Brianna Jones
Video Preservation 1
Haydon & Turkus
October 2nd, 2019

Heterodyne:Color-Under Recording

When it comes to analog media formats, there are three different methods for capturing color signals during videotape recording [VTR]: Component, Direct Color, and Heterodyne - also known as color-under recording. While I will be giving a brief overview of each method, mainly for comparison, the majority of paper will be focusing on the Heterodyne process.

The first method I will be talking about is Component. Component color VTR was the first method developed when television transitioned from black and white to color display. The following formats supported this method: Betacam, Betacam SP, and M-|| via three signal paths - *Y, B-Y [Blue-Y]*, and *R-Y*[*Red-Y]*[1]. The *B-Y* and *R-Y* signals, both known as color difference signals or chrominance[chroma], are the combined red, green, and blue signals that are generated when recording using a color camera, split into two signals. The *Y* signal, also known as luminance [luma], is the three color signals from the color camera combined to form a black and white signal. Having three signal paths to convert and transmit color allowed for the recreation of the color information captured during recording to be transmitted during broadcasting on color televisions, while effectively separating out the black and white color signals[2].

The second method developed was Direct Color, also known as Composite color VTR. The two main differences between Component and Direct Color, is that Composite VTR combines both luma and chroma signals into one signal path and that the Composite color process requires a subcarrier signal. The subcarrier signal allows multiple signals at different frequencies to share a common physical transmission medium via frequency division multiplexing[3][4]. Similar to Component color VTR, the Direct Color method was only used for professional broadcasting formats, specifically, 1-inch Type *B* and *C*. During recording the luma Y' is combined with the chroma, overlapping both the red, green and blue color signals with the black and white signals via the subcarrier, this signal is commonly known as S-Video[5]. For broadcasting transmission on color television, these two signals are separated through the

[1] R-Y and B-Y are also known as *P*R and *P*B
[2] The Component color VTR also separated out the color signals to allow color televisions to transmit black and white broadcast.
[3] "frequency-division multiplexing (FDM) is a technique by which the total bandwidth available in a communication medium is divided into a series of non-overlapping frequency bands, each of which is used to carry a separate signal." "Frequency-Division Multiplexing." Wikipedia, Wikimedia Foundation, 19 Sept. 2019, https://en.wikipedia.org/wiki/Frequency-division_multiplexing.
[4] "Carrier Wave." Wikipedia, Wikimedia Foundation, 15 Sept. 2019, https://en.wikipedia.org/wiki/Carrier_wave.
[5] "Component Video vs. Composite Video? What's the Difference?" Multicom, https://www.multicominc.com/training/technical-resources/component-video-vs-composite-video-whats-the-difference/.

subcarrier[6]. If an excessive amount of overlap exists post-separation, it can lead to playback/transmission distortions and cross-coloring[7].

The final analog color videotape recording method and the one I will be spending the remainder of the paper on is the Heterodyne method, also known as Colo-Under VTR. Invented by engineer Reginald Fessenden in 1901, Heterodyne is the process of combining two frequencies via a nonlinear signal-processing mixer[8], in order to create a new frequency range. This is done through two sub-processes, modulation, and demodulation[9]. Modulation is the process of transferring a low-frequency signal over a higher frequency signal. Demodulation is the process of extracting the signal with the original information- the higher frequency signal, from the subcarrier[10] [11] [12]. For the purposes of video preservation, the Heterodyne Color-Under method is used for consumer-based VTRs, with the exception of U-matics, because of their limited bandwidth/channel space[13] the VTR formats couldn't capture the full range of color information during recording.

The Color-Under process separates the luma and chroma signals prior to recording and sends them on two different signal paths. The luminance signal, which mainly holds the sync tip and black and white color information, goes through FM modulation via a subcarrier before recording onto the VTR. The chrominance signal, which holds the red, green and blue color information, is heterodyned via an oscillator signal[14]before being recorded onto the VTR. During this process, the chroma signal is down-converted from 3.58MHz frequency NTSC standard to a lower kHz frequency that's format specific. The luma frequency is reduced or increased within a set deviation range dependent on format and format generation; the luma signal is what mainly determines the resolution output for the Color-Under method. For playback or broadcasting, the two signals are reconfigured with the full-color information and frequency standards through the heterodyne process via a mixer; for video preservation purposes, the mixer is usually a time-base corrector[TBC]. [15][16][17]

---

[6] The signals are never fully separated due to the bandwidth capacity of various TV channels.
[7] Can show in the form of a pattern of dots or as rainbow patterns across textured and patterned surfaces during broadcasting or playback."Cross Colour & Cross Luminance - What's All That about Then!: Camera Hire, Lenses, TV Crew: Procam UK, NYC." Procam, https://www.procam.tv/useful-info/video/cross-colour-cross-luminance.
[8] In the video preservation/archival field, the mixer is usually a Time-Base Corrector[TBC].
[9] "Heterodyne." Wikipedia, Wikimedia Foundation, 16 Sept. 2019, https://en.wikipedia.org/wiki/Heterodyne.
[10] "Modulation." Wikipedia, Wikimedia Foundation, 27 Sept. 2019, https://en.wikipedia.org/wiki/Modulation.
[11] "Demodulation." Wikipedia, Wikimedia Foundation, 15 Aug. 2019, https://en.wikipedia.org/wiki/Demodulation.
[12] "Implementation of Analog Modulation on SpinCore PulseBlasterDDS And RadioProcessor Boards." Analog Modulation, https://www.spincore.com/products/PulseBlasterDDS-300/Modulation_Techniques/analog_modulation.shtml.
[13] Information frequency recorded needs to be less than 1 MHz bandwidth *(Heterodyne.wikipedia.org, 2019)*
[14] "An Oscillator is an electronic circuit that produces a periodic repetitive vibration between two or more varying states. It also converts direct current (DC) from a power source to an alternating current (AC) signal."Electronic Oscillator." Wikipedia, Wikimedia Foundation, 19 Sept. 2019, https://en.wikipedia.org/wiki/Electronic_oscillator.
[15] Jack, Keith, and Vladimir Tsatsulin. Dictionary of Video and Television Technology. Newnes, 2002.

To close out my paper, I will lay out the technical specs of the color-under method for the formats and format generations that it supports. VHS, VHS-C, S VHS, S VHS-C, Beta, Super Beta, 8 MM, Hi-8, U-Matic, and U-Matic SP all require the color-under method to capture and playback color information.[18]

VHS, VHS-C, S VHS & S VHS-C

These formats downconvert the chroma frequency levels from 3.58 MHz to 629 kHz[19]; the chroma remains the same across format generations[20]. The difference in picture quality/resolution comes from variations in luma [sync tip(ST), deviation[21], and peak white(PW)] frequencies between the standard and superior generations[22]. For standard, the frequency levels are as follows: ST 3.4MHz, PW 4.4MHz, and a deviation of 1MHz; this results in 240 lines of resolution; that's 90 lines less than the NTSC standard. For superior, the luma levels are raised to reduce signal mixing with the chroma resulting in the following: ST 5.4MHz, PW 7MHz, and a deviation of 1.6MHz; this results in 400 lines of resolution.

Beta & Super Beta

These formats downconvert the chroma frequency levels from 3.58 MHz to 688KHz.For standard, the frequency levels are as follows: ST 3.6MHz, PW 4.8MHz, and a deviation of 1.2MHz; this results in 240 lines of resolution. For superior, the luma levels are raised to the following frequencies: ST 4.4MHz, PW 5.6MHz, and a deviation of 1.2MHz; this results in 400 lines of resolution.

8 MM & Hi-8

These formats downconvert the chroma frequency levels from 3.58 MHz to 743KHz.For standard, the frequency levels are as follows: ST 4.2MHz, PW 5.4MHz, and a deviation of 1.2MHz; this results in 272 lines of resolution. For superior, the luma levels are raised to the following frequencies: ST 4.4MHz, PW 5.6MHz, and a deviation of 1.2MHz; this results in 432 lines of resolution.

U-Matic & U-Matic SP

---

[16] Seth Anderson Video Preservation 1 Assignment #2 December ...https://www.nyu.edu/tisch/preservation/program/student_work/2011fall/11f_3403_anderson_a2.pdf.

[17] Diehl, Richard N. LabGuy's World: 1977 Ampex TBC-1 Direct or Heterodyne Color Digital TBC, http://www.labguysworld.com/Ampex_TBC-1.htm.

[18] The superior format generations were able to produce better quality visuals due to the switch to metal-particle tape from ferric-oxide tape. *Comparison Of VCR Formats - Av-Iq.com. https://www.av-iq.com/avcat/images/documents/pdfs/tt189 - 4611.pdf*

[19] Based on NTSC broadcasting standards; for PAL broadcast standards the signal is instead downconverted from 4.43 MHz to 629KHz.*(Heterodyne.wikipedia.org, 2019)*

[20] This is true for all the formats that support the color-under method

[21] Refers to the deviation max during the FM modulation

[22] True for all the formats that support the color-under method: VHS & VHS-C [standard],S VHS & S VHS-C [superior]; Beta[standard],Beta SP[superior]; 8 MM[standard],Hi-8[superior]; U-Matic[standard],U-Matic SP

The only professional broadcast format that supports this method of color recording. These formats downconvert the chroma frequency levels from 3.58 MHz to 688KHz. For standard, the frequency levels are as follows: ST 3.8MHz, PW 5.4MHz, and a deviation of 1.6MHz; this results in 250 lines of resolution. For superior, the luma levels are raised to the following frequencies: ST 5.0MHz, PW 6.6MHz, and a deviation of 1.6MHz; this results in 330 lines of resolution.

Work Cited

- "Carrier Wave." *Wikipedia*, Wikimedia Foundation, 15 Sept. 2019, https://en.wikipedia.org/wiki/Carrier_wave.

- *Comparison Of VCR Formats - Av-Iq.com*. https://www.av-iq.com/avcat/images/documents/pdfs/tt189 - 4611.pdf

- "Component Video vs. Composite Video? What's the Difference?" *Multicom*, https://www.multicominc.com/training/technical-resources/component-video-vs-composite-video-whats-the-difference/.

- "Cross Colour & Cross Luminance - What's All That about Then!: Camera Hire, Lenses, TV Crew: Procam UK, NYC." *Procam*, https://www.procam.tv/useful-info/video/cross-colour-cross-luminance.

- "Demodulation." *Wikipedia*, Wikimedia Foundation, 15 Aug. 2019, https://en.wikipedia.org/wiki/Demodulation.

- Diehl, Richard N. *LabGuy's World: 1977 Ampex TBC-1 Direct or Heterodyne Color Digital TBC*, http://www.labguysworld.com/Ampex_TBC-1.htm.

- "Electronic Oscillator." *Wikipedia*, Wikimedia Foundation, 19 Sept. 2019, https://en.wikipedia.org/wiki/Electronic_oscillator.

- "Frequency-Division Multiplexing." *Wikipedia*, Wikimedia Foundation, 19 Sept. 2019, https://en.wikipedia.org/wiki/Frequency-division_multiplexing.

- "Heterodyne." *Wikipedia*, Wikimedia Foundation, 16 Sept. 2019, https://en.wikipedia.org/wiki/Heterodyne.

- "Implementation of Analog Modulation on SpinCore PulseBlasterDDS And RadioProcessor Boards." *Analog Modulation*, https://www.spincore.com/products/PulseBlasterDDS-300/Modulation_Techniques/analog_modulation.shtml.

- Jack, Keith, and Vladimir Tsatsulin. *Dictionary of Video and Television Technology*. Newnes, 2002.

- "Modulation." *Wikipedia*, Wikimedia Foundation, 27 Sept. 2019, https://en.wikipedia.org/wiki/Modulation.

- “r/VIDEOENGINEERING - A U-Matic Question for the Old-Timers...” *Reddit*, https://www.reddit.com/r/VIDEOENGINEERING/comments/5rdyly/a_umatic_question_for_the_oldtimers/.

- *Seth Anderson Video Preservation 1 Assignment #2 December ...*https://www.nyu.edu/tisch/preservation/program/student_work/2011fall/11f_3403_anderson_a2.pdf.