Composite video, Y/C and Comb filtering

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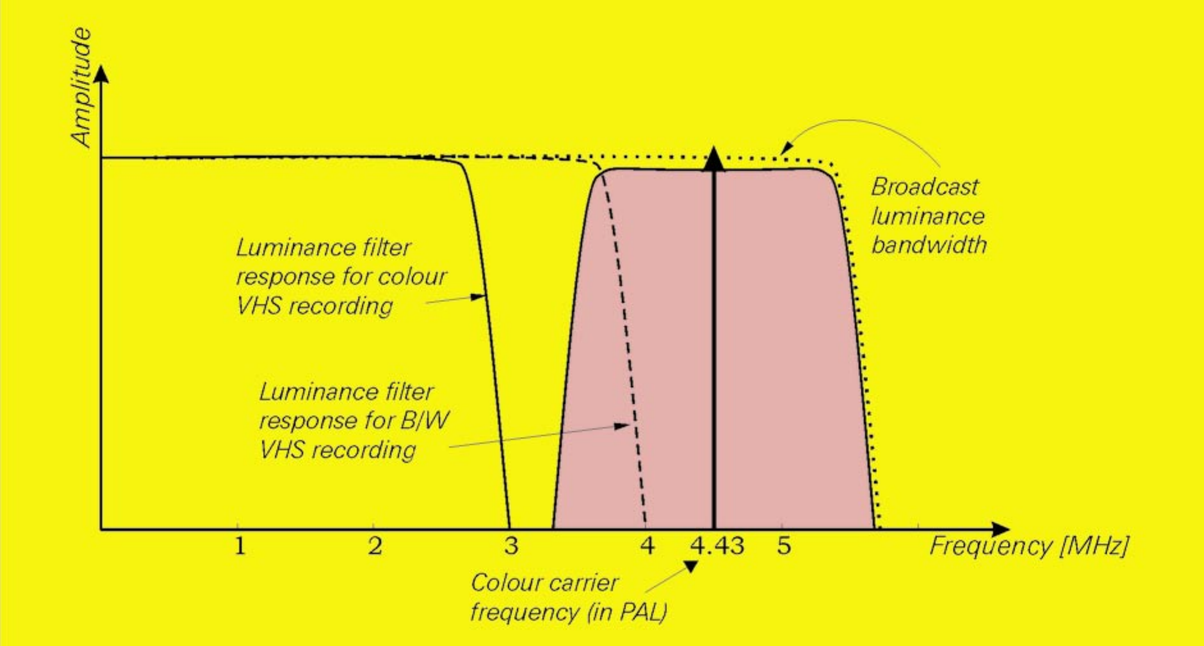
In 1987 the **Super VHS** concept was introduced by JVC.

The Super VHS format improved the luminance and chrominance quality of the recorded video signals, yet preserved downward compatibility with the VHS format. This means the same type of video heads, rotating with the same speed at the same angle.

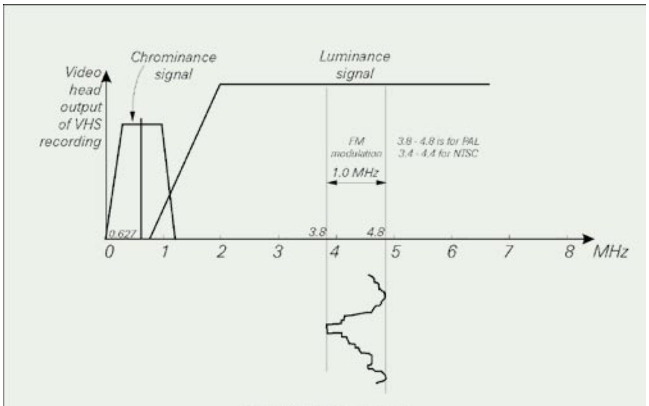
S-VHS recorders differ from the VHS essentially with their wider bandwidth. This is achieved by separating the colour and luminance from the composite video signal with a special **comb filter** and then modulating the luminance signal with a higher and wider FM band, whose frequency now deviates from 5.4 MHz to 7 MHz. This means that a video luminance bandwidth of over 5 MHz can be recorded, giving 400+ TV lines resolution. Video heads of the same physical dimensions are used, but they have better characteristics. Also, although videotapes of the same size are used, the magnetic coating is of a much better quality.

S-VHS VCRs can record and play back VHS and S-VHS. For a S-VHS recording to be activated a S-VHS tape must be used (the S-VHS recorder recognizes a S-VHS tape by a little slot on the cassette box). A VHS VCR cannot playback S-VHS tapes.

When colour and luminance signals are combined in a composite video signal, there are always visible cross-colour and



The Composite video signal spectrum



The VHS concept

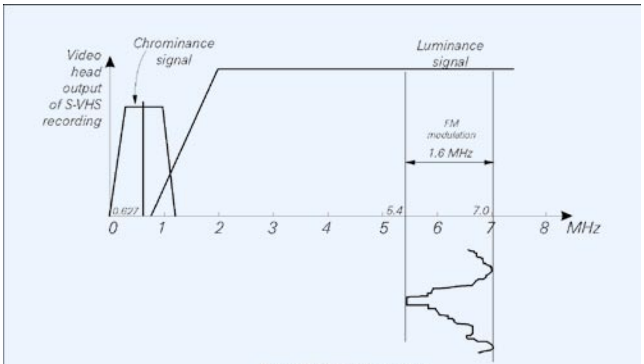
cross-luminance artifacts (see the test images illustration on page 37). In order to minimize such deterioration, S-VHS recorders permit direct input and output of the uncombined luminance and chrominance components.

This pair is called **Y/C** (Y stands for luminance and C for chrominance) and is found at the back of all S-VHS VCRs and monitors in the form of miniature DIN (Deutsche industrie norme) connectors.

If you have a video source that produces Y/C signals (like some multiplexers, cameras, DVRs or S-VHS VCRs), they can be connected to the S-VHS VCR or Y/C monitor with a special Y/C cable that is composed of two miniature coaxial cables.

There is misinterpretation among some users who believe that we can only record a high quality video when a Y/C signal is brought to the S-VHS. This is not true, since the S-VHS was designed primarily for recording composite video signals. For this purpose, a special adaptive comb filter was designed for S-VHS, where the colour information is separated from the composite video signal **without losing significant luminance resolution** (as is the case with the low-pass filter in VHS).

An early solution to the Y/C separation problem was to put a low pass filter on the composite signal and filter out the colour signal above about 2.5 MHz in NTSC



The S-VHS concept

(above 3 MHz in PAL) to recover the Y signal. The reduced bandwidth of the Y signal dramatically limited the resolution in the picture. A bandpass filter was used to recover the colour signal but it was still contaminated by high frequency luminance crosstalk and suffered serious cross-colour effects.

It is known though that the basic composite video signal is periodic in nature as a result of the horizontal and vertical scanning and blanking processes. This means that when such a signal is represented in the frequency domain (a Fourier analysis is applied) it will be represented by **harmonics in precise locations, rather than have a uniform spectrum throughout the spectrum** of the entire video signal. This is a very important and fundamental fact in television signal analysis.

By picking the horizontal and vertical scanning rates and the colour sub-carrier frequency in particular harmonic relationships, the Y/C separation process can be simplified. The colour sub-carrier frequency in NTSC (and similar logic can be applied to PAL), Fsc, is chosen to be 3.579545 MHz (usually referred to as simply 3.58 MHz). This corresponds to the 455th harmonic of the horizontal scanning frequency, Fh, divided by two (as per the NTSC definitions).

Fh = 15,734.26 Hz

Fsc = 455 × Fh/2 = 3.579545 MHz

Since there are 525 lines in a NTSC video frame and a frame consists of two interlaced fields, there are 262.5 lines in a field. Therefore, the vertical field rate is:

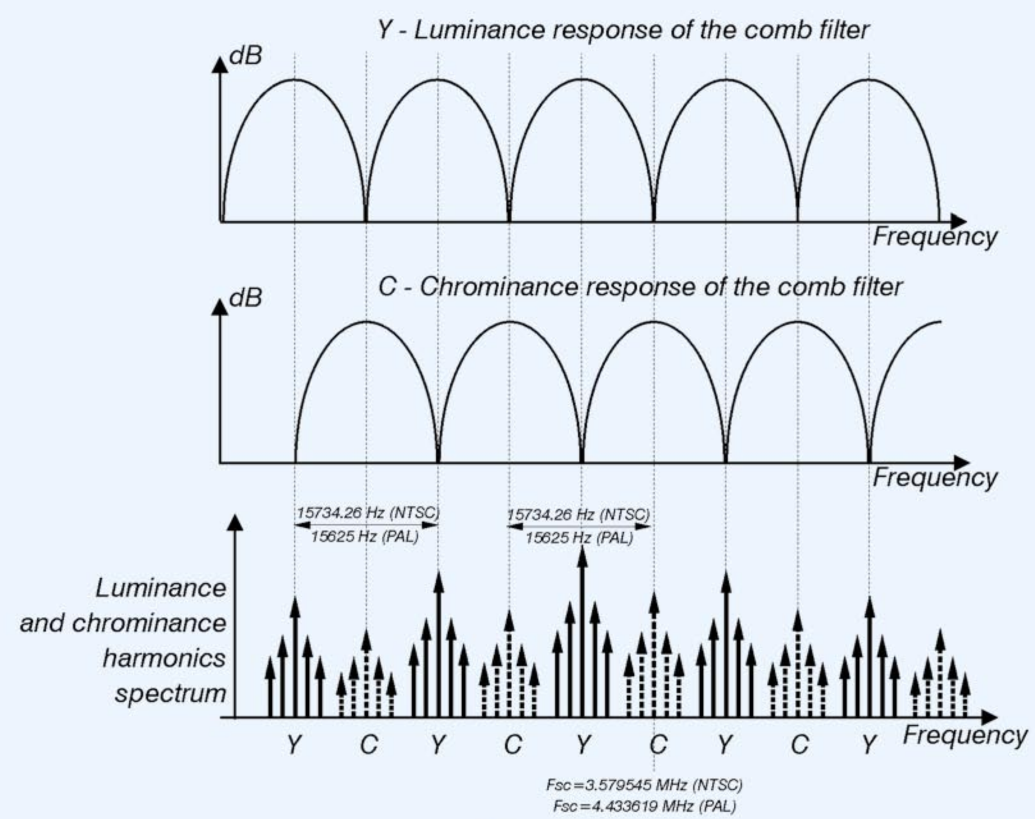
Fv = Fh/262.5 = 59.94 Hz.

There are also two fields in a frame, so the frame rate is Fv/2 = 29.97 Hz.

Since the video signal is periodic in nature, the spectral distribution of the video frequencies are grouped together in clusters. The Fourier analysis of a static video signal shows that the energy spectrum is concentrated in clusters separated by 15.734 kHz, which is the horizontal scan rate. Each cluster has sidebands with 59.94 and 29.97 Hz spacing. Therefore, the luminance signal does not have a continuous distribution of energy across its bandwidth. Instead, it exists as clusters of energy, each separated by 15.734 kHz. These clusters are not very wide so **most of the space between them is empty**.

The chrominance signal is also periodic in nature, since it appears on each horizontal scan and is interrupted by the blanking process. Therefore, the **chrominance signal will also cluster** at 15.734 kHz intervals across its bandwidth. By picking the colour sub-carrier at an odd harmonic (455) of Fh/2, the chroma signal clusters are **centered exactly between the luminance signal clusters**. Therefore, the Y and C signals can occupy the same frequency space by this process of frequency interleaving.

This is the idea behind the comb filters design. A comb filter can be designed to have a frequency response with nulls at periodic frequency intervals. At the center frequency between the nulls, the comb filter passes the signal. If the comb filter is



The Comb filter theory

Photo illustration of the difference between a composite (on the left) and Y/C (on the right) video signal of the same test channel

tuned to be periodic at the same 15.734 kHz intervals as the Y/C frequency interleaving, it will **pass the Y signal while rejecting the C** signal or visa versa.

When using Y/C cables between S-VHS components there is minimal cross-luminance and cross-colour interference, but for CCTV this is quite impractical since it requires two coaxial cables. The miniature Y/C cable that comes with some S-VHS VCRs is a twin-coaxial cable designed for short runs only, as it has a much higher attenuation than the popular RG-59/U. The main intention of such Y/C connections is for dubbing purposes.

It should also be noted that the technology of comb filtering is improving daily. Today the most advanced comb filters are imployed not only in S-VHS VCRs but also in high quality monitors and television sets.

First it was the 2D-comb filter where not only one line in the video signal but the previous and the next one was used to compare the colour content and decide on the optimum filtering (thus 2D). Further improvement brough the 3D-comb filtering and digital comb filtering, where not only information in one TV field, but the previous and next fields are processed for the colour content (thus 3D). New developments are further improving the resolution and colour fidelity.

It is possible that of the units you might have, an S-VHS recorder (or DVR), for example, and a TV monitor, both of them have comb filters but not necessarily of equal type and quality. It is worth experimenting as it may happen that a better picture quality will be reproduced if a composite video signal is brought from the recorder and let the TV extract the colour information with it's own comb filter (if it is of a better design), rather than having Y/C cable connection between the S-VHS VCR and TV monitor.

So, using S-VHS recorders or DVRs in CCTV with high resolution colour cameras and a single coaxial cable for composite colour video signal is still far superior than using VHS VCRs. The quality of the recorded signal is ensured by the high quality adaptive comb filter built in the S-VHS VCR and the played back signal will be as good as the monitor can show. If a high resolution colour monitor is used, which would also have its own comb filter, the quality will be much better than using TV monitors designed for commercial use. If we assume a camera has 470 TV lines of horizontal resolution, the S-VHS VCR has about 400 and the monitor is 600 TV lines, the VCR will still be the bottleneck for the played back resolution and the played back signal should have around 400 TV lines (providing, of course, S-VHS tape is used). ☺