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tech tips

Understanding Video Comb Filters

In recent years many video systems, such as television receivers and VCRs, have incorporated a circuit which is able to separate the chroma and luminance signals from the composite video signal. This circuit is called a comb filter and provides several improvements to NTSC video systems. Understanding how the comb filter works, will help you in servicing them.

Luminance and Chroma Signal Spectrum

A composite video signal is made up of separate luminance and chroma signals as shown in Figure 1. The luminance signal represents the black and white portion of the video picture and is comprised of many video frequencies and harmonics from 0 - 4.2 MHz. The luminance signal is responsible for forming large and small detailed objects on the CRT screen.

The chroma signal represents the color portion of the picture. The chroma signal is comprised of separate I and Q chroma signals that result from mixing the separate colors at the transmitter. The I and Q signals are converted to upper and lower sideband signals centered at approx. 3.58 MHz by a balanced modulator. The I chroma sideband frequencies extend 0.5 MHz above 3.58 MHz and approximately 1.3 MHz below. The Q chroma sideband frequencies extend 0.5 MHz above and below 3.58 MHz. The chroma signals are responsible for adding color to the objects formed by the luminance signals.

To be compatible with B&W receivers and utilize existing bandwidth requirements, the chroma I and Q signals are combined within the same bandpass as the luminance. The luminance and chroma signals then occupy a portion of the same frequency spectrum. Since chroma signals extend from about 2.5 MHz to 4 MHz, the high frequency end of the video spectrum is affected. To prevent interference between the luminance and chroma signals within this spectrum, a system called frequency interleaving was adopted.

Luma Spectrum | Chroma Spectrum | Luma Chroma Spectrum

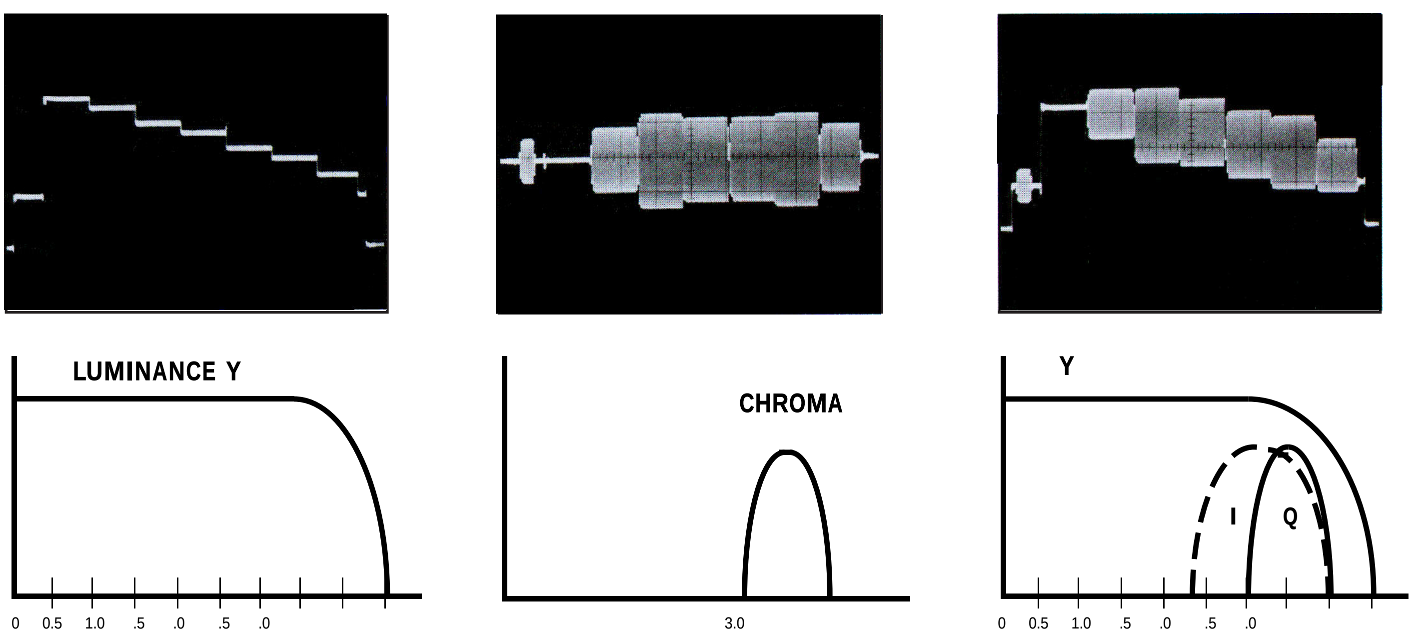

Fig. 1 Luminance and Chroma signals and their bandwidth characteristics.

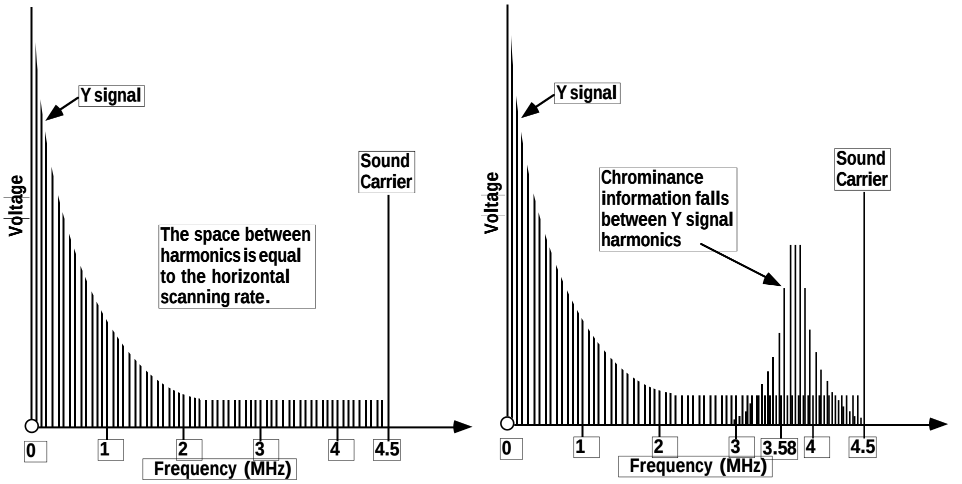

Fig. 2: Frequency interleaving creates chroma I and Q sideband signals that fall into empty spaces between the luminance.

Frequency interleaving creates chroma I and Q sideband signals that fall between harmonics of the high frequency luminance. This is accomplished by placing the chroma sideband signals at odd harmonics of one-half the horizontal scanning frequency of 15,734 Hz so that the chroma sideband signals fall exactly between the luminance signals. To achieve this, a color subcarrier frequency of exactly 3.579545 MHz is used. The resulting sidebands appear similar to the teeth of a comb. Thus, the circuit that is used to separate the luma and chroma sidebands is called "comb" filter.

Luminance and chroma signals sharing the same frequency spectrum causes a few problems and poses a challenge to video equipment which must separate the luminance and chroma signals. The luminance and chroma sidebands may overlap at times with video signals that have a high frequency luminance content. When high frequency luminance signals (between 3 and 4 MHz) get into the chroma circuits, they simulate color information and are processed by the color circuits. These luminance signals cause color swirls or wrong colors in detailed portions of the picture. This occurs most often when the spacing between the objects in the picture repeat at a frequency near 3.58 MHz. This may be seen in objects such as a striped tie.

If chroma gets into the luminance stages, beat interference is created that produces a grainy look to the picture. This is especially noticeable in picture areas of highly saturated colors. It can also cause the edges of graphic characters to develop a "steppy" look depending on the combination of foreground and background colors.

Benefits of the Comb Filter

Before the advent of comb filters, chroma interference in the luminance was prevented by limiting the luminance bandwidth with passive bandpass filters. The frequency response of the luminance was limited to about 3 MHz out of a possible 4.2 MHz. As a result, the video picture suffered from the loss of fine-detail information contained in the high frequency luminance.

Comb filters provide four picture improvements compared to conventional bandpass filtering: 1) The luminance signal has higher resolution; 2) The color signal can have higher resolution if fed to a "wideband I & Q" demodulator; 3) There is less color and color subcarrier interference in the luminance signal; and 4) Objects with a fine geometric pattern are less likely to cause color swirl from luminance interference.

The biggest advantage of comb filters is added resolution. The comb filter recovers the high frequency luminance information that would normally be filtered by conventional filtering. By recovering the higher luminance sideband signals from the composite video, the comb filter greatly increases the resolution of a television receiver. The filter increased resolution increases the picture detail and makes small objects more visible.

The smallest object that can appear on the TV screen in color is illustrated in Figure 4. A typical television receiver has a limited color resolution of about 0.5 MHz, or objects about 2.5% the width of the TV

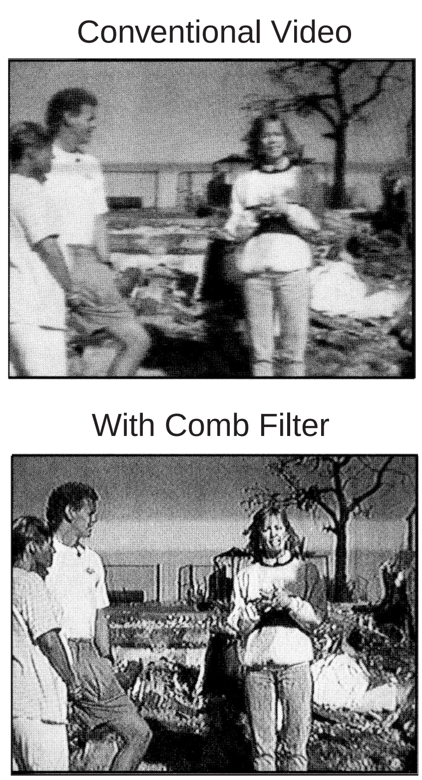

Fig. 3: The biggest impact of a comb filter is the extra video resolution, which makes smaller objects in the picture show more clearly.

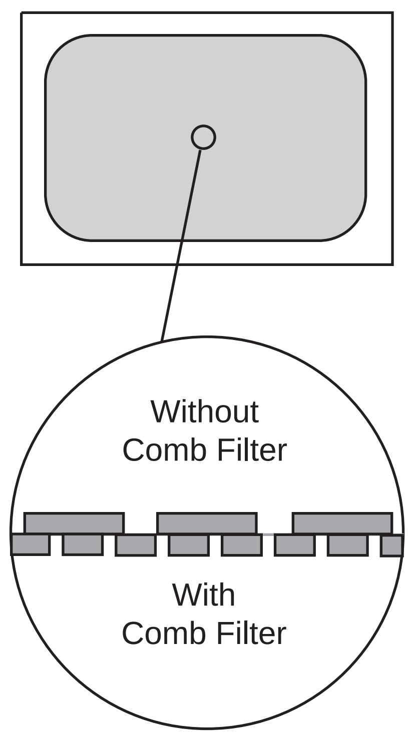

Fig. 4: When combined with a wideband color demodulator.

screen. On a 27" screen, color objects are limited to about 0.55 inches wide. Smaller objects appear in black and white, even if the camera detects color.

The comb filter, when combined with wide-band "I & Q" color demodulators, can show objects in proper color with an equivalent luminance frequency of 1.2 MHz. This is 42% smaller than in a conventional receiver.

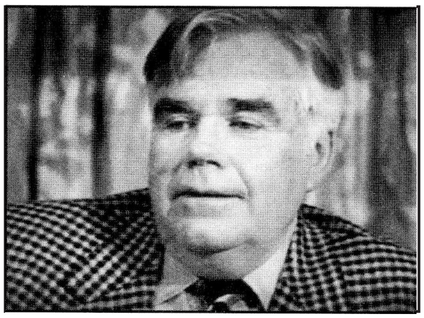

Fig. 5: Comb filters greatly reduce the random color swirls that appear in fine detailed objects such as a stripped tie or herringbone jacket.

Another advantage of comb filters is reduced interference between the luminance and chroma signals. This prevents graininess in highly saturated colors. Comb filters also greatly reduce the color swirl effect that appears when a TV scene includes objects with fine pattern, such as a herringbone jacket or striped tie.

How The Comb Filter Works

The operation of the comb filter is based on four characteristics of the NTSC video signal: 1) The harmonics of the luminance occur at intervals equal to the horizontal scanning rate; 2) The color harmonics fill the spaces between luminance and the chroma signal and reverse phase from one horizontal line to the next; 3) Adjacent horizontal lines of luminance are almost identical; and 4) All of the video components have definite timing or phase relationships at the start of each horizontal line.

The basic operation of the comb filter can be broken into two sections. First, the luminance information is removed ("combed") from the composite video signal to leave only the chroma signal and its sidebands. Second, the"combed" chroma is used to remove the color from the original composite video, leaving only the luminance information. These two simple steps provide the clean chroma and luminance information require for a high resolution picture on the CRT We will start our discussion with the removal or "combing" of the luminance from the composite video to obtain the chroma only signal.

In Figure 6, composite video is applied to the input of a delay device that delays the signal by one complete horizontal scanning line. The chroma information at the output of the delay device will be out out of phase with the non-delayed chroma applied to the adder circuit because the color information is phase alternated and changes phase for each succeeding horizontal line, We have actually delayed the first line and are now comparing it with the second line of video information.

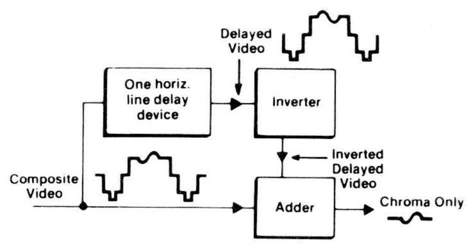

Fig. 6: Basic comb filter operation to separate luminance from the composite video signal to leave the "combed" or chroma-only signal.

The delayed signal is then inverted so that the chroma information of the two signals will now be in phase. But, because the luminance does not change phase from line to line, inverting the signal will now make the delayed luminance signal out of phase with the non-delayed signal supplied to the adder circuit. When the inverted (and delayed) signal is mixed with the non-inverted (and non-delayed) signal in the adder circuit, the chroma information will add. The luminance information is out of phase and will cancel. This leaves only the "combed" chroma signal at the output of the adder stage. See Figure 7 for a direct comparison of the waveforms involved.

Now that we have the "combed" chroma signal (with the luminance information "combed" out), we can, in turn, use this signal to remove the color information from the composite video, We simply incorrect the combed chroma signal so

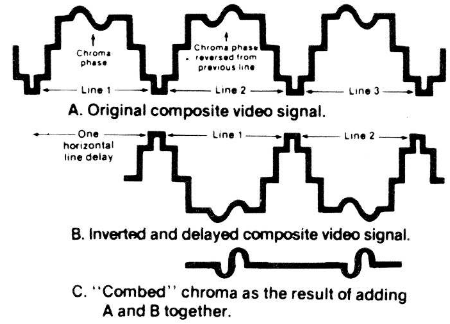

Fig. 7: (A) The original composite video signal . (B) The delayed and inverted composite video signal. (C)The results of adding A and B together. The luminance information is A and B will cancel and the chroma information will add to produce only a chroma signal.

that it is now out of phase with the chroma information in the composite video. In Figure 8, the inverted "comb" chroma signal is added to the composited video so that the chroma information cancels, leaving only the luminance. In effect, we have used the "combed" chroma to "combed" the color from the composite video.

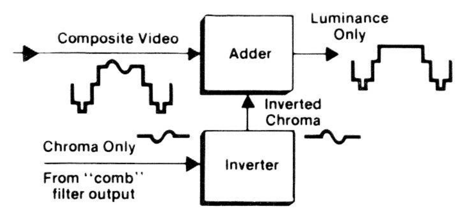

Fig.8: By adding the "combed" chroma signal back to the original composite video signal, the two chroma signals will cancel and "comb" the chroma from the composite video signal to leave luminance without chroma.

Comb filter operation assumes that there are few changes in the luminance signal from one horizontal line to the next. There are some picture conditions, however, which seem to cause a phase reversal between lines in the luminance signal. For example, a bright object in the top of the picture sitting next to a dark object in the bottom of the picture causes a one-line phase reversal where the two meet. The comb filter thinks this is a chroma signal, and removes it from the signal fed to the luminance amplifiers. This slightly reduces vertical detail.

Some comb filters correct this by limiting the frequency response of the delay line to those frequencies where the color and luminance signals overlap. Combing then happens only at high frequencies. Other comb filters add a "vertical detail enhancer" circuit which re-inserts the luminance signals which were accidentally combed out.

Comb filters use two common methods of getting the needed 63.5 microsecond delay. The first method uses a "glass" or "acoustical" delay line based on a piezo-electric crystal. Glass delay lines generally operate over a narrow range of frequencies, so they do not need separate circuits to recover the vertical detail.

The second delaying method uses an integrated circuit called a "charge coupled device" (CCD). These digital delay lines operate over the entire video frequency range and need circuits to re-insert vertical transitions.

Symptoms Of A Bad Comb Filter

Comb filters fail in one of two ways:

1. One or both outputs missing.
2. Both outputs produce signals, but the signals are improperly separated.

If the chroma output is missing, the receiver usually produces a good black and white picture with weak or missing color. If the luminance signal is weak or missing, the receiver produces a dark or blank CRT. If the raster is not blanked, there may be broad areas of color, without the detail carried by the luminance signal.

Often both comb filter outputs produce a signal, but a bad component or a change in the comb filter's alignment causes the signals to separate incorrectly. The receiver may appear to work normally, but the picture lacks the extra detail that the comb filter makes possible.

At other times, a defective comb filter causes the receiver to produce a worse picture than a conventional receiver, because of improper combing. The poorly combed signals cause excessive interference in the chroma and luminance circuits producing false colors and grainy color picture areas.

Tech Tip #202 "Servicing Video Comb Filters" provides information on how to troubleshoot problems related to the comb filter.

For More Information,
Call Toll Free 1-800-SENCORE
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