

Testing the three types of video signal required an increased understanding of the individual parts of the video signal and how they interact within each signal type. The encoding of the video signal has distinct variations in each type, resulting in various fluctuations in color values, image resolution, and possible video errors. Analyzing the three types, via monitoring tools and qualitative analysis, revealed both minute differences in detail and wide variations in quality, providing valuable insight into the decision-making process of video capture.

The composite signal, also known as CVBS (color, video, blanking, and sync or composite video baseband signal),¹ encodes all video elements into one channel for transmission. Composite video was introduced by the NTSC in the 1950's as a solution for broadcasting color signals to television. Using a technique known as multiplexing—the addition of subcarriers to the signal, which are subsequently modulated upon transmission²—the inventors of the NTSC signal were able to transmit the color information in the higher frequencies of the video signal.³ For recording on analog videotape formats such as VHS and U-matic, the color signal is modulated further. Using the color-under method, to downconvert the broadcast color sub carrier frequency to one that can be recorded within the smaller bandwidth of the videotape.⁴

¹ <http://www.maxim-ic.com/app-notes/index.mvp/id/734>

² *Wikipedia*, s.v. “Composite video,” last modified November 29, 2011, http://en.wikipedia.org/wiki/Composite_video.

³ Marcus Weise and Diana Weynand, *How Video Works: From Analog to High Definition*, (Burlington, MA: Focal Press, 2007): 59-62.

⁴ *Wikipedia*, s.v. “Heterodyne,” last modified November 22, 2011, <http://en.wikipedia.org/wiki/Heterodyne>.

The composite signal introduced the concept of color-difference signals to video transmission. To lower the necessary bandwidth in transmission, only two color values are transmitted in a composite signal (the same is true for all signal types tested in this project). The strength of the luminance signal is calculable using corresponding ratio or percentage values related to the Red, Green, and Blue chrominance levels. The composite signal transmits two color values, represented as color difference signals, Red-Y (where Y represents luminance) and Blue-Y. The third color difference value, Green-Y, is calculated using the Pythagorean theorem, and is not needed in transmission. The generation of the third color difference value is known as decoding color. A combination of these video elements, with the necessary sync information, produces the video image.⁵

The composite signal may be transmitted using RCA cables, or BNC connectors, an RF (radio frequency) coaxial connector. Because of the large amount of picture information being transmitted through one signal, composite signals require decoding to separate the various elements of the signal. The decoding of the signal makes the composite format susceptible to video errors such as dot crawl, an intermingling of the chroma and luma elements of the signal, resulting in checkerboard patterns in the picture.⁶

Separate video, commonly referred to as S-video or Y/C, separates the video signal into elements, chrominance and luminance. Like the composite video signal, s-video transmits two color difference signals, R-Y and B-Y in one chrominance signal. The luminance channel, designated as Y on s-video connectors, carries the luma information plus the horizontal and vertical sync pulses. The standard s-video connector uses four pins, two pins are designated for

⁵ Weise, *How Video Works*, 65-69.

⁶ *Wikipedia*, s.n. "Dot Crawl," last modified on September 20, 2011, http://en.wikipedia.org/wiki/Dot_crawl.

grounding, and the remaining two carry the luminance and chrominance signals separately. Since the color difference signals are transmitted via one cable, the s-video signal requires decoding, similar to the composite signal, to display the video image. Still, the format is less susceptible to video errors due to the higher bandwidth of the luminance information, meaning less crosstalk occurs between the chroma and luma frequencies.⁷

Component signals (YP_BP_R) separate the chrominance and luminance signals during recording. By separating the information into three channels, the component system eliminates the need for color subcarrier encoding. In a component transmission, one cable carries the luminance (Y) and sync channels and the second and third connections carry chrominance signals recorded as individual color difference signals Red-Y (R-Y or P_R) and Blue-Y (B-Y or P_B). Since component video signals do not require multiplexing and decoding, the separated elements of the signal are not susceptible to interference with one another. This results in fewer errors and better image quality.⁸

To compare the three types of signal, I captured SMPTE color bars and clips in the formats available through each playback deck. The BetaSP deck has outputs for component, composite, and s-video, I captured bars and clips of each format. From the U-matic deck, I was able to capture bars and clips in composite and s-video. There were no SMPTE bars at the beginning of the available VHS tapes and I was only able to capture a clip from a composite signal. The following table displays the clips captured for this study:

Source Format	Signal Type	Content
Betacam SP	Component (YP _B P _R)	SMPTE color bars
Betacam SP	Component (YP _B P _R)	clip of Sonic Youth's "Incinerate" music video

⁷ *Wikipedia*, s.n. "S-Video," last modified November 12, 2011, <http://en.wikipedia.org/wiki/S-Video>.

⁸ Weise, *How Video Works*, 106.

Betacam SP	Composite	SMPTE color bars
Betacam SP	Composite	clip of Sonic Youth's "Incinerate" music video
Betacam SP	S-Video	SMPTE color bars
Betacam SP	S-Video	clip of Sonic Youth's "Incinerate" music video
U-matic	Composite	SMPTE color bars
Umatic	Composite	clip of Sonic Youth's "Beauty Lies in the Eye" music video
U-matic	S-video	SMPTE color bars
U-Matic	S-Video	clip of Sonic Youth's "Beauty Lies in the Eye" music video
VHS	Composite	clip of rushes from the film <i>Demonlover</i>

The signal path used to capture each clip traveled as direct to the PCI Card as possible. From a Sony BCT10MA tape, the Betacam signals were routed, via component BNC component and composite cables, and an s-video connector, from the Sony UVW-1800 straight to the Black Magic Design Decklink Studio 2 PCI Card. The U-matic signals required the intermediation of a time base corrector to stabilize the signal that would be transmitted to the PCI Card. This signal, recorded to a Sony BVU-950 U-matic tape, was first transmitted to the Digital Processing Systems Inc DPS-295 TBC via a composite connection, then routed to the PCI Card for digital capture via BNC composite and an s-video connection. The introduction of composite connection into the path of the s-video capture was not ideal for the purposes of this test, but variance in the signal is still noticeable despite the additional encoding. The VHS signal was captured from a Fuji E-30 SHG VHS tape routed from a Samsung SV-5000W VHS deck via RCA composite cables to the Black Magic PCI Card. Lack of an appropriate connector kept me from capturing an s-video signal from the VHS deck. For this reason, I was unable to compare the differences in composite and s-video signals from a VHS recording.

A combination of available signal monitors and qualitative analysis of the captured footage was used to assess the differences in signal types and identify any errors introduced during capture. The first step was a comparison of the waveforms for each set of bars, against a standardized set generated with Final Cut Pro to gauge the clarity of the signal. Then the bars were evaluated against each other, noting any variations in IRE levels of the chrominance and luminance. The different levels provided clues to the appearance of the clips and reasons for various video errors that appeared in the captured video.

It was assumed prior to the study that the component signal would present the clearest signal, hitting all luminance targets closely for each color. S-video would follow next in quality of image and color values, with composite, because of the larger amount of required encoding presenting the lowest quality image. Video errors were also a point of interest, especially dot crawl as it manifests during the decoding of the signal.

In the following two tables, luminance and chrominance values are listed. The Final Cut Pro waveform monitor displays the analog wavelengths of what is actually a digital signal, for this reason there are no sync elements displayed and black is displayed as 0 IRE units.⁹ The scope also displays the bars with different targets than an analog waveform monitor. The target IRE levels in the tables below were recorded from a set of SMPTE color bars generated by Final Cut Pro. The waveform display does not display the entire spectrum of the signal when viewing chrominance information. Levels that could not be read below -5 IRE were designated with a question mark because of this.

⁹ Weise, *How Video Works*, 149-152.

Color	Target Luminance Levels (IRE)	Target Chrominance Levels (IRE)	BetacamSP component Luminance	BetacamSP component Chrominance	BetacamSP composite Luminance	BetacamSP composite Chrominance	BetacamSP s-video Luminance	BetacamSP s-video Chrominance
White	100	0	99	0	100	0	103	0
Yellow	66	33 to 100	65	31 to 100	67	34 to 99	68	36 to 101
Cyan	52	5 to 100	52	4 to 100	53	6 to 99	54	8 to 100
Green	44	0 to 88	44	-1 to 88	43	0 to 88	45	1 to 87
Magenta	31	? to 75	32	? to 76	30	? to 75	32	? to 76
Red	22	? to 69	23	? to 72	21	? to 69	22	? to 69
Blue	8	? to 42	9	? to 44	7	? to 42	8	? to 41
Black	0	0	1	0	-1	0	-1	0

Surprisingly, the color bars in the Betacam SP captures did not vary much between one another, at the most 2-3 IRE per bar. Of note is the peak level of the white luminance value in the S-Video signal. A possible explanation for this peak is the increased bandwidth of the luminance carrier in the S-video transmission. A similar result is not present in the component signal, which when provided a slight margin of error hits nearly all target values with a steady signal frequency. The composite signal was steady throughout playback and the saturation levels of the color bars were nearly identical to the component signal, varying by only 1-3 IRE levels. Dot crawl is easily identifiable in the composite signal, but does not appear in either the S-Video or component signals. Black values for all signals, in each Pluge bar, hit their targets. There is no visual evidence of noise in the captured clips.

The high signal quality in each format is likely due to the recording mechanism of the source material. Betacam SP records as a component signal,¹⁰ meaning that the transmission from the tape had gone through no multiplexing modulation prior to transmission. In the capture

¹⁰ Weise, *How Video Works*, 192.

using a component connection, there is higher color detail and image clarity because of the lack of encoding from recording to capture. This is only slightly evident when viewing the captured clips.

In Figures 1 and 2, frame grabs from the component and s-video captures, the slight differences in the signal. The high white level of the s-video capture manifest here in the diagonal band of white light across the upper right corner of the image. Looking at the waveforms of these two images side-by-side (Figure 3), it is evident that the luminance levels in the rest of the image are nearly identical. This is also evident when comparing the chrominance levels of the two frames.

The Betacam SP transfers prove that the component signal is remarkably stable across multiple generations. The minute difference between even the component and composite (despite the evidence of dot crawl, which is not apparent when playing the clip), the signals are identical to the naked eye. Component's reputation as the higher quality signal type is confirmed in these tests, as close scrutiny reveals fine detail, especially in darker areas of the image.

A similar outcome was not the case in the U-matic transfers. The introduction of the Time Based Corrector added additional impedance and an extra stage of modulation into the signal path. Unfortunately, as noted above, the signal path for the transfer via S-video began as a composite output from the U-matic deck into the TBC. It is unknown whether the modulation of the signal from composite to S-video through the TBC had any effect on the signal captured. The methodology of this test was the same as the Betacam SP transfers. Below are the luma and chroma values recorded for the SMPTE color bars captured in each signal type:

Color	Target Luminance Levels (IRE)	Target Chrominance Levels (IRE)	U-matic composite luminance	U-matic composite chrominance	U-matic s-video luminance	U-matic s-video chrominance
White	100	0	89	0	105	0
Yellow	66	33 to 100	60	26 to 94	71	38 to 105
Cyan	52	5 to 100	47	0 to 95	58	12 to 103
Green	44	0 to 88	40	-3 to 84	49	6 to 90
Magenta	31	? to 75	29	? to 73	35	-9 to 79
Red	22	? to 69	21	? to 69	26	? to 72
Blue	8	? to 42	9	? to 42	11	? to 44
Black	0	0	1	0	2	0

The variance between the two signals is far more drastic in this format. In the white levels, there is a difference of 16 IRE levels. Again, the s-video signal's white level peaks above the 100 IRE target, this time at 105 IRE. This supports the hypothesis that the increased bandwidth available in the S-Video signal is causing the white level to exceed the 100 IRE target. The 10-15 IRE gap in luminance and chrominance levels appears to diminish along the color spectrum, ending in nearly identical black levels. A noted difference from the Betacam SP signals is wider fluctuation in the peaks of the signal's waveforms, pointing to the instability of the highly modulated composite signal. Again evidence of dot crawl is prevalent in the SMPTE color bars; in these transfers it is noticeable in both signals. The dot crawl in the S-video transfer may be a result of the composite output of the U-matic deck, or it is possibly recorded into the signal on the source tape. An odd fluctuation in the color bars signal of the composite transfer is unexplained. The error is manifested as a diagonal waves moving right to left across the image.

Examination of frame grabs from the captured clips (Figures 4 and 5), display the results of the high white levels in the S-video. The s-video capture suffers from low color resolution, resulting in moments of washed out colors when brightness of the image increases. In Figure 5,

details are lost because the color saturation of the image is off. There are also issues with hue in this clip; a segment featuring rippling water is a purple hue, instead of the correct blue.

The S-video capture features greater detail than the composite transfer. Figure 4 displays the distortion extant in the composite signal; the image lacks the sheen of Kim Gordon's face that is so apparent in the S-video image. The chroma levels, in Figure 6, of the composite signals display the higher levels of saturation, but a lower level of definition in the wavelengths, resulting in a loss of detail.

The instability of the composite and s-video signals transferred from the U-matic deck reveal the result of signal degradation through generations of recordings. Like the Betacam SP transfers, the digitization of the source material is influenced by the original recording signal. The U-matic tapes used to capture the SMPTE bars and music video clip were recorded as a composite signal. Beginning with a composite signal means the captured signal will undoubtedly contain some level of distortion. The source's recording format is an influential element in preparing for digital capture. In the Betacam SP captures, the inherently stable recorded component signal remained relatively uninfluenced by the transferring signal type. Unfortunately, the same was not true in the U-matic transfers. The composite signal represents a challenge when planning for migration. As seen in the clips captured, neither format available for digitization was ideal; a decision between greater detail or better color representation is necessary.

The results of these tests prove the assumption that composite signals are of the higher quality, but the surprising result was the limited effect of signal modulation used in composite and S-Video signals on the captured digital video. Further testing using the VHS signal could offer more evidence of the effects of modulation in composite and s-video signals.



Figure 1 – Frame grab from Betacam SP Component Capture



Figure 2 – Frame grab from Betacam SP S-Video Capture

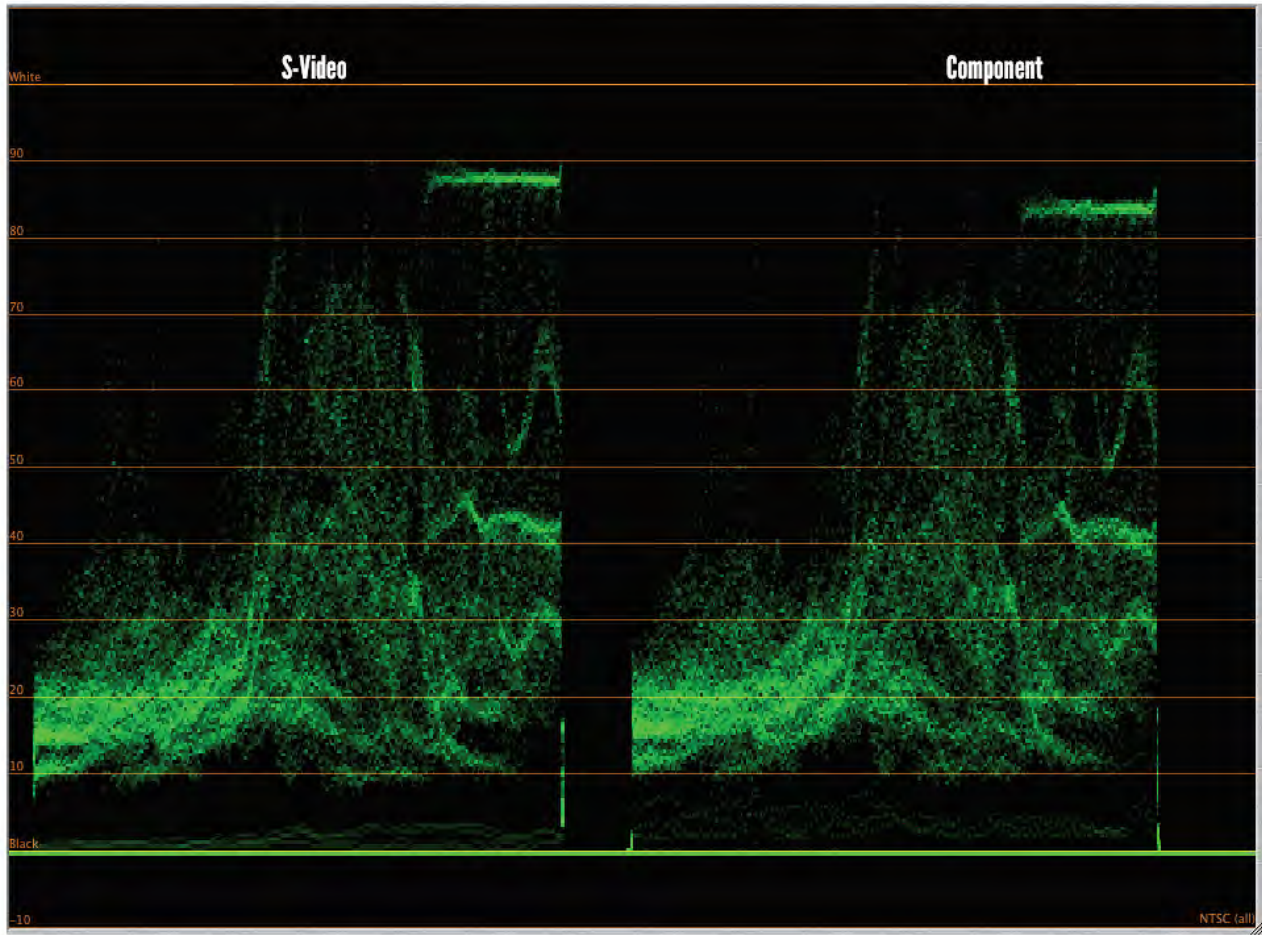


Figure 3 – Waveform monitor display of S-video (left) and Component (right) signals



Figure 4 – Frame grab from U-matic composite clip



Figure 5 – Frame grab from U-matic s-video clip

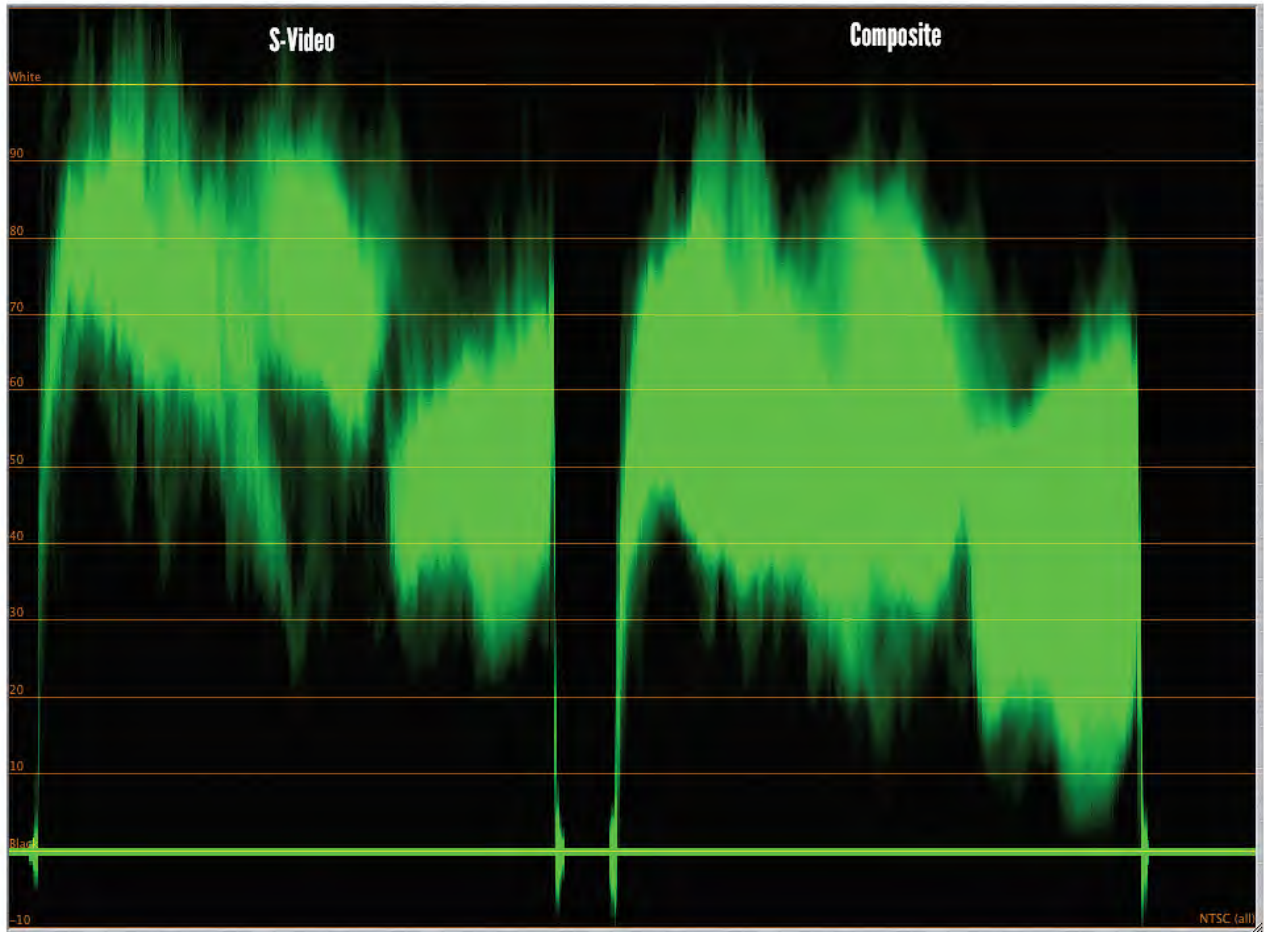


Figure 6 – Waveform monitor display of S-video (left) and Composite (right) chrominance values