition of 12.5T Waveform

The upper waveform of figure 7 is this 12.5T pulse, generated from the above formula. It occupies a spectrum from nearly

0 frequency, to 320 KHz. The spectrum occupancy is relatively uniform over this range (though not as uniform as illustrated), which is also where the majority of the luminance energy is located. To make a modulated 12.5T pulse out of this, we use it to amplitude modulate the 3.58 MHz chroma subcarrier. The modulation is done by multiplying the subcarrier by $v(t)$ above. This is equivalent to double sideband suppressed carrier amplitude modulation, and produces the waveform and spectrum shown in the middle of figure 7. The spectrum is centered at 3.58 MHz (the "carrier"), and extends 320 KHz either side. This is the spectrum occupied by a majority of the chroma energy (the extremes of the chroma band are further out, but this band includes most of the energy). We can measure the chrominance to luminance delay by combining (adding) the two signal components shown in figure 7a. and b., obtaining the waveform shown in c. This is the ideal modulated 12.5T pulse, having the combined spectrum shown.

We can use this waveform to test for channel amplitude and delay irregularities, as intuitively developed below. We obtain the waveform of figure 7c by adding the waveforms of a and b. The baseline of the modulated pulse is flat because waveform b is of precisely the correct amplitude to fill in waveform a. If the channel response is higher at 3.58 MHz than at low frequencies, the amplitude of b will be greater than it should be to fill in a. It is easy to see that in this case, the baseline of waveform c will "hang down" below the normal flat baseline, with the maximum value in the center of the pulse. The envelope of the baseline describes a cosine function in this case. On the other hand, if the amplitude of waveform b is correct but is delayed with respect to waveform a, then the peak of the 3.58 MHz envelope will arrive too late to properly fill in the center of waveform a. This is the delayed chroma case illustrated in figure 7. The baseline envelope describes a sinusoid. In general, a channel can have both amplitude and delay errors, resulting in a waveform between a sinusoid and a cosinusoid. The response errors can be determined with the aid of the nomograph referenced above.

Figure 6 includes a small spectrum display showing the concept of delay in the frequency domain. The theory behind measuring group delay with a modulated 12.5T pulse is based on the assumption that the delay is flat over the luma bandwidth occupied by the modulated 12.5T pulse. It is also assumed to be flat over the spectrum occupied by the chroma subcarrier, but between the two bands the delay changes. This is a useful approximation, but is hardly real world! In practice, one can often assume that the delay is flat over the luma band. Over the chroma band, the amplitude and delay response are often anything but flat. The effect is to distort the baseline of the 12.5T pulse, so that it is not sinusoidal. Reading the delay in such a case is somewhat questionable, as is the whole concept of group delay. The group delay concept is none-the-less useful, and going further is the subject of future work.

## Getting All of These Test Waveforms

The test waveforms shown in the previous section are all available from any of a number of test signal generators that you might own. However, you don't need (or really want) to use them for most signals, because what you need to measure is the performance of the entire headend signal chain. Fortunately, almost all broadcasters and cable programmers supply these signals free of charge. These and other signals are located in the vertical blanking interval

(VBI) of signals you are carrying now. We call these "Vertical Interval Test Signals," or VITS. To evaluate the overall performance of your system, simply demodulate the output of the channels you are carrying, and look for the VITS in the VBI. You will need a waveform monitor (vector scope required for measuring differential phase) and a good demodulator. Many measurements can be made with an oscilloscope and the circuits described in the appendices.

Your first requirement will be for the best demodulator you can get. Since demodulators will add distortion, it will be worth your while to buy a professional demodulator if possible. Some excellent professional demodulators only tune one channel, having been designed originally for off-air applications not requiring agility. Fixed channel input converters will yield the highest quality input, but make it difficult to test all channels. If your demodulator will accept an IF input at the TV standard IF of 45.75 MHz, you can take the IF output from your modulators and processors, and demodulate it. This will generally allow you to test most of the signal chain, with the exception of the output converter of the modulator or processor. The output converter can affect frequency response but is not likely to have an appreciable effect on delay response. You can sweep the output converter with a conventional sweep set-up to confirm its performance.

Alternatively but not recommended, you can use an RF (never a baseband) set top converter in front of the demodulator, but you must be very careful to confirm the performance of the set top converter. They are not made for measurement applications, and do not have appropriate specifications. If you must use one, you should consult the manufacturer for instructions as to how to sweep it, and pick out the best converter response you can find. After taking into account the response of the converter, it may still be a limiting factor in how well you can measure VBI signals. Caution: the response of a converter will not be the same on every channel. Some of the photographs in this article were taken using S-A RF set top converters and 6250 demodulators.

If you can't get anything better, you will still be able to get some information from the baseband output of a TV or VCR. In this case, unless you have some way to independently test the performance, your ability to make measurements will be very limited, and you may well not be able to measure to the limits prescribed in the agreement between the cable industry and the cities. However, you will be able to get some idea of the performance of your signals in the video blanking interval, and you should be able to check depth of modulation with the calibrator we'll tell you about later.

In order to measure baseband characteristics, you ideally will have a waveform monitor and vector scope. At this time, we don't know of any way to measure differential phase except by using a vector scope. Lacking a waveform monitor, you can do most tests using any good dc coupled oscilloscope having a video response of 10 MHz or more. See appendix B for more information.

Thus, the minimum set-up for observing baseband signals is a TV or VCR with a baseband output, an oscilloscope and the sync separator circuit here-in described. This will be enough to make some important measurements, though not all those required by the agreement. A better set-up is a professional quality demodulator with agile front-end (or using IF interface as described above), with a waveform monitor and vector scope. Automated test indicators are also available, but are very expensive and have their own set of limitations in some situations.

## IMPAIRMENTS WE HAVE SEEN

### Depth of Modulation

While not specified in the agreement, video depth of modulation (DOM) is a most important parameter, and we have found that some systems are not good about maintaining it. Low depth of modulation will cause pictures to look dark, and can sometimes cause sync circuits to work poorly. With some scrambling systems, incorrect depth of modulation will cause even more severe problems. High depth of modulation will cause light areas of the picture to wash out, and will cause an audio buzz in some sets.

The FCC specifies that depth of modulation should be set to 87.5% for optimum picture quality. One would expect that the DOM on the majority of channels would be close. However, this turned out not to be true at two cable systems measured. Figure 8 shows the result of DOM measured on one of the cable systems. The system offered 53 channels. The average DOM of all 53 channels measured was 81%. The lowest DOM measured was 65% and the highest DOM measured was 94%. The standard deviation was 6.5%. It was interesting to note that even on several of the premium channels, DOM was below 80%.

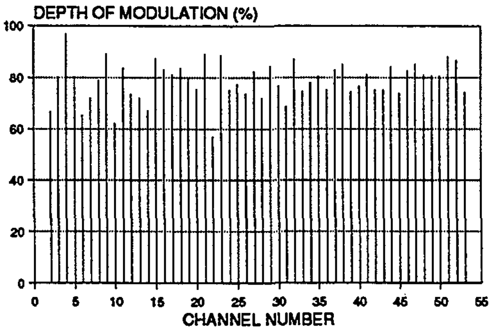


Figure 8. DOM of All Channels Measured on One Cable System

Depth of Modulation is a measurement of percent modulation. It is the ratio of an RF carrier's amplitude change during peak white modulation, to the maximum amplitude. Figure 9 illustrates DOM of a video modulated carrier. For a discussion of what constitutes a video signal and the definition of various levels, see appendix A.

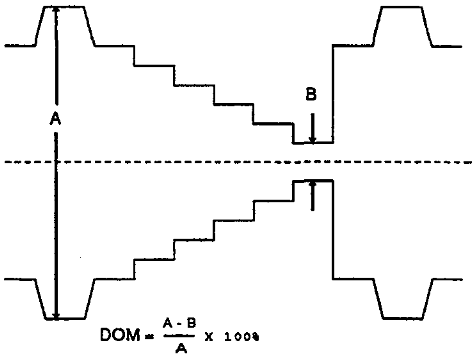


Figure 9. Depth of Modulation of a Video Carrier

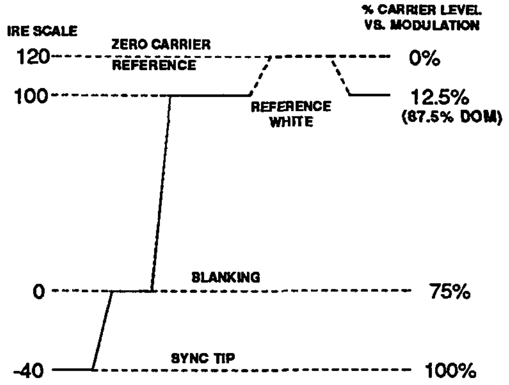


Figure 10. Relationship Between Video Level and Carrier

In an NTSC video system, peak carrier is reached during the sync tips, -40 IRE. During this time 100% of the video carrier is transmitted. Horizontal and vertical blanking, 0 IRE, result in 75% of the RF carrier being transmitted. White level, 100 IRE, produces 12.5% of the available video carrier. Figure 10 illustrates the NTSC depth of modulation.

## DOM Measurement Methods

The three most common methods for measuring DOM are: A) spectrum analyzer, B) demodulator with zero chop, and C) calibrated video demodulator. The method one uses is primarily a function of available equipment, knowledge of measurement technique, or personal preference.

### A. Spectrum Analyzer

Depending on the type of analyzer used, analog or digital, there are several variations and limitations regarding the spectrum analyzer's settings. With an analog spectrum analyzer, DOM can be monitored either at a video field rate or horizontal line rate. With a digital spectrum analyzer DOM becomes very difficult to monitor at video line rates. Regardless of the type of analyzer used, the spectrum analyzer must have an IF bandwidth of at least 300 KHz, zero frequency span capability, and a linear display scale mode or calibrated decibel vertical axis. Video triggering is also required if sweeping at a horizontal line rate.

To measure depth of modulation:

1. Connect the modulated RF or IF output from the modulator under test to the spectrum analyzer's input.

2a. Configure the analog spectrum analyzer as follows for displaying a full video field:

Bandwidth:300 KHz min.
3 MHz preferred
Frequency Span:Zero span
Trigger:A.C. Line
Scan Time:200 ms
Video Filtering:None,
1 MHz preferred

2b. Configure the analog or digital spectrum analyzer as follows for displaying several video lines.

Bandwidth:300 KHz min.
3 MHz preferred
Frequency Span:Zero span
Trigger:Video
Scan Time:200 8 µs
Video Filtering:None,
1 MHz preferred

3. Tune the analyzer to the output frequency of the modulator under test. The displayed waveform represents the peak detected video signal. Fine tune the

analyzer's center frequency control to maximize the amplitude of the detected video signal.

4. Use the linear amplitude display, positioning the sync tips on the top most graticule, as shown in figure 10, by adjusting the amplitude sensitivity (often called *reference level*). This calibration sets the top most graticule to 100% modulation and the bottom most graticule to 0% modulation. Percent modulation of the displayed waveform can now be expressed as follows:

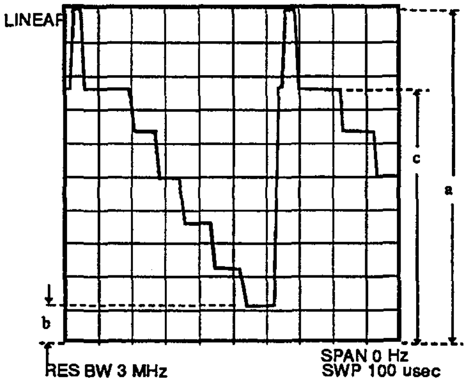


Figure 11. Measurement of Depth of Modulation Using A Spectrum Analyzer

$$\%DOM=\frac{a-b}{a}\times 100\%$$

Where:

"a" is equal to the total number of major displayable vertical graticules.

"b" is equal to the number of major graticules the 100 IRE signal is displaced from the bottom most graticule.

For example, if the RF carrier is modulated by a 5 step linearity signal such as that shown in figure 11 and an analyzer display of 10 major graticules, 87.5% DOM would place the 100 IRE step at 1.25 major divisions from the bottom most graticule.

Unfortunately, when observing DOM with active video signals, a 100 IRE reference pulse is not always present. In this situation DOM can be monitored by observing the blanking level with respect to sync tips. The percent of modulation referenced to blanking, assuming no sync compression from the headend, can be expressed as follows:

$$\%DOM=3.5\times\frac{a-c}{a}\times 100\%$$

Where:

"a" is equal to the total number of major displayable vertical graticules.

"c" is equal to the number of major graticules the 0 IRE, blanking, signal is displaced from the bottom most graticule.

3.5 is the ratio of peak to peak video with respect sync tip amplitude.

An even easier way to set up the spectrum analyzer display is to position the sync tips 8 divisions up from the bottom. The peak white should then just reach 1 division from the bottom. Sync tips should be 6 division from the bottom.

### B. Zero Chop

In order to measure depth of modulation using the zero chop method, two references must be established. One reference corresponds to the transmitted peak carrier level, 100% of available carrier, and the other corresponds to zero, 0% of available carrier. By establishing these two references and knowing that a standard NTSC video signal has an amplitude of 140 IRE units (40 IRE units from sync tip to blanking level, 100 IRE units from blanking to peak white, and 160 IRE units from peak carrier to zero carrier) DOM can easily be determined by taking the ratio of the 100 IRE signal amplitude (measured from sync tip) with respect to the amplitude of the zero chop signal (measured from sync tip).

A zero carrier reference cannot be transmitted from the modulator without causing severe system problems. Most professional video demodulators have the ability to switch off the IF signal for a few microseconds during the vertical interval. This simulates a situation in which the transmitted signal is 100% modulated. Figure 12 shows the zero chop signal generated by an S-A 6250 demodulator.

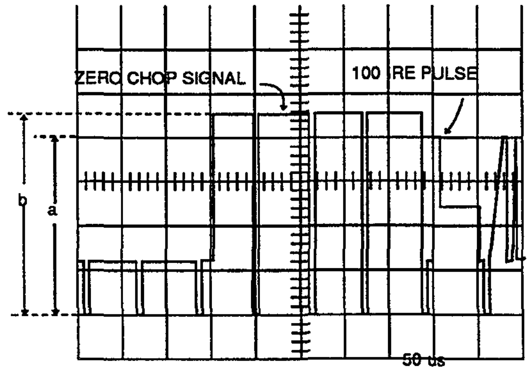


Figure 12. Zero Chop Pulse Produced by a Professional Demodulator

To measure depth of modulation:

1. Tune or set the input converter of the video demodulator to the output frequency of modulator under test.

2. Switch the demodulator's zero chop function on.

3. If incidental carrier phase modulation is present, set the demodulator to envelopment detection. If not, synchronous detection often gives more accurate results.

4. Display the output of the video demodulator on a video waveform monitor or oscilloscope. If using an oscilloscope without TV triggering, use the TV triggering circuit described in this paper.

5. By using a combination of the demodulator's signal output level adjustment and the oscilloscope's vertical gain adjustments, set the amplitude of the video signal to 160 arbitrary units from sync tip to peak of zero chop pulse. Figure 13 illustrates this setup by showing a portion of the vertical blanking interval with an inserted zero chop signal. The 100 IRE signal identified in the illustration is a portion of the VITS reference for the mulitiburst signal. DOM can now be determined using the 100 IRE bar reference

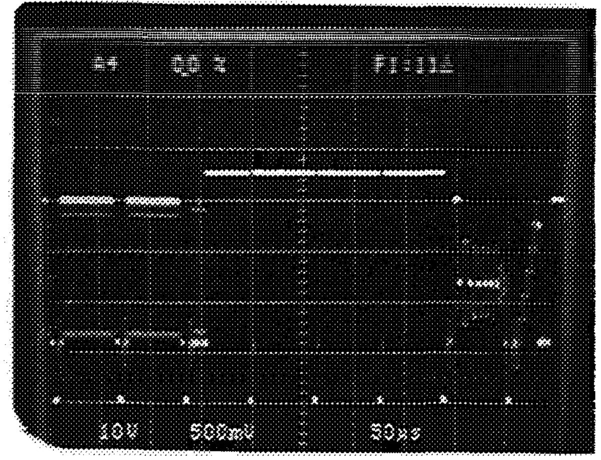


Figure 13. Zero Chop Display

and zero chop signal as follows:

$$\%DOM=\frac{a}{b}\times 100\%$$

Where:
"a" is equal to the amplitude of the 100 IRE signal.

"b" is equal to the amplitude of the zero chop signal.

If VITS or a 100 IRE signal in not available, DOM can be measured using the amplitude of the sync pulse as follows:

$$\%DOM=3.5\times\frac{c}{b}\times 100\%$$

Where:
"c" is equal to the amplitude of the sync pulse.

"b" is equal to the amplitude of the zero chop signal.

3.5 is the ratio of peak to peak video (inclusive of sync) with respect to sync amplitude.

C. Calibrated Video Demodulator

Video depth of modulation can also be determined by using the calibrated video demodulator technique. This method is primarily used when a zero chop demodulator is not available. It is also an excellent method for measuring DOM when using a VCR with a baseband video output. An advantage of using a VCR with a baseband video output, is that it can double as an agile demodulator.

As the method's name implies, the demodulator needs to be calibrated. Calibration is accomplished by measuring the output of the demodulator when supplying a known input signal. Once the output of the demodulator is calibrated, DOM can easily be determined by taking the ratio of the amplitudes of the unknown signal with respect to the calibrated signal. The calibrated input signal can either be from a video source and modulator pair or from the demodulator calibrator circuit described in appendix C. If using the video source and modulator pair, the modulator should be set to 87.5% DOM using the spectrum analyzer method or zero chop method. If using the demodulator calibrator circuit, the output signal simulates a signal with 87.5% DOM. This is accomplished by attenuating the input carrier by 18.06 dB at the horizontal line rate. The attenuation level of 18.06 dB was derived from the following equation:

$$attn\ level(dB)=20\log(1-\frac{\%DOM}{100})$$

Where:

"%DOM" is equal to 87.5%

To measure depth of modulation:

1.Configure the test setup as shown in figure 14.

2.If using the demodulator calibrator circuit, verify that there is no video modulation on the output from the channel 3 modulator.

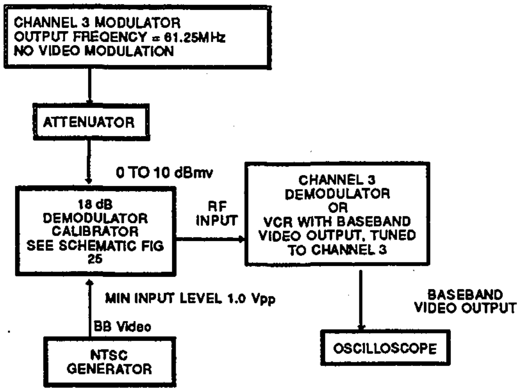


Figure 14. Calibrated Demodulator Set-up

3. If using the video generator and modulator pair, verify that the modulator is calibrated to 87.5% DOM.

4. To minimize the effects of incidental carrier phase modulation distortion, set the demodulator to envelopment detection if necessary (though you may not get a choice).

5. Display the output of the video demodulator on a video waveform monitor or oscilloscope. If using an oscilloscope without TV triggering, use the TV triggering circuit described in this paper.

6. For maximum accuracy, adjust the oscilloscope's gain control for maximum displayable peak to peak signal.

7. Measure and record the peak to peak amplitude of the displayed signal, $V_{\text{cal signal peak to peak}}$. The amplitude of this signal represents this modulator's output amplitude for a signal with 87.5% DOM.

8. Remove the demodulator calibrator and connect the output of the modulator under test to the input of the demodulator.

9. Tune the demodulator to the output frequency of modulator under test.

10. Adjust the oscilloscope's delayed trigger control to view the 100 IRE pulse located in the vertical interval test signal.

11. After measuring the amplitude of the 100 IRE pulse, $V_{\text{100 IRE peak to peak}}$, DOM can be determined as follows:

$$\%DOM=\frac{87.5\times V_{(p-p)}}{V_{(cal\ p-p)}}$$

12. Similar to the spectrum analyzer method and zero chop method, if a 100 IRE pulse is not available DOM can be determined by measuring the amplitude of the sync pulses. The following equation is used:

$$\%DOM=3.5\times 87.5\times\frac{V_{(0IRE\ p-p)}}{V_{(cal\ p-p)}}$$

## Vertical Blanking Interval Problems

The only video signals that are permitted to descend below blanking, 0 IRE, are the color burst and synchronizing pulses. Some dark colors may also cause the color subcarrier to go below 0 IRE during active video. All other signals descending below blanking are improper and may cause trouble. As previously mentioned, if any portion of the video signal were to cause grief it would likely be the vertical interval. Unfortunately, one cable system demonstrated several good examples of

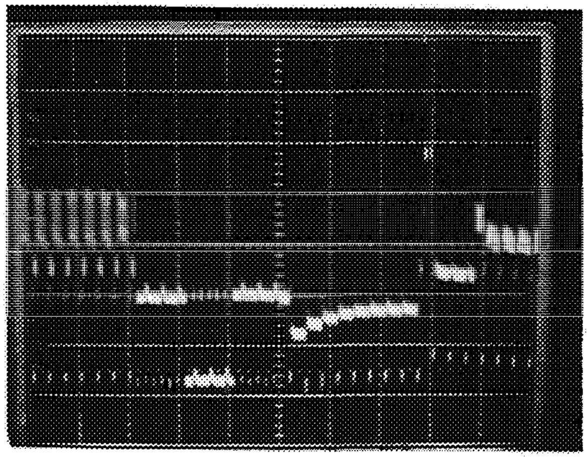


Figure 15. Descending Vertical Blanking

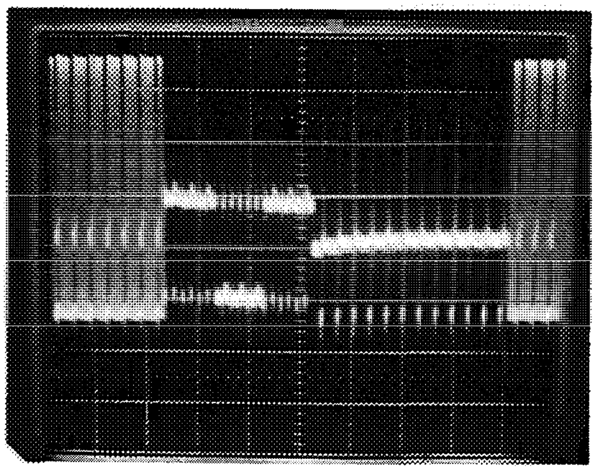


Figure 16. Shift of Sync Tips in Vertical Blanking Interval

illegal video. Figure 15 shows a good example of a problem seen in the vertical interval, in which the vertical interval blanking signals are descending below normal blanking level. Notice the nearly 20 IRE of blanking droop starting immediately after the post equalizing interval. This descent exponentially decreases to 0 IRE after about 10 lines. Notice also that the sync pulses after this period, beginning at about line 17, are raised. Problems of this type may not be noticed during casual television viewing. However, descending vertical blanking could manifest itself in professional and consumer equipment that relies on the integrity of the vertical interval. The most likely cause of the problem is a defect in baseband equipment. In one case it was traced to a defective VITS generator at the uplink, and in another case it was due to a defective character generator at the headend.

Another problem seen in the vertical interval was the shifting of many line of sync. Here the pre equalizing, vertical sync pulse, and post equalizing intervals were shifted above the horizontal sync pulses by 10 IRE. Figure 16 shows an example of sync shifting. A problem of this nature also has the potential of causing problems with vertical sync separators in VCR's, TV's, and closed caption equipment. It was again traced to a defective character generator at the headend. Also notice the extremely high chroma. This channel had lots of problems!

## Sync Compression

This is a common problem with lower cost and consumer equipment, which can manifest itself as unstable sync on some TV sets, poor character generator performance and poor video tape results. The FCC specifies that the amplitude of synchronizing pulses should be 40 IRE. Anything less than 40 IRE is considered to be compressed. Sync compression is measured by taking the ratio of blanking to peak white, divided by blanking to sync tip. This ratio should equal 2.5.

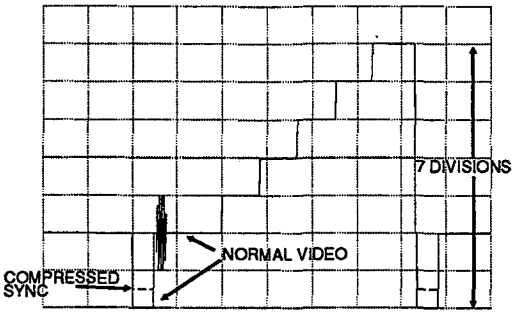


Figure 17. Sync Compression

Figure 17 illustrates sync compression. The easiest way to check this is to adjust the vertical position and gain on your oscilloscope until the blanking interval is 2 divisions from the bottom, and the peak white is 7 divisions from the bottom. If the sync is not compressed, the sync tips will be on the bottom graticule as shown. Compression will result in higher sync tips.

One source of sync compression is the headend modulator. Compression in the modulator could be a result of poor clamping or output amplifier nonlinearity. Another less controllable source of sync compression is from local UHF and VHF transmitters. The high output power from these transmitters has been know to compress sync pulses. We encountered one such example a few months ago, at a UHF PBS affiliate. A call to the station's engineer indicated that he was operating on one Klystron rather than the three normally used. The station was installing a new transmitter, and he couldn't get replacement klystrons for the month until the new transmitter was ready. He was amazed that we weren't measuring even more severe problems! If your headend is processing a signal with sync compression there is nothing to be done short of correcting this problem at the transmitter. If converting to baseband then remodulating, a video processor should do the trick.

## Descending Characters

Most headends today have the capability of inserting on-screen characters on some channels. For example, the Weather Channel allows local cable operators the option of inserting local weather forecasts and current conditions using on-screen characters. The problem with overlaying locally inserted on-screen characters is that the incoming video signal level may not match the inserted on-screen character levels. One manifestation is that the black level boarding the characters will drop below the input video's black level. When this occurs, video equipment that relies on sync pulses becomes confused when it sees additional pulses dropping below the black level. Fortunately, this problem is usually easily corrected by monitoring the video signal at the baseband input to the modulator while making the appropriate adjustments to the on-screen inserting equipment.

## Audio Deviation

Similar to video depth of modulation, headend audio deviation is not one of the proposed operational standards. However, inconsistent deviation is the source of many subscriber frustrations and complaints. Deviation is a measure of the loudness of a signal. Figure 18 shows the relative detected audio levels measured on one cable system. The relative audio deviation was computed by first measuring the detected audio level on all channels using a VCR's vu meter. (By the way, "vu" stands for *volume units*, not "view" or some of the other strange

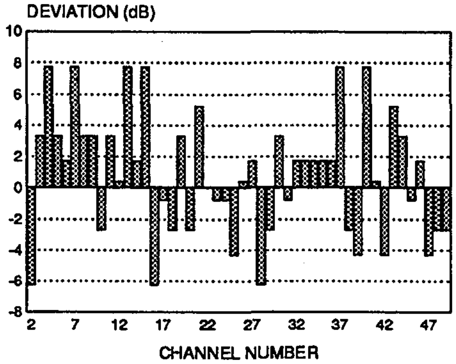


Figure 18. Audio Deviation as a Function of Channel

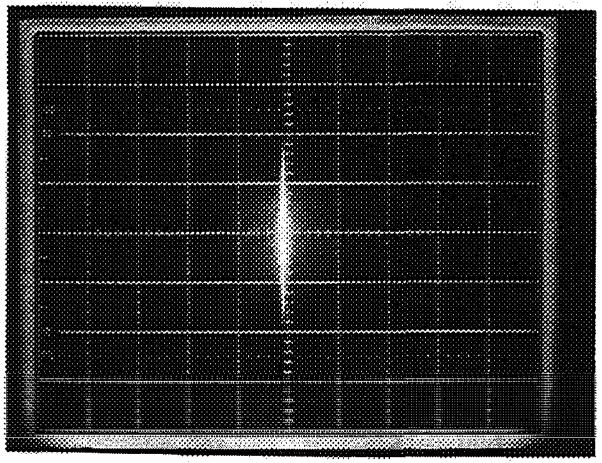


Figure 19. Peak Audio Deviation Displayed on an Oscilloscope Having No X-Deflection

terminology sometimes applied.) Since typical audio programs vary in level the average meter reading of the channel being measured was recorded. After recording all channels, the average reading of all channels was determined. This average was then used as a reference to compute the relative audio deviation on each channel. The horizontal line on the chart indicates the average level of the three network stations.

Notice the wide variation in relative audio deviation across the 50 channels measured. This type of variation can become annoying when scanning the dial. Subscribers are frequently adjusting the TV or converter volume control for the desired audio level. Today's television viewers have become more discriminating to audio quality. CD players, hi-fi VCR's, BTSC stereo, and digital music on cable has sensitized many subscribers to high quality audio. Therefore, it is imperative that cable operators maintain high quality audio through-out the headend.

Audio levels can be evaluated several ways, average, peak, peak factor, and loudness. Average refers to averaging the amplitude of the audio signal over a period of time (RMS). This is usually accomplished with the use of a VU meter.

Peak is an instantaneous measurement of the audio signal's peak amplitude. A peak program meter is usually used to make this measurement. However, an oscilloscope can also be used with adequate accuracy. Figure 19 shows a sample of audio metering using an oscilloscope with the sweep speed set to XY and no deflection horizontally. The meter is first calibrated by connecting it to the output of a demodulator tuned directly to an off-air signal. Broadcasters are usually pretty good about maintaining the correct peak deviation, so you can use a broadcast signal to calibrate your modulation indicator if you have nothing better available.

Peak factor refers to the ratio

between the peak voltage and the RMS voltage in an audio signal. Measuring peak factor requires a specialized piece of equipment called an audio deviation meter.[4] The final method of monitoring deviation is loudness measurement. The human ear's ability to sense loudness is very similar to measuring the RMS value of an audio signal. This is true because the human ear perceives loudness as a power derived factor. Unfortunately, the human ear's poor loudness memory makes it very difficult to set deviation accurately.

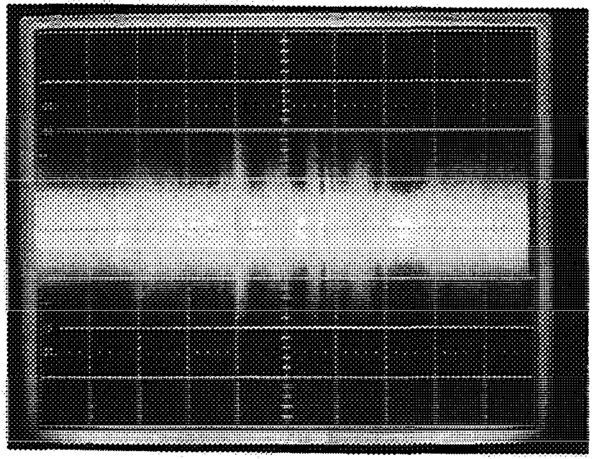


Figure 20. Time Elapsed Oscillograph Tracing of Deviation

As previously mentioned, an oscilloscope can be used to balance the audio deviation in a headend. Basically, this is done by monitoring the demodulated audio signal using an oscilloscope with its horizontal sweep set to 500 ms or higher. The vertical trace, similar to the one shown in figure 19, sweeping across the oscilloscope is the audio signal. The peak to peak excursions represents peak to peak deviation. Figure 20 shows deviation v.s. time for about 3 seconds of audio. The audio deviation on all channels can now be set to some predetermined reference peak level. Since off-air network channels usually have their volume levels carefully monitored, they should be used to establish this reference.

Using an oscilloscope calibrated against a local broadcaster may not be the perfect method to set deviation, but is a lot better than what some systems are doing now. The peak flasher on many modulators may also be used, but is really intended more as an alarm to indicate that the legal deviation is being exceeded. The NCTA engineering committee is painfully aware of many subscriber complaints of poor audio consistency, and is working with program suppliers to do something about it.[5] Hopefully this fall, a reference tone will be transmitter once a week from one or more program suppliers, which will allow you to set deviation on all modulators supplied from VideoCypher decoders. We urge you to take advantage of this test tone when it becomes available.

## ACKNOWLEDGEMENTS

The authors wish to acknowledge the help of the few cable systems who unwittingly provided a plethora of examples of what not to do, for us to write about.

Brenda Roberts constructed and tested the circuits shown and took many of the photographs.

# APPENDIX A. A REVIEW OF VIDEO BASICS

## The Picture Composition

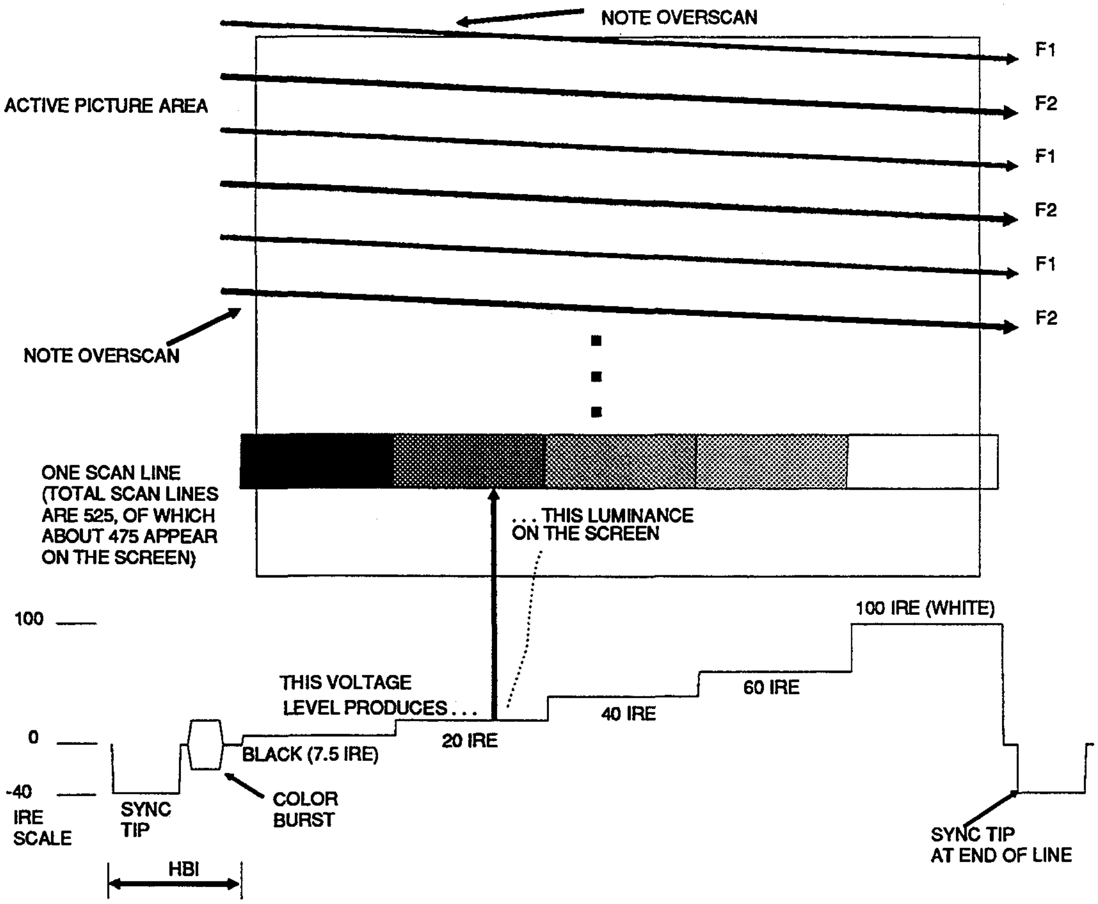


Figure 21. Composition of TV Picture

The picture is painted on a TV screen one line at a time, moving from left to right and top to bottom of the screen - the same trajectory our eyes follow as we read. A complete picture consists of 525 lines, of which, at most 475 actually appear on the TV screen. The complete picture is "painted" about 30 times a second, and consists of two halves, each half "interlaced," or occupying every other line.[6] The complete picture is called a *frame* (similar to the motion picture use of the term), with each half picture being called a *field*. Unimaginatively, each line of the picture, is called a *line*. This is illustrated in figure 21, which shows the active picture area of a TV set in the proper 4:3 ratio (four units wide to three units high). Scanning starts above the active picture area in field 1, and proceeds from left to right as illustrated by the lighter lines labeled "F1." When the electron beam reaches the bottom of the picture tube, it resets to the top and begins painting, or *scanning*, the in-between lines which, form field 2.

Intentionally, the lines reach beyond the left and right edges of the active picture area, as well as above and below. This is done so that under almost all conditions the picture will still take up the entire screen. Most scrambling systems take advantage of this overscan, as do a number of VBI services.

Thus, we have the following composition of the picture.

1 complete picture = 1 frame
1 frame = 2 interlaced fields
each frame = 525 lines

We can compute some important parameters of the picture from this. We said that we painted about 30 frames a second - the actual frame rate is 29.97 frame per second. We have twice as many fields as frames, so the field rate is 59.94 fields per second.[7] Since we have 29.97 frames per second and 525 lines in each, we have a line rate of 29.97 times 525, or 15.734 KHz. The time or period of a horizontal line is 1/15734 = 63.56 µS. This time is often referred to as the H-time, or simply H. You will often see times in video referenced with respect to H. For example, the width of a sync tip is often stated as 0.075H, or 0.075 times 63.56 = 4.767 µS (we frequently round down to 4.7 µS). These are all important numbers which should be committed to memory.[8]

## Horizontal Synchronization

Obviously, if the TV is going to paint the same picture seen by the camera, it must scan in synchronization with the camera. When the camera beam resets left to right or top to bottom, the TV must do the same. How does the TV know when to do this? Synchronization ("sync") information is carried with the TV signal. Horizontal sync tells the TV that its electron beam should be at the right edge and should be resetting to the left. Vertical sync does the same thing top to bottom.

Figure 21 shows a line of TV signal properly positioned with respect to the screen. Sync tips occupy a unique voltage level in the picture. As the baseband TV signal is normally presented, this is the most negative voltage level in the picture. Horizontal sync tips last for 4.7 µS (microseconds). When sync arrives, the TV makes sure that the electron beam is just off the screen to the right, and that the beam resets to the left. Thus, the sync tip shown to the left is really the same as the sync tip on the right, but one line earlier. The time from just before the sync tip begins to just before active video begins, is called the "horizontal blanking interval," or HBI. The other primary feature of the HBI is the color burst, with which we shall deal presently. To an engineer this is one of the most exciting parts of the television picture.

## Luminance

During the active video line, voltage levels represent brightness of the picture. The higher the voltage level the brighter the picture at that spot. We illustrate one line on the screen, which consists of 5 shades of gray, from black to white. The higher the voltage level the brighter the picture at that spot. Note that we are only talking about the black and white picture now - we'll add color later. The black and white picture information is known as the *luminance*, or sometimes, *luma*. It is measured on a scale called the "IRE" scale.[9] The starting point of the IRE scale is 0 IRE, which is the blanking level. Black level is defined to be 7.5 IRE[10], and white is 100 IRE. Sync tips are at -40 IRE. This IRE scale can be related to voltage, in that video is normally at a voltage of 1 volt peak to peak, which comprises the sync tip to peak white, or 140 IRE. Thus, one IRE is normally 1/140=7.14286 millivolts. Note that 0 volts is not generally 0 IRE because video is often interfaced using ac coupling. The actual 0 volt level will be a different IRE level depending on the complete make-up of the signal.

## Vertical Synchronization

You will sometimes (including in this paper) see the signal drawn inverted from that shown. For example, in the FCC Rules, the waveform is drawn upside down from this. Doing so makes reasonably good sense when modulation of the waveform is discussed. You should be able to recognize the signal regardless of the polarity shown.

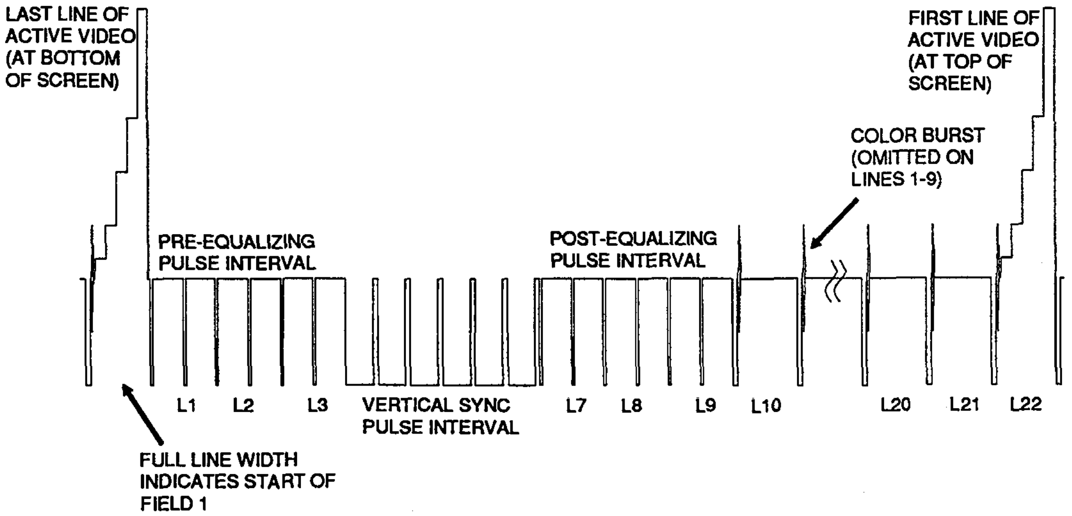


Figure 22. Vertical Blanking Interval

We have seen how the picture is painted on the screen and how horizontal synchronization is achieved. Remaining is to see how vertical synchronization is achieved. Figure 22 shows the vertical blanking interval, or VBI. This corresponds in function to the HBI, in that the vertical sync tells the TV that the beam should be at the bottom of the picture and should now reset to the top. Figure 22 is on a much different time scale than is figure 21. One line of the horizontal signal shown in figure 22 occupies only a small portion of figure 21 (see for example, L22 (line 22), in figure 21, which bears the same video signal as did the illustrated line in figure 21). The vertical blanking interval consists of several features, the most significant of which is the three lines of vertical sync. The vertical sync signal spends almost all of its time at -40 IRE, and this is the way that the TV recovers vertical: it looks for a signal staying at -40 IRE for a long time. The first 9 lines of the field, beginning 3 lines before the vertical sync, are "serrated," or split into two halves separated by a brief transition between sync level (-40 IRE) and blanking (0 IRE).[11]

Notice that the average voltage during the VBI is much lower than during the rest of the signal. This often causes grief for equipment handling the signal. We show an example in this text, of a very distorted VBI on a real cable system. If you have a channel that seems to jitter up and down on some TVs, or if you have complaints about VCR or on screen display problems, look for a problem in the VBI.

The reason for at least 11 (usually more) non video lines after the post equalizing interval, is that the electron beam in the TV, being deflected by magnetic circuits, requires a finite time to retrace from the bottom to the top of the picture tube. The TV signal waits around doing nothing (with video) for a while, waiting for the retrace. This retrace time has recently become one of the most popular parts of a TV signal. It is used to transmit test signals ("VITS," or vertical interval test signals) and VIRS, or vertical interval reference signals. It is also used to transmit closed captioning information (standardized on line 21 of field 1), and is often used to transmit other data. The VBI is at the heart of a great controversy now: does this time belong to the TV broadcaster, the cable operator, or someone else? For example, a PBS subsidiary sells this time to people who want to distribute data. Other broadcasters and cable programmers do the same. Some operators are considering asking for additional money to carry these signals, which generally are not part of the TV program. Some scrambling systems also use the VBI to transmit control and/or addressing information.

## Adding Color

The complete process of adding color to the signal is beyond the scope of this paper. Here we will delve into the subject only far enough to relate to measurements we need to make. Color is transmitted as a subcarrier on the main TV signal. The frequency is about 3.58 MHz. Color information is carried in both the amplitude of the color subcarrier and in its phase.

Figure 23 shows part of a TV line, magnified so we can examine the details related to color. The reference at the top of the picture shows the portion of the line that we are magnifying (we modified the first luma level a bit compared with figure 21, from 7.5 to 20 IRE). The color burst consists of a minimum of 8 cycles of the color subcarrier. Color information in active video rides on this subcarrier. Two characteristics of color apply: color saturation and tint. Saturation is the degree to which a color is "pure," or not tainted with white. As you adjust the "color" control on many TVs you are adjusting saturation. Tint is determined by comparing the phase of the subcarrier with that of the burst. When you adjust the tint control of a TV you are effectively adjusting this relative

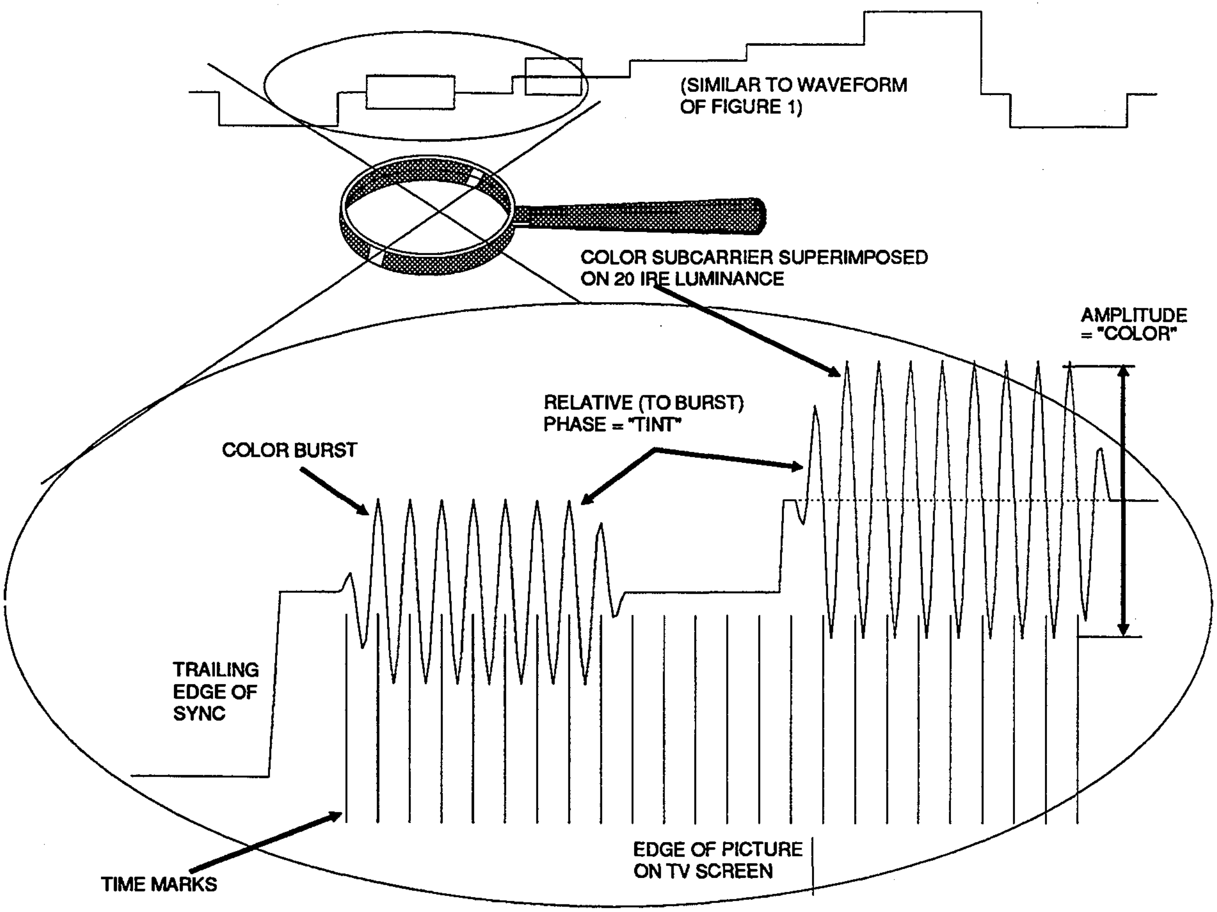


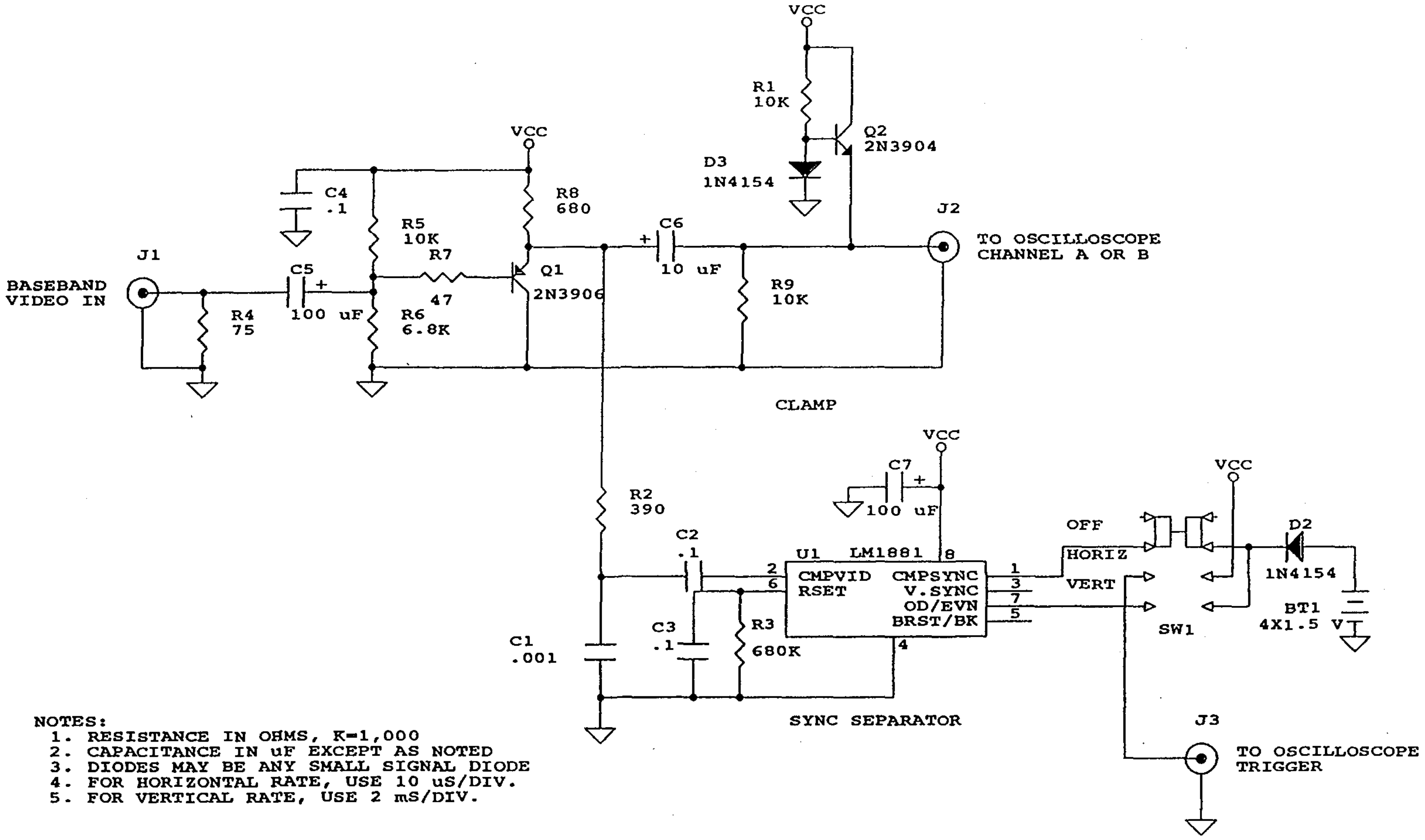
Figure 23. Beginning Part of a TV Line, Showing Color Information

phase. We have added time marks spaced one subcarrier cycle apart, so you can see that the phase of the chroma (color subcarrier) during active video is shifted with respect to the burst - note that the bottom of the color subcarrier aligns differently with the time marks during the burst and during the active video.

## APPENDIX B A SIMPLE CLAMP AND SYNC SEPARATOR

We will now show you a couple of simple circuits that may prove useful in making measurement. We do so at the risk of giving the incorrect impression that this is all you need. *It is not.* These, with an oscilloscope and simple demodulator, will allow you to measure certain important parameters. Rather, they will allow you to get an *indication* of the measurement. These techniques are no substitute for good, professional equipment. If you can get such, please do so. We present these ideas because we know that not every system can get the proper equipment. Intelligent use of this kind of equipment should be better than nothing but, we repeat, it is not nearly as good as getting the proper equipment and doing the job right.

One of the problems you will have making baseband measurements without a waveform monitor, is that an oscilloscope does not have a clamp, or dc restorer, to allow you to see a signal without getting



NOTES:
1. RESISTANCE IN OHMS, K=1,000
2. CAPACITANCE IN uF EXCEPT AS NOTED
3. DIODES MAY BE ANY SMALL SIGNAL DIODE
4. FOR HORIZONTAL RATE, USE 10 uS/DIV.
5. FOR VERTICAL RATE, USE 2 mS/DIV.

Figure 24. A Simple Clamp and Sync Separator for use with Oscilloscopes

vertical bounce as the program material changes. Also, many low cost oscilloscopes have sync separators, but don't have the ability to distinguish between fields one and two, yielding an almost impossible display when you try to look at field rate signals. Figure 24 shows a schematic of a simple clamp and sync separator you can build to use with an available oscilloscope. Your scope will need to be dc coupled and have a bandwidth of at least 10 MHz. In order to observe the VITS you will need a delayed trigger time base. Many scopes in the $500.00 range these days have these characteristics. A convenient way to measure video is to set the signal from sync tip to peak white, to take up 7 divisions vertically. Then the scope is calibrated at 20 IRE per division. When using the zero chop method of measuring DOM, the chop pulse will be on the top graticule.

The circuit in figure 24 consists of three parts. An input amplifier, Q1, buffers the input signal. The clamp, Q2, forces the sync tips to be at ground potential (practically, just below ground - you can make the sync tips closer to ground by lowering R1, at the cost of more battery drain). This provides a signal to the scope that doesn't change level as the video information changes. The third part of the circuit is the sync separator, U1, which uses an integrated circuit make expressly for this purpose.

Resistor R4 provides a proper termination to the video source. If your demodulator doesn't drive 75 ohms (almost all do), you can remove this resistor. Transistor Q1 is an emitter follower to isolate the load from the source. When the input video goes negative at the sync tip, if the output side of C6 is at too low a voltage, clamp transistor Q2 turns on, charging C6 more positive on the output side, raising the output voltage. If the output voltage is higher than zero volts, Q2 never comes on, and the output voltage drops as C6 discharges through R9.

Video signal from the emitter of Q1 is applied to the sync separator through low pass filter R2-C1, which provides a degree of immunity to noise on the input signal. A clamp circuit inside U1 charges C2, to form a clamp circuit similar to that of C6/Q2, but with time constants optimized for sync separation. The IC includes all circuits necessary to recover composite sync, which is switched to the output for horizontal rate triggering. For vertical rate triggering, we use the "OD/EVN," or *odd/even*, output. This signal changes state during every vertical interval, going positive at the beginning of field 1 and negative at the beginning of field 2. This allows you to select one field or the other by changing the trigger polarity on your oscilloscope from + to -. You will need this feature in order to measure VBI signals. One problem you may have with low cost oscilloscopes is that the brightness may be low when observing VBI signals. This is because the signal is repeated only 30 times a second, and the sweep rate during the signal is high. The only solution outside of buying a more expensive scope, is to observe the signals in near darkness (the author must do this with his Heathkit scope).

All parts including the IC are available through DigiKey, (800)344-4539, or through many commercial parts distributors. All parts except the IC are likely available at Radio Shack. You are not too likely to go wrong unless you get hold of a leaky capacitor for C6, or a bad transistor. Diode D2 is included to protect the circuit should you put the batteries in backwards. You could also run the circuit from a 6 volt cube power supply or from a lab supply.

## APPENDIX C. A SIMPLE MODULATION CALIBRATOR

The circuit shown in figure 25 is intended to simulate a video signal modulated 87.5%. This is accomplished by attenuating a 61.25 MHz input signal by 18 dB at the horizontal line rate. Resistors R5, R6, and R12 are configured as a tee attenuator. Since C6 and L5 are in series with R12, the reactance of C6 and L5 at 61.25 MHz was also considered in determining the proper resistor values. In order to improve matching between the signal source driving the switched attenuator and the demodulator's RF input, pads were placed either side of the tee attenuator. Diodes D1, D2, and D3 are PIN diodes. PIN diodes were used because they exhibit very low AC on resistance. In order to supply complementary signals to the diodes for proper switching, Q1 and Q2 are used in a differential switch configuration.

When the input on J3 is at low, D3 is off while D1 and D2 are conducting. This essentially shorts the tee attenuator, thus allowing all of the input signal to pass to the output. When the input on J3 is high, D3 is conducting while D1 and D2 are open circuit. During this time the 18 dB attenuator is switched in line with the input signal and output.

The input on J3 can come from any 15 KHz signal source. The composite sync output available on most NTSC generators makes a convenient source. If a function generator is used, the waveform's period is not too critical, but should roughly match the 4.7 µS period of horizontal sync.

If possible, after constructing the video demodulator output level calibrator it would not hurt to verify the 18 dB attenuation level. This can be accomplished by using the spectrum analyzer method for measuring DOM.

This method of measuring DOM puts you at some risk of error, because not all demodulators have the linearity to make the measurement. However, if you calibrate to 87.5% DOM then adjust sources to 87.5% DOM, you should be OK.

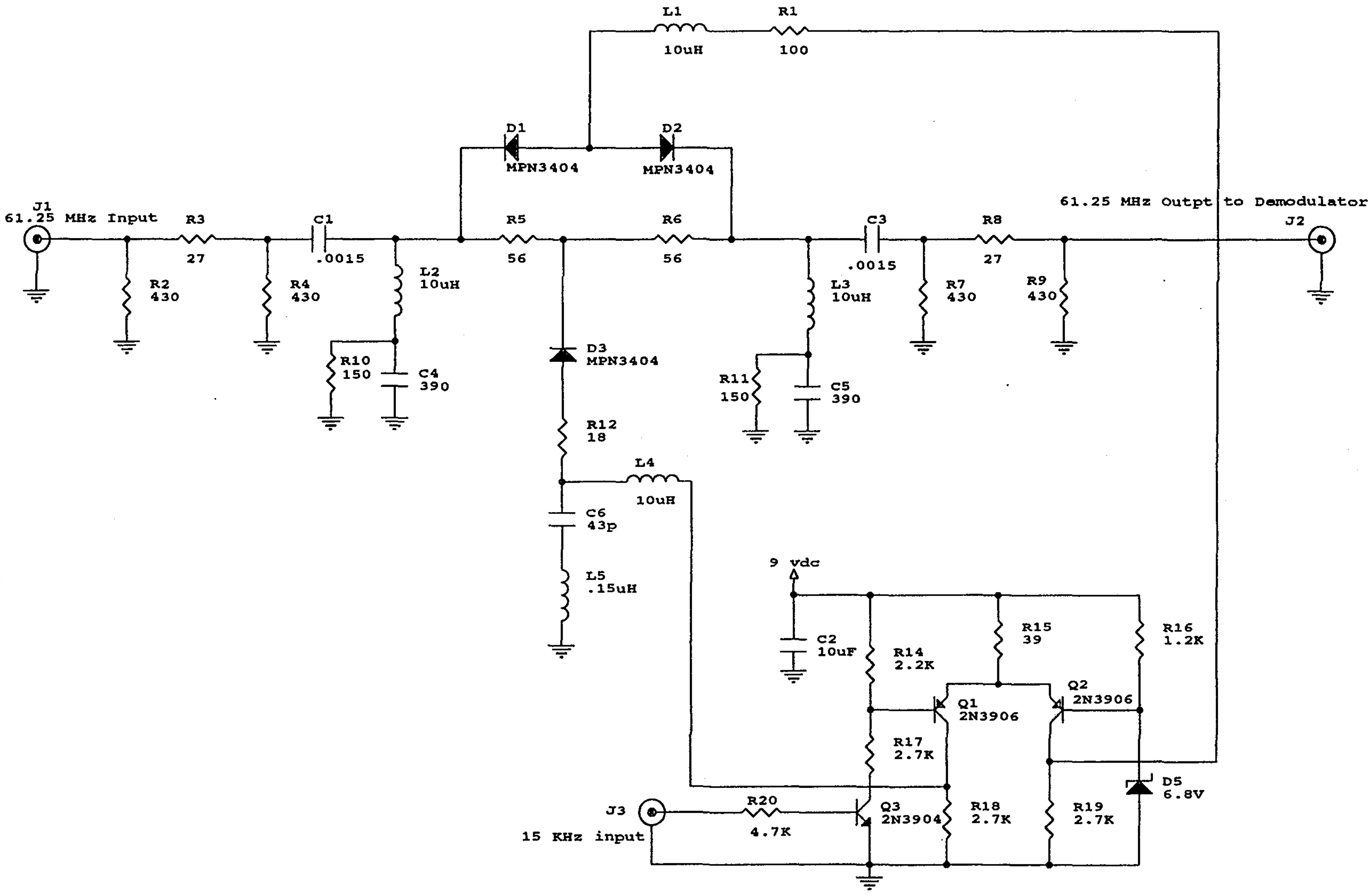


Figure 25. A Simple Depth of Modulation Calibrator

# END NOTES

1. Ambiguity exists in the definition of worst case differential gain and phase in the agreement. This will be resolved shortly by a joint committee which is defining measurement procedures.

2. More generally, the term *group delay* is applied. We often use the terms interchangeably, though technically, they are not quite the same: Group delay is a general term, and chroma to luma delay is a special case.

3. We are aware of the sloppy use of "pulse," v.s. half cycle of a sine wave. The two are not the same, but the effect of a pulse and a half cycle of a sine wave are similar when viewed on a TV screen, and the concept is useful.

4. McClatchie, Frank F. "How To Measure It, Set It Right, And Keep It That Way" NCTA 1988 Technical Proceedings

5. Mountain, Ned, private communication.

6. In the PAL and SECAM systems used in Europe and elsewhere, the picture has 625 lines and is updated 25 times a second. The added number of lines is one reason that European TV is often "sharper" than is North American TV, but the reduced number of pictures per second results in more flicker than is seen in North America.

7. In the old black and white days, the field rate was identically equal to the ac frequency of 60 Hz (then cycles per second). In those early days, it was harder to filter ac to get dc to operate the TV, and the result was hum bars on the TV. To reduce the visible effect of hum, the picture was locked to the ac line, resulting in still hum bars. The change from 60 Hz to 59.94 Hz came about when NTSC color was added, and results from the need to interlace the beat between the sound and color carriers. The details are beyond the scope of this paper.

8. An outstanding reference for baseband video is the Video Reference Data chart published in CT magazine, November 1991. This issue includes several good articles on baseband video.

9. The Institute of Radio Engineers (IRE) was one of the organizations which merged to form the Institute of Electrical and Electronic Engineers (IEEE) about 1960. Much of the early work aimed at standardizing the TV system we have was done under the auspices of this organization.

10. Black is at blanking in PAL. It is offset for historical reasons in NTSC.

11. The reason for the serrations in vertical sync is historical, relating to how early receivers operated. The need today is debatable, but no one is willing to remove something, the removal of which could cause unpredictable reaction on some TV.