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Summary of Claims

Trade Secret:
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TruColor™, Specification originally published in 2012 ─ A **Luma**/**Chroma** matrix with **RGB** weighting that produces an even stair step **Luma** signal when the 'WhYlCyGrMgRdBlBk' color bars are generated. When the **U** & **V** **Chroma** signal levels are adjusted and combined in quadrature they produce an equilateral hexagon on the Cartesian grid (vector scope), optimizing **Chroma** signal levels. The **I** & **Q** channels are positioned ±45° away from the **U** & **V** channels. The hue of TruColor's **I** channel is **#FB6E00** and is <2⅕° away from NTSC's **I** channel hue of **#FC6600** and TruColor's **Q** channel's hue of **#E700FB** is <4⅛° away from the **Green**-**Magenta** axis. This **YUV** (4:2:2) weighting and matrixing scheme could also be used for photographic still image files or digitized motion picture image files for which a file format could be optimized for the digital storage of these analog TV systems described here. This **RGB** weighting provides a better orthochromatic **B** & **W** visual representation to the eye than the panchromatic weighting used in most image file formats while also offering a symmetrical color wheel with the axes spaced 60° apart and of equal level, the same as the panchromatic weighted images. This lends its self to very similar **YUV** color processing used in the panchromatic image formats.

Chroma Rotary Phase™ (**CRP™**) ─ Simulates PAL's on screen **Chroma** rotation (shift) while elegantly re-engineering it using a 3:1 interlace without the consequences of the objectionable on screen dot pattern. PAL broke NTSC's **2** frame repeat **Chroma** dot pattern by modifying its 180° ½ cycle/line **Chroma** phase offset to 270° ¾ cycle. PAL partially resolved this issue by adding **1** frame rate of cycles to the **Chroma** sub-carrier frequency creating a 180° phase inversion of the **Chroma** signal at the start of a new field to break up the dot pattern but still has a **4** frame repeat. With NTSC using an odd number of scan lines per frame and the 180° ½ cycle/line **Chroma** phase offset naturally produces this effect. When used with TruColor™ the rotating Chroma signal is spectrally balanced and the equilateral hexagon provides better color correction when **Chroma** phase variance occurs during marginal signal conditions. Vector [Phase] Rotation can be realized using two methods. **U** & **V** signals are both electrically rotated 90° per line in opposite directions or **U** & **V** are inverted 180° every two lines at the H/4 rate where **U** & **V** switching is offset by one line from each other. In the direct **U** & **V** 90° rotation scheme this indirectly causes **I** & **Q** to invert 180° every two lines at the H/4 rate and are offset by one line from each other. Likewise in the direct **U** & **V** 180° inversion this indirectly causes **I** & **Q** to rotate 90° per line in opposite directions. With an **I** & **Q** dual bandwidth setup where the two **I** & **Q** **Chroma** channels have different resolutions they too can be modulated using the same methods. In all schemes the on screen vector rotation (shift) is in the opposite direction of its electrical rotation as a result of the ½ cycle/line offset. With the ½ cycle/line offset and the H/4 modulation this places the sidebands at the ±¼ positions as it is in PAL in relation to the ½ position. In PAL the ¾ position for **U** is realized with the ¾ cycle/line offset of the **Chroma** sub-carrier period in relation to the horizontal period and V's sub-modulated sidebands at ¼ positioning is a result of the H/2 switching modulation. The ¾ cycle/line offset causes both U & V to rotate (shift) on screen in the same direction but the H/2 switching of V reverses its on screen rotation (shift).

3:1 Interlace, **72i/24p** ─ Using a 3:1 interlace with this faster field rate reduces flicker and with the frame rate set to conventional motion picture stock eliminates the need for Telecine or 3:2 pull down in NTSC or increasing the frame rate by 4⅙% to 25FPS for PAL. Using a 3:1 interlace with the 4 phase state **CRP™** (or PAL for that matter) realizes the simple diagonal chroma dot pattern very similar to NTSC. To achieve a natural 2 frame **Chroma** dot repeat rate the number of lines in 2 frames must be evenly divisible by 4 with an odd quotient but not by 8, which would result in a ½ line remainder. To achieve the 3:1 interlace a field must end with either ⅓ or ⅔ line when the number of lines per frame is divided by 3. It is also desirable to have the number of lines per frame of active picture area be a factor of 16. With these requirements lines per active picture frame increment by 48, e.g. 384, 432, 480, 528, 576... When using a ⅔ line offset the **Chroma** dot crawl moves up the screen as it does with NTSC. For a given color depending on the phase of the **Chroma** when the diagonal dot crawl pattern is symmetrical along a vertical line it closely resembles NTSC's dot pattern. When the **Chroma** phase is ±45° off from this the diagonal dot pattern angle could be shifted by up to ±15° from symmetrical. For CRTs if a 3:1 interlace motion pattern is visible greater phosphor persistence could minimize this without creating tracers during fast motion.

36FPS & 3:1 Interlace ─ If this faster motion picture rate of 36FPS is used for filming it is possible to easily convert this to a 72i/24p format by using 2 of the 3 scan lines to represent a frame for a quasi 2:1 interlace 72i/36p at ⅔ resolution. If the received signal is digitized and de-interlaced the missing line can be interpolated from the other 2 lines representing a full frame of lines for motion areas. Whether the signal is 24 or 36 FPS based the completed stored frames could be read from memory in a progressive or 2:1 interlace fashion.

4 Phase State Rotating Chroma combined with a **3:1 Interlace** ─ A 3:1 interlace produces harmonics that are spaced at the frame rate for both **Luma** & **Chroma**. When the **Chroma** is placed at the ½ cycle/line offset and not rotated Luma/Chroma adjacent cluster harmonics do not interfere with each other but **Chroma** interference does occur to **Luma** 1½ clusters away when the proper number of scan lines are used for a 3:1 interlace and 4 state **Chroma**. Rotating the **Chroma** phase at the H/4 rate shifts all **Chroma** harmonics ±½ frame rate and off of the **Luma** harmonics. The combined fine mesh spectrum is an alternate of **Luma** & **Chroma** harmonics evenly spaced at ½ the frame rate, just as it is with NTSC. It seems that a 4 phase state **Chroma** signal, be it **CRP™** or PAL is better suited using a 3:1 interlace although a PAL **Chroma** signal is less balanced so **CRP™** with TruColor™ should offer better phase variance cancellation during marginal signal conditions. Since the phase reversal of the **Chroma** signal happens on a per line basis within a whole frame for a 3:1 interlace Hanover lines are created instead of Hanover bars making any on screen severe phase variance effects twice as fine as a PAL 2:1 interlace system when not using a delay line. A 3:1 interlace offers an alternating pattern for both field and frame lines. For 4 state **CRP™** that means phase rotation reversal and for 2 state NTSC it means phase inversion. There are no adjacent lines in a completed frame that are in the same state.

Vertical Sync Pulse Staggering – While it can be demonstrated that a 3:1 interlace when used with a 4 phase **Chroma** rotation system can produce a simple diagonal dot pattern the order in which the lines arrive for each sequential field does not provide optimal line alignment for a frame. By delaying or advancing a field by **1** field line (3 frame lines) in relation to the other two fields, depending on whether a ⅓ or ⅔ line offset is used, will align the **Chroma** dots in a uniform diagonal pattern. Also the diagonal shifting pattern of the **Chroma** dots for a field is in the opposite direction of a completed frame. While this solution may seem like a kluge, i.e. adding the frame rate to the **Chroma** frequency in PAL, it does not alter the precise structural relationship between the **Chroma** and horizontal frequencies thus maintaining the precise ½ cycle/line offset and simplicity in digital processing. Only the video signal information is slightly altered on a per line basis not the base format structure of the signal. For vertical lines on a screen it is of no consequence and the spectral content of the signal would look essentially the same as a non-staggered arrangement. However a diagonal line on screen using sync staggering would look like a saw tooth when displayed with an un-staggered sync pulse and may correlate with a slightly more complex spectral emission which should not produce any critical issues. Video signal content alone in a non-staggered system may produce a similar spectral effect if a diagonal line had a saw tooth characteristic to it. For 2:1 interlace PAL in lieu of adding the frame rate to the chroma frequency using staggered sync pulses would maintain a perfect ¾ cycle/ line offset providing digital processing simplicity and only a slight adjustment to the horizontal (15625.08811Hz) and vertical (50.00028194Hz) frequencies for which a conventional PAL receiver can handle. Using a 625 line analysis with a 2:1 interlace shows that a staggering of 2 field lines (4 frame lines) is needed to create the 180° chroma phase inversion at the start of a new field. Delaying either the even or odd field lines by 2 field lines will create the same pattern that adding the number of frame rate cycles to the **Chroma** frequency does. Staggering would create issues for PAL receivers using a TBC to generate an evenly spaced vertical sync pulse. 613, 621 or 629 scan lines will also work in lieu of vertical sync staggering.

Synergy – TruColor™ with its symmetrical and level balanced color wheel, **CRP™** with its electrically balanced rotation scheme, 3:1 interlace producing a 2 frame uniform dot pattern and repeat rate like NTSC, and 24FPS film speed, all work together to create a fully optimized analog Color TV signal that has the hue correction feature of PAL with optimized performance, a **Luma**/**Chroma** composite spectrum with NTSC's ½ frame rate spacing, a frame rate that allows a seamless conversion from film to video and a signal that is easily digitized. All of this is accomplished with normal and conventional analog TV signal formatting and possible more than 60 years ago. If only all of this was though of back then.

The **ΣHSλ** to **λUV** TruColor™ Matrix

(**Y**et **A**nother **C**hroma **M**atrix ;-). What **NTSC** should have been?

A method for converting **ΣHSλ** Color with a modified **Luma**(**λ**) to analog Color TV **λUV** to balance for better **Chroma** (**UV**) matrixing.

Where: **Σ** = **Chroma** level is a vector matrix sum/difference
and not a saturation percentage factor.
H = Hue of the **Chroma** signal in θ°
derived from the quadrature matrix.
S = Saturation level (R) of the **Chroma** signal as
quadrature summation of the U & V vectors.
λ = Brightness, or intensity
factor of the **Luma** signal.

12-bit Luminance.

20-bit Polar Color Definition.
(Where **Chroma** scaling for R & θ° is assigned 20 Bits)

2^{13}:1 Contrast Ratio, 2.6 Γ (Gamma), D65 White Point, Expanded 6 **Color** Gamut encompassing DCI-P3, Pro 400h, Vision 3 & Portra 400

Matrixing

Let:

1931 CIE Color Gamut Graph

	Ranges		3 Primary			+3 Secondary	
		nm	x	y	nm	x	y
R = **Red**	−½ to 1	**620**	0.691	0.308	**492**	0.100	0.341
G = **Green**	−¼ to 1	**539**	0.220	0.750	**−539**	0.359	0.111
B = **Blue**	0 to 1	**467**	0.136	0.053	**571**	0.450	0.550

λ = Matrixed **B & W** **Luma** sub-channel.						
U = Matrixed **Blue** **Chroma** sub-channel.	**U**	**#3300FF**	252.00°	**−U**	**#CCFF00**	72.00°
V = Matrixed **Red** **Chroma** sub-channel.	**V**	**#FF0055**	340.00°	**−V**	**#00FFAA**	160.00°
W = Matrixed **Green** **Chroma** sub-channel.	**W**	**#00FF33**	132.00°	**−W**	**#FF00CC**	312.00°
			HSV Hue			HSV Hue
Enhanced channels:						
I = Matrixed Skin **Chroma** sub-channel.	**I**	**#F96D00**	26.27°	**−I**	**#008CF9**	206.27°
Q = Matrixed **Purple** **Chroma** sub-channel.	**Q**	**#E700FB**	295.22°	**−Q**	**#14FB00**	115.22°

For 3 **Color** Gamut use D65 White Point,
1st **TruColor™**, 2^{13}:1, 2.6 Γ, DLP or Laser
2nd **DCI-P3** , 2^{13}:1, 2.6 Γ, DLP or Laser
3rd **sRGB** , 2^{12}:1, 2.4 Γ, CRT or LCD

We have:

$$\lambda = +1/7 \times B \quad +2/7 \times R \quad +4/7 \times G$$

$$B - \lambda = +6/7 \times B \quad -2/7 \times R \quad -4/7 \times G$$

$$R - \lambda = -1/7 \times B \quad +5/7 \times R \quad -4/7 \times G$$

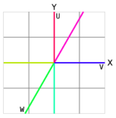
$$G - \lambda = -1/7 \times B \quad -2/7 \times R \quad +3/7 \times G$$

$$G - \lambda = -1/4 \times (\, B - \lambda \,) \; -1/2 \times (\, R - \lambda \,)$$

[**W**, **B−λ** Scaled with √3/2]

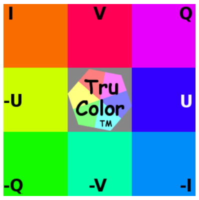
Encode:

If: $U(x) = \sqrt{3}/2 \times (\, B - \lambda \,) \times 0°$ ⌉ Quadrature
$V(y) = (\, R - \lambda \,) \times 90°$ ⌋ Sub-Carrier
Then: $W = \sqrt{3} \times (\, G - \lambda \,)$ @ 240°

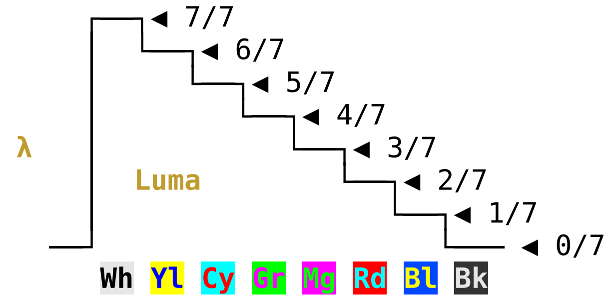


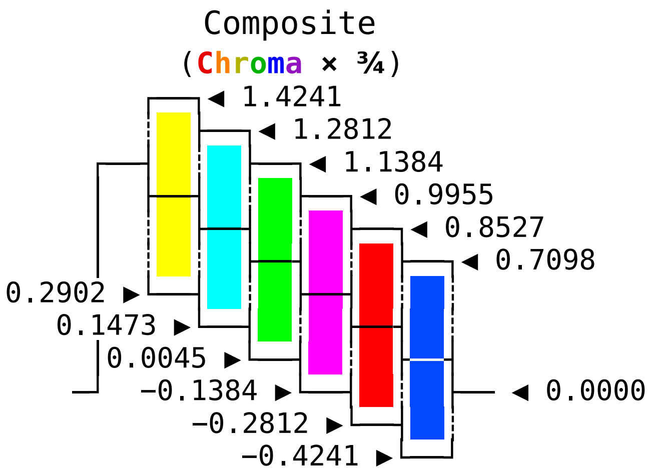
Chroma Vector $R = \sqrt{U^2 + V^2}$
Chroma **Hue** θ = [aTan2(**V**,**U**) ; If θ < 0 Then θ + 2π]

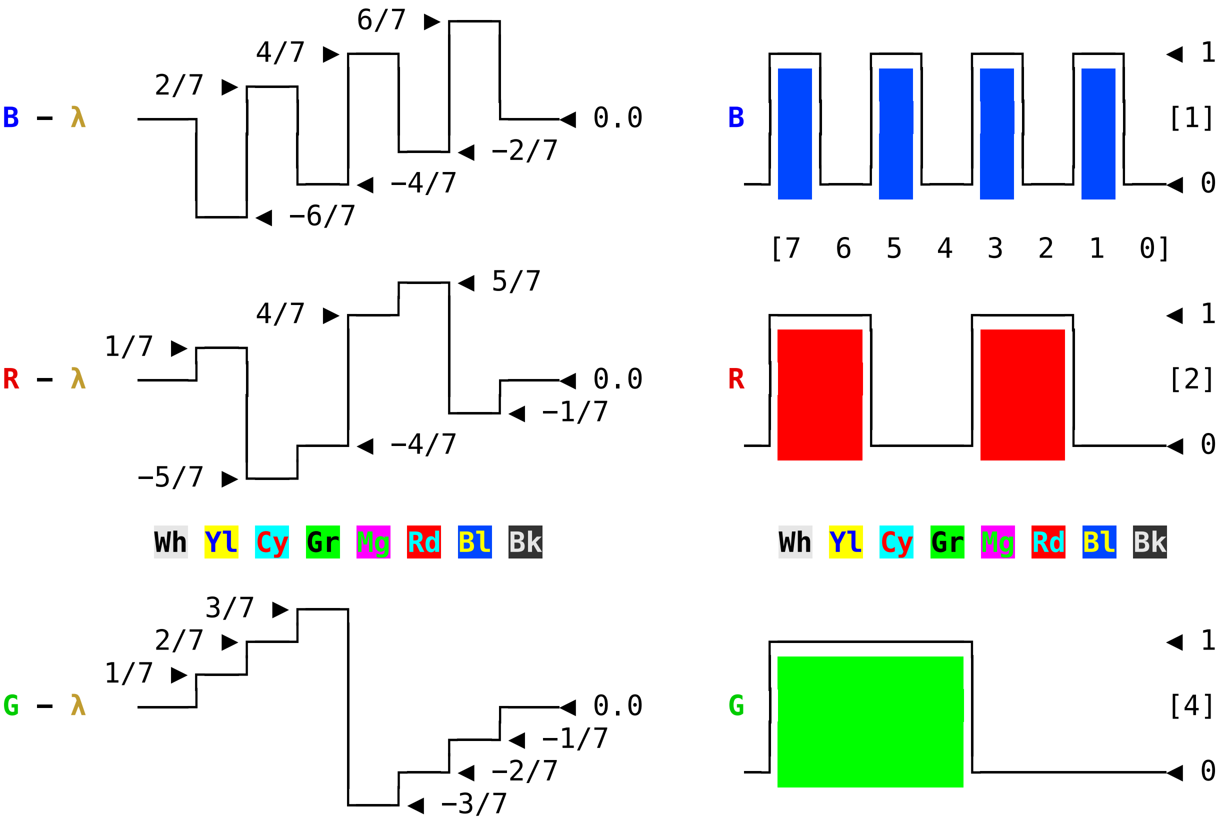
Decode: SyncDet
U: **B** − **λ** = -┼- @ 0° ÷ √3/2
V: **R** − **λ** = -┼- @ 90°
W: **G** − **λ** = -┼- @ 240° ÷ √3



100% Color Bars







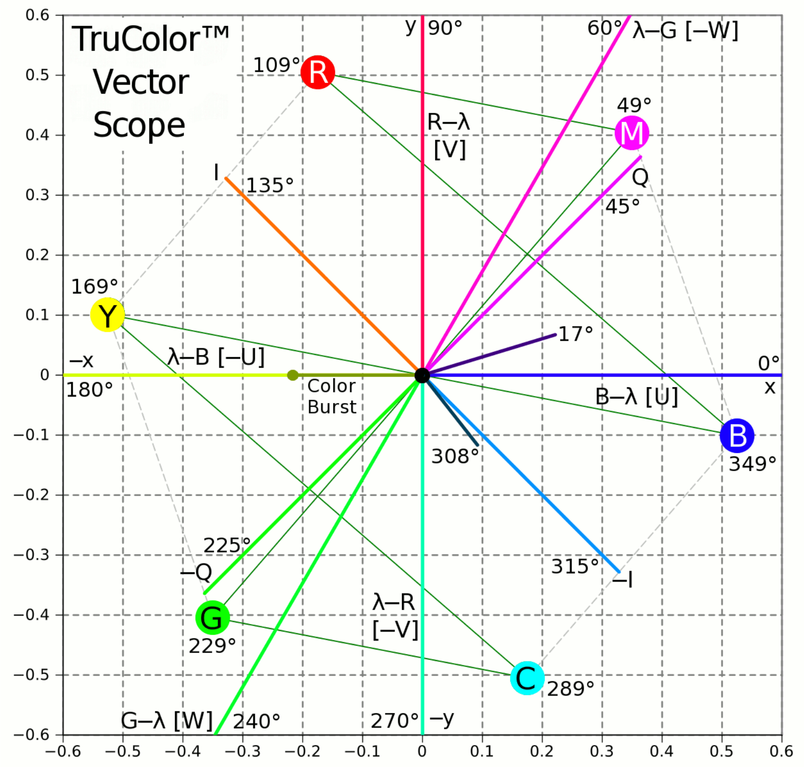
		Rectangular		Polar	
Color Bar	Luma Level	Chroma U×√3/2	Levels V	Chroma Hue θ	Chroma Peak Level
White	100.00%	N/A	N/A	N/A	N/A
Yellow	85.71%	−3×√3/7	+1/7	169.11°	2/√7
Cyan	71.43%	+1×√3/7	−5/7	289.11°	2/√7
Green	57.14%	−2×√3/7	−4/7	229.11°	2/√7
Magenta	42.86%	+2×√3/7	+4/7	49.11°	2/√7
Red	28.57%	−1×√3/7	+5/7	109.11°	2/√7
Blue	14.28%	+3×√3/7	−1/7	349.11°	2/√7
Black	0.00%	N/A	N/A	N/A	N/A

The composite **Chroma × ¾** scaling for all colors with full saturation produces a level of **0.5669**pk or **1.134**p-p when modulated. When combined with **Luma** the **Luma** + **Chroma** peak for **Yellow** is at **142⅖%**, and **Blue** is at **-42⅖%**, slightly more foot room than PAL for **Blue** when composite scaling is applied with sync + setup added.

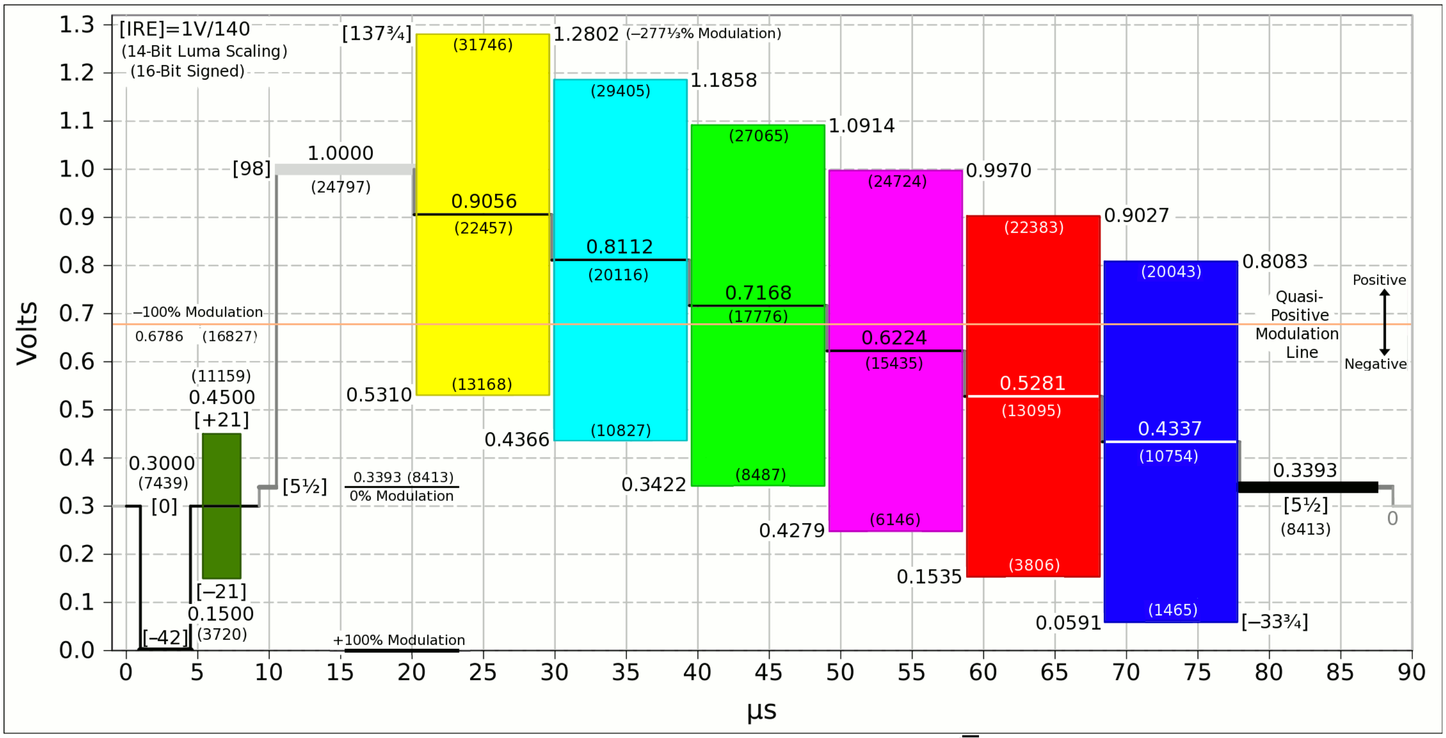
There is a 60° separation between the MgRdYlGrCyBl color axes respectively for the composite Chroma and all Chroma levels for each color at full saturation are equal to each other thus creating a perfect hexagon in the vector image.

The Enhanced Chroma Channels:

Skin	(I)	135°	(V − U) ÷ √2
Purple	(Q)	45°	(U + V) ÷ √2

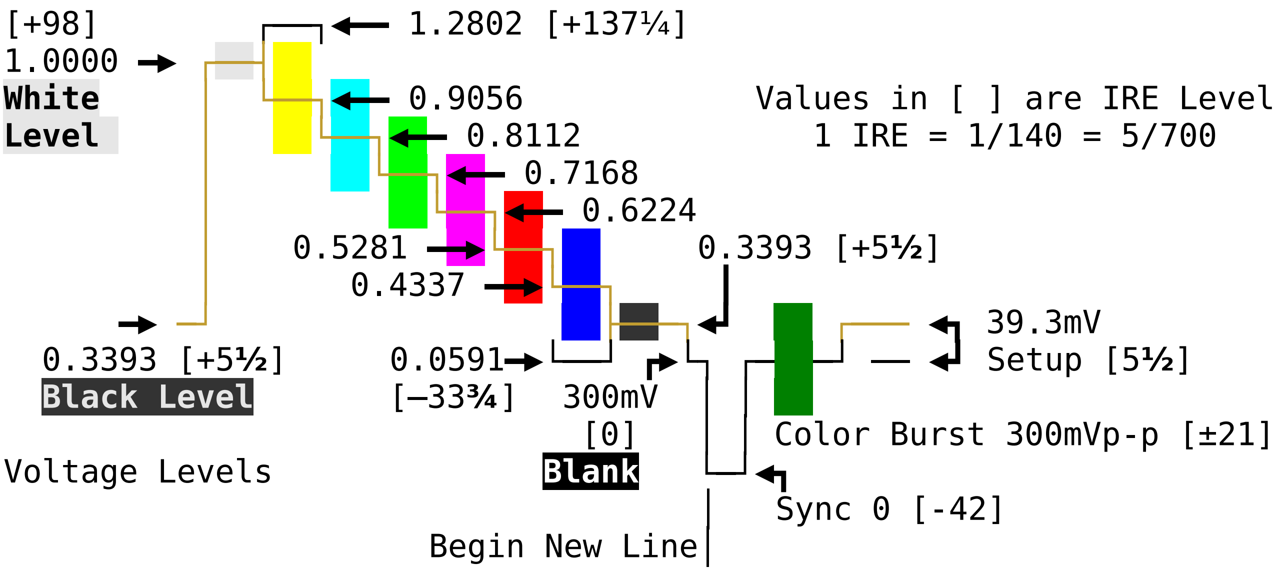


TruColor 432i72 Composite Luma/Chroma



Graphically the Chroma signal levels in the vector image above are scaled @√2/2 for a Luma of 0 to 1. Composite image with updated IRE levels is scaled width a Luma of [92½] (0.6607), Chroma @¾ & SetUp of [5½].

Analog Scaling



Values in [ ] are IRE Levels.
1 IRE = 1/140 = 5/700

Voltage Levels

λ = **Luma** ; **Chroma** = Quadrature -┼- × **Chroma** Reduction ¾ [105]

Composite = (**Luma** + **Chroma**) × 0.660714286 + 0.339285714 (sync + setup [47½])
[92½]

For a 1Vp-p B & W video signal with sync 0.6607 composite scaling is used with a **Chroma** level of 749mVp-p for each color, on par with the **Luma** : **Chroma** NTSC RMS ratio. Blanking level is exactly 300mV [−42]. **ColorBurst** is 300mVp-p [±21], centered on blanking level, 150mV [−21] to 450mV [+21].

Digital Scaling

Digital scaling uses **Luma** & **Chroma** values prior to composite scaling. The power factor is for A/D and does not include the analog display gamma correction. The extra bit can denote motion.

Luma λ , Where $0 \leq \lambda \leq 1$
12-Bit Scaling = $\lambda \times 4095$ [Power Factor 2^{12} ; 4096:1 Contrast]

Chroma Vector $R = \sqrt{U^2 + V^2}$, Where $0 \leq R \leq 2/\sqrt{7}$
10-Bit Scaling = $R \times (3095.529034 \div 2/\sqrt{7})$ [Power Factor 2.2339502^{10}]

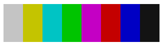
Chroma Hue θ = [aTan2(V,U) ; If $\theta < 0$ Then $\theta + 2\pi$]
9-Bit Scaling = $\theta \times (511 \div 2\pi)$, Where $0 \leq \theta \leq 2\pi$

The natural **Chroma** phasing here will set the colors at:

Red @ 109.11° , **Green** @ 229.11° , **Blue** @ 349.11°

this is different than the NTSC/PAL spacing, but to align the hue with the standard HSV space and to place **Red** at 0° rotating the phase by -109.1066° is desirable before bit scaling is done. In order to produce a balanced color wheel for the **Chroma** signal, placing the MgRdYlGrCyBl axes 60° apart, the **RGB** weighting for the **Luma** is balanced to integer ratios of:

Red @ 28.57% , **Green** @ 57.14% , **Blue** @ 14.29%

which are the fractions 2/7, 4/7, and 1/7 respectively and the **U** **Chroma** channel was reduced by √3/2, Sin(60°), before quadrature matrixing . When the standard color bars  are processed an even level stair step for the **Luma** signal is produced. This is a slight variation from the **YUV** **Luma** weighting used for NTSC/PAL which is:

Red @ 29.9% , **Green** @ 58.7% , **Blue** @ 11.4%

and is not a noticeable difference for the black & white portion of the signal.

While this is defined as a 32 bit encoding it could be defined with 24 bits or less as well but with lower resolution. Defining both the **Luma** and **Chroma** as levels and the hue as a phase allows for more efficient use of the assigned bits. Regarding phase this could be defined as a palate with non-linear assignment around the color circle to optimize the color perception of the eye and/or scene optimization of image. This palette also could be dynamic as the scene changes. For the more sensitive hues to the eye and/or scene use smaller steps and in the less sensitive areas larger steps thus reducing the number of bits necessary for the same color range. The eye is also less sensitive to color saturation than to overall intensity so having both the **Luma** and **Chroma** intensity channels separate from the hue allows for better **Luma**/**Chroma** bit balance for best fidelity. Dithering of the **Chroma** signal in both hue and level would also help to minimize the perception of using a lower bit level.

For example: **24** bit = **8** **Hue**, **7** **S**aturation, **9** **Luma**

NOTES:
The 'λ' (Lambda) symbol is used for the **Luma** instead of 'Y' to differentiate the altered **Luma** weighting from the standard NTSC/PAL weighting.

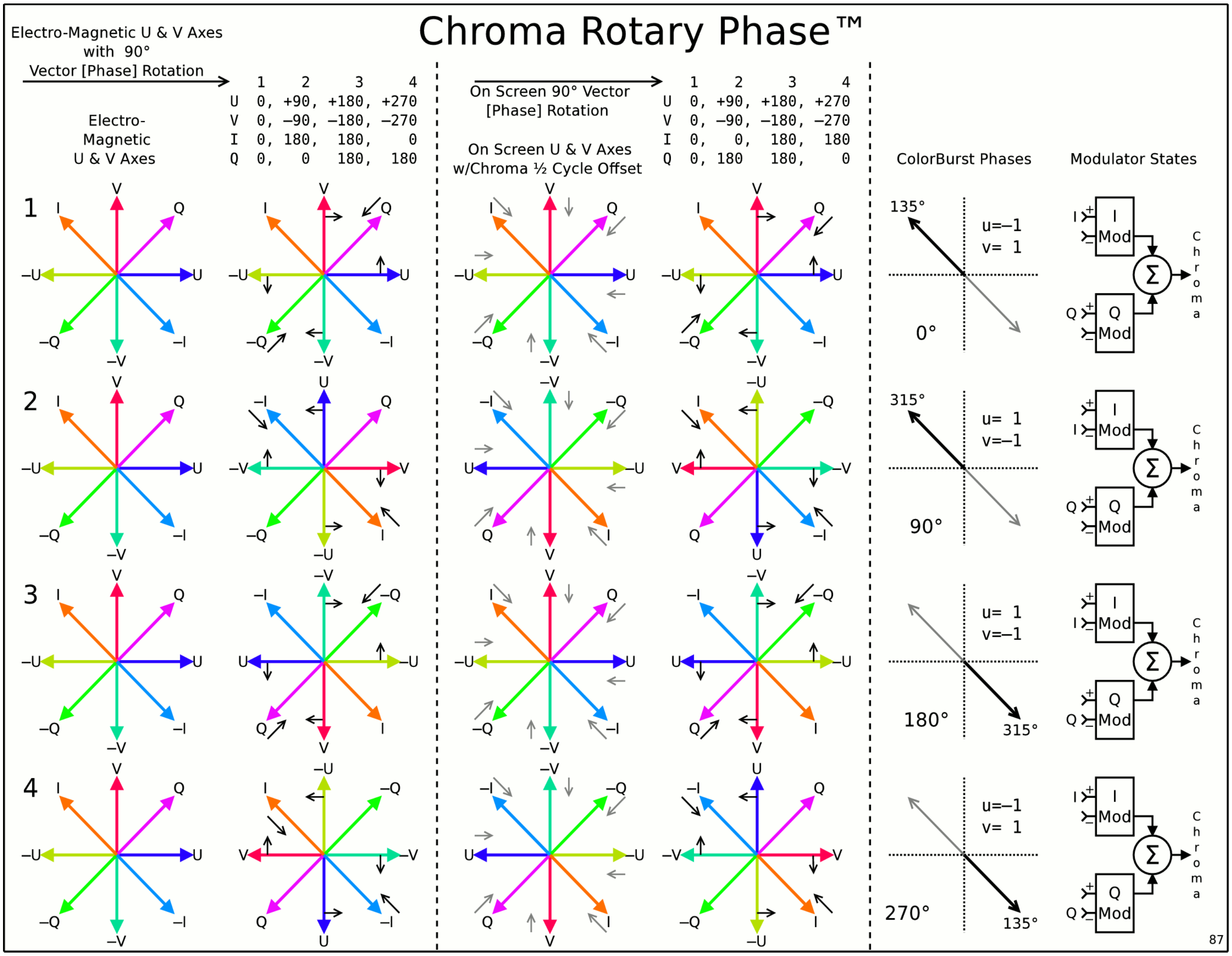
The 'Σ' (Sigma) symbol denotes that this HSλ color space uses a sum/difference method to matrix the **Red**, **Green**, and **Blue** signals into the **Luma** & **Chroma** channels and not a scaling percentage for the **Chroma** saturation.

Chroma Rotary Phase™

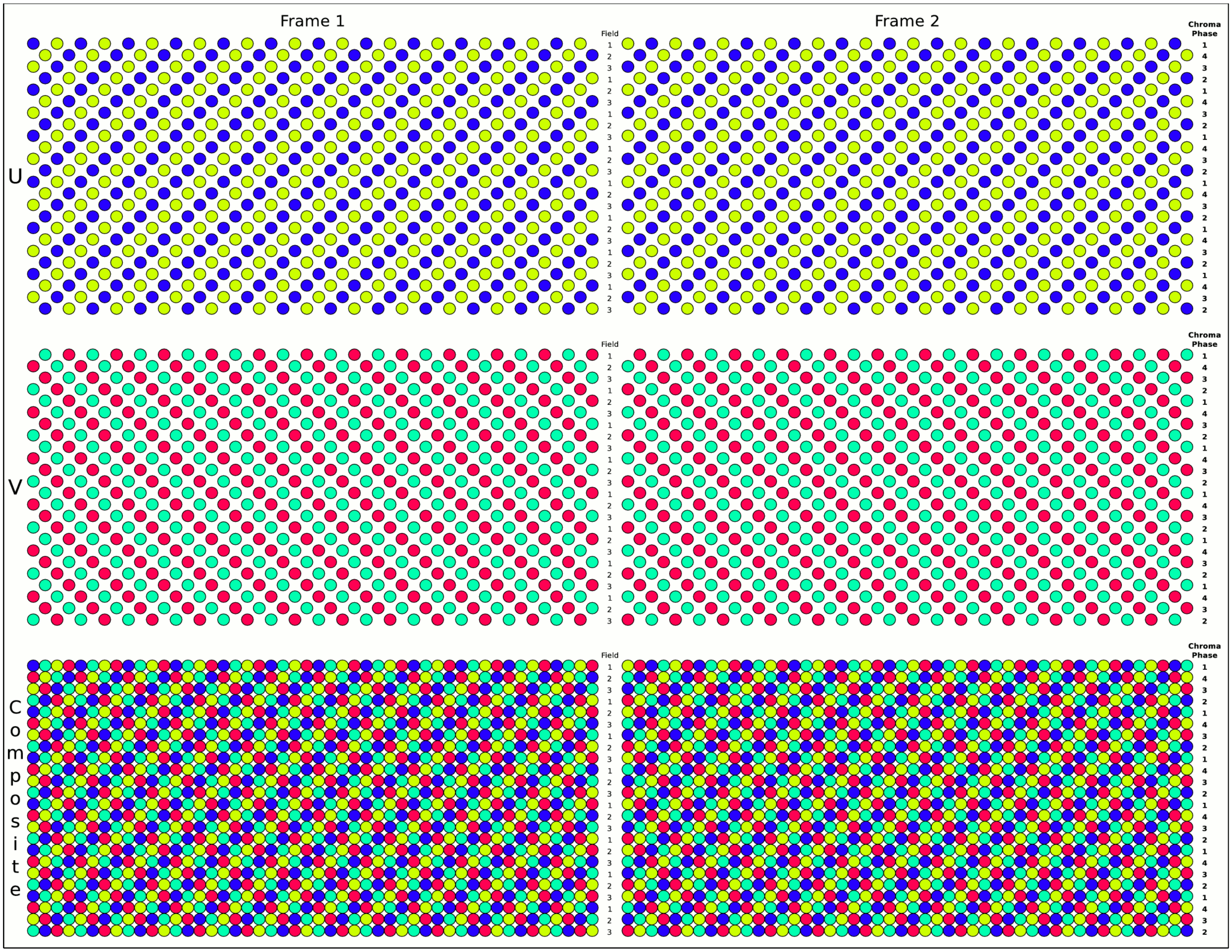
Vector [phase] rotation by **90°** for each horizontal line is a process used in **VHS** video recording for the **Chroma** signal. The lack of signal stability in the tape's higher frequency range is inadequate to record the **Chroma** signal but in the lower frequencies it is minimal but is still present. The head azimuth angle used to eliminate adjacent track cross-talk in the higher frequencies for **Luma** recording is ineffective in the lower frequencies. Vector [phase] rotation increases signal stability and cancels out adjacent track cross talk which would degrade the signal.

The **Chroma** signal is heterodyned down to 629kHz in a process called color under. During the heterodyning process the mixers use an oscillator with quadrature outputs that rotates the mixer phase by **90°** for each line in opposite directions for each head so the phase will rotate through **360°** in **4** lines before repeating and then being put onto tape. During playback they are up converted back to the original sub-carrier frequency and the mixer phases are rotated in opposite directions reversing the rotations and restoring the **Chroma** to its original phasing. A comb filter is used during playback to cancel out cross talk and phase jitter.

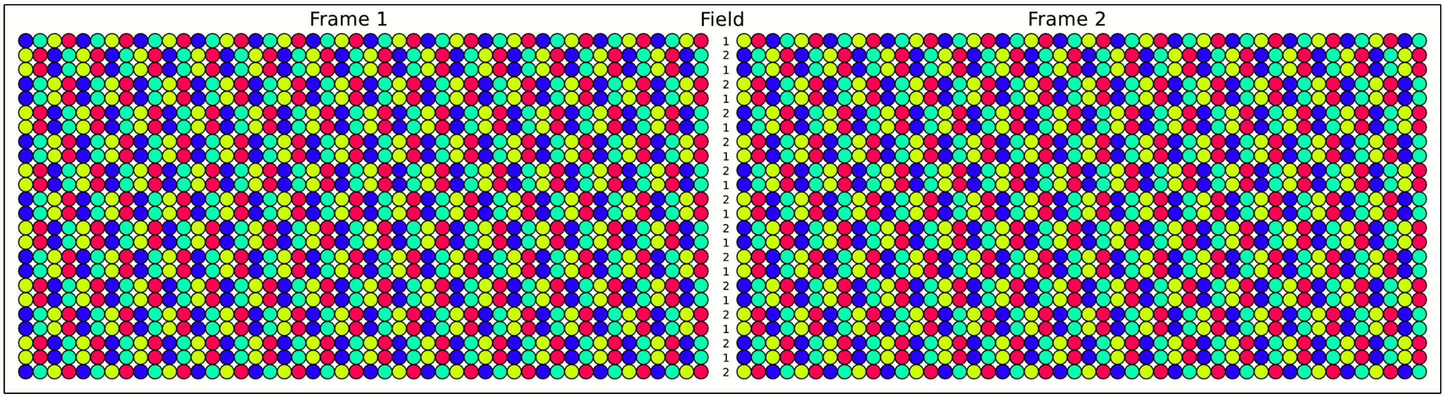
Chroma Rotary Phase™ can be used to reduce **Chroma** signal degradation during transmission. The **Chroma** modulators will rotate the two sub-carrier phases by **90°** per line for the **B–λ & R–λ** signals in opposite directions instead of for each head as it is done in **VHS**. In **NTSC** the **Chroma** sub-carrier frequency is an odd multiple of **½** the horizontal frequency which causes the clusters of **Chroma** energy to sit in between the clusters of **Luma** energy in a process called interleaving. As a result each horizontal line ends with only **½** cycle of the **Chroma** sub-carrier inverting the phase **180°** for both **B–λ & R–λ** in relation to the previous line on the screen. This is sometimes seen as a diagonal dot crawl pattern on the screen. When phase rotation is applied it also causes the vectors on screen to rotate in opposite directions compared to the electrical signal.



In the image above are 4 video lines labeled `1, 2, 3, & 4`. The 1st column of vectors are of the **U & V** electrical axes. The 2nd column of vectors are of the **U & V** electrical axes rotated `90°` per line. The 3rd column of vectors shows the natural phase inversion created by each line ending with only **½** cycle of the **Chroma** sub-carrier inverting the phase `180°` for every other line as displayed on screen but in reference to the **ColorBurst** PLL lock the phase has not inverted. The 4th column shows how the vectors are positioned on the screen when the **U & V** axes rotate by `90°` per line. The 5th column shows how the **ColorBurst** angle is used with each rotation for identification. In the 6th column are the **I & Q** modulators and how the modulating signals are applied for each line. Line `1` is normal having the **I & Q** signals sent to their respective modulators. In line `2` the **I** modualtor swaps phase. In line `3` the **Q** modualtor swaps phase. In line `4` the **I** modualtor swaps phase. Returning to Line `1` the **Q** modualtor swaps phase and process then repeats itself for another set of `4` lines. To decode the rotation process is reversed at the receiver and the use of a comb filter provides an added benefit.



Next are the dot patterns for regular NTSC **Chroma**.

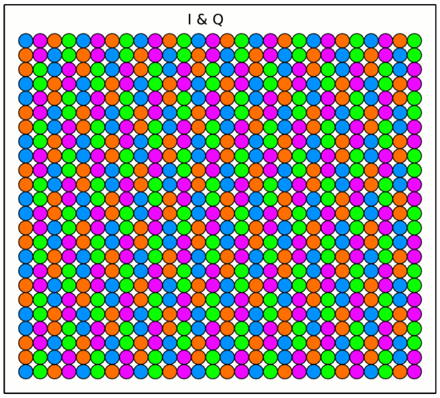


Using a 3:1 interlace with a ⅔ line offset allows the use of an even number of lines per frame providing a 2 frame repeat rate when using **Chroma** Rotary Phase™. The dot pattern is a little less randomized than a PAL 2:1 interlace but a little more than the regular NTSC **Chroma** 2:1 interlace. Whether the randomness with a 2 frame repeat rate is enough to outweigh the other two 2:1 interlace modes is unknown. The **U & V** patterns are completely diagonal at 45° per frame whereas the NTSC **Chroma** 2:1 interlace have the same pattern between fields for line pairs which are also at 45°. Interlacing is accomplished by delaying the vertical sync pulse by a fraction of a line. For a 2:1 interlace the delay would be ½ line using an odd number of lines or for a 3:1 interlace it would be ⅔ line where the number of lines per frame divided by 3 would produce the number of lines per field ending with ⅔ line. On screen field 2 would start ⅔ line later than field 1 and field 3 would start

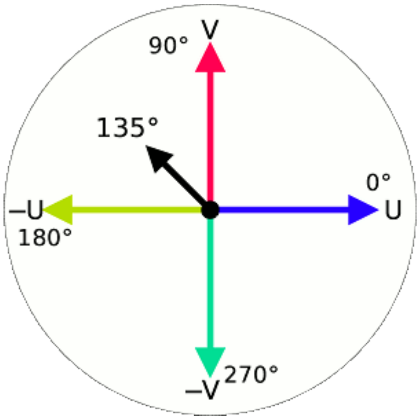
⅔ line later than 2. Unfortunately this would produce a larger and less uniform Chroma pattern than either of the other 2:1 interlace methods. To eliminate this and produce a uniform rotation pattern on screen the sync in field 1 starts on line −2 instead of line 1 within a frame shifting all the lines in field 1 down by 1 on screen. This will allow the use of the most optimal lines to start the fields within the 4 line Chroma Rotary Phase™ repeat pattern. The 1st line in the odd frames on screen will start the 4 line Chroma rotation pattern at the beginning and every other frame line will have the U & V Chroma axes swapped as it is in every other field line but the 4 line rotation pattern is reversed from the field rotation direction. The even frames will start the Chroma rotation pattern in the middle to produce the 2 frame repeat rate.

Tru Color ™ Chroma Rotary Phase

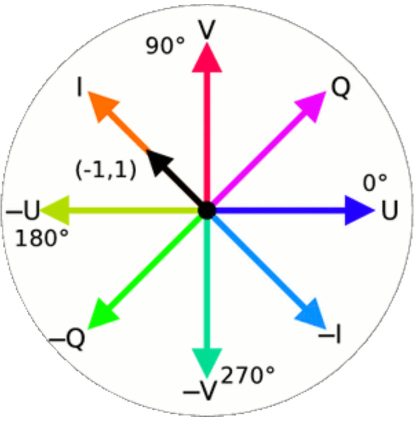
On page 10 are the Composite, U & V dot patterns for a 3:1 interlace. On the bottom right is the pattern for the I & Q vectors. When any Hue falls on either one of these axes it will generate the same pattern as standard NTSC Chroma with the only difference in the pattern is that the I & Q line pairs are not on the same two lines but are offset by one line. This is of no consequence compared to NTSC since a Hue will fall on either one or the other axis however for the 3:1 interlace the dot crawl pattern will manifest itself different than it would for a 2:1 interlace. This will apply for all Hues and the angles of the dots will vary from vertical pairs at 45° if they fall on an I or Q axis to a pure ±45° if they fall on a B−λ or R−λ axis. The U & V Chroma axes swap on a per line basis instead of line pairs within a frame as it would be for a 2:1 interlace will make any Hue error effects on screen twice as fine if a comb filter is not used. It is the 3:1 interlace and selectively starting the fields within a frame with a 1-5-6 pattern that makes the Chroma rotation pattern lay down in this way on screen.



PAL On Screen Vector Rotation & Vswitch Animation (¼ offset)

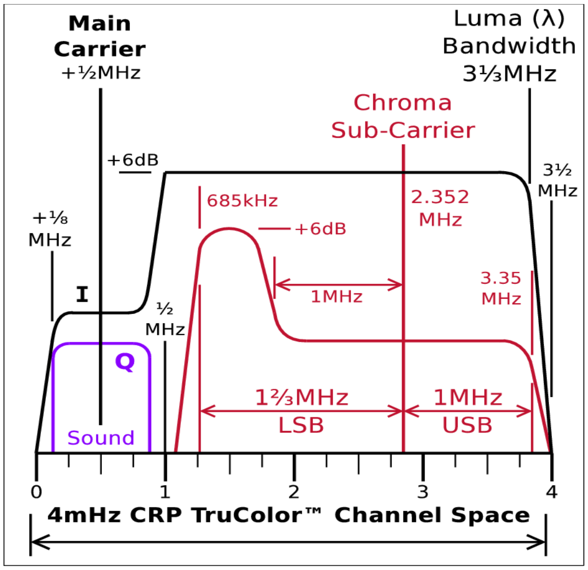


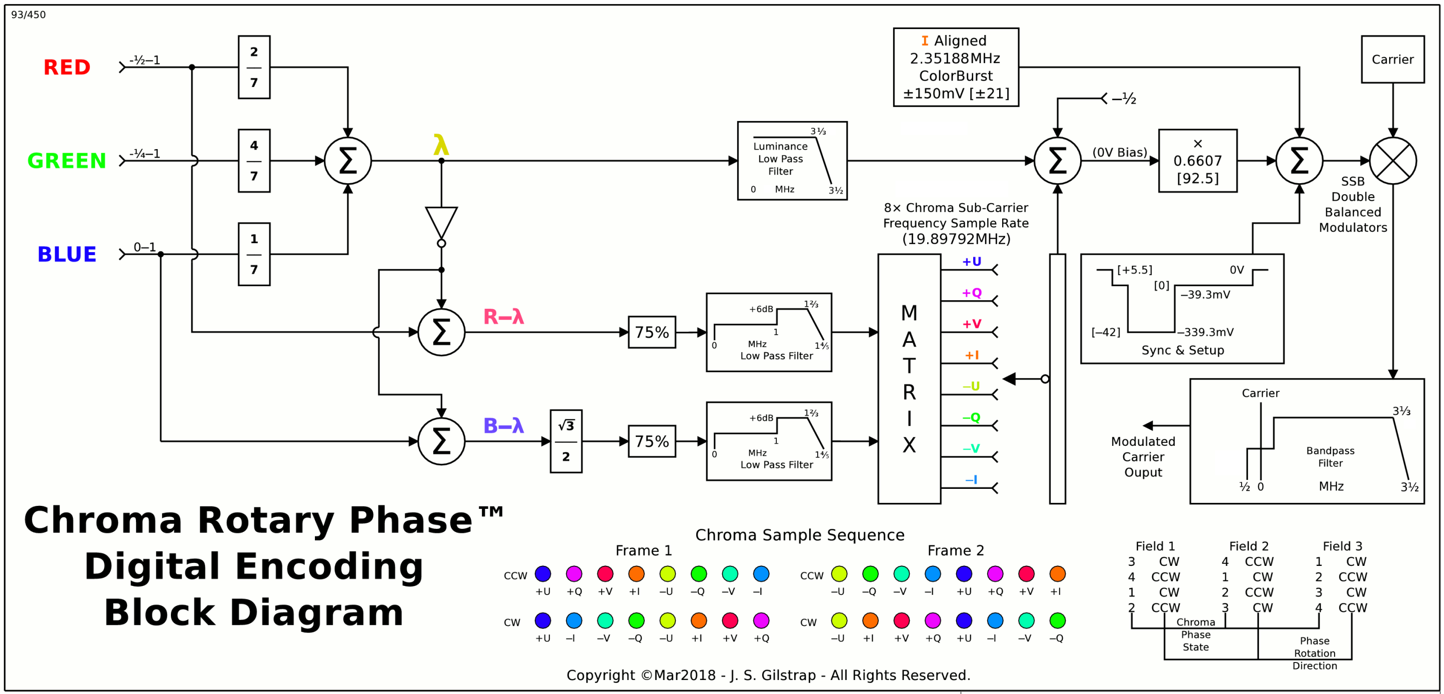
Chroma Rotary Phase U & V Vector Rotation Animation



PAL ¾ offset equiv.

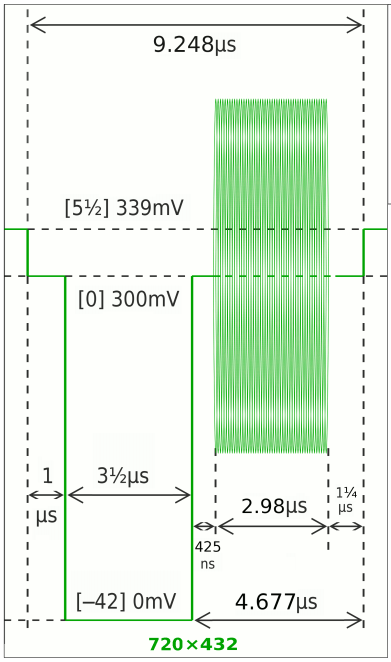
For transmission using a mostly suppressed carrier for the composite video not including sync (zero carrier modulation by Luma at 50% gray, or another fixed level that minimizes carrier level on average program material [–12dB PEP?], or a content variable level carrier to maximize carrier suppression on a per scene basis) with synchronous detection of the I channel will greatly improve transmitter efficiency and signal reception integrity. Only the ColorBurst, color modulation and Sync pulses will rise above the Luma PEP level with the sync pulses being the strongest. CarrierBurst tracking will happen during the sync pulses with a 0° phase angle, the same way the ColorBurst does. The ⅓MHz vestigial sideband provides space for a Q channel on the main carrier. This could be used for a digital channel for 5.1 audio (opus), Luma HF information for up scaling, motion assist, or other data services.

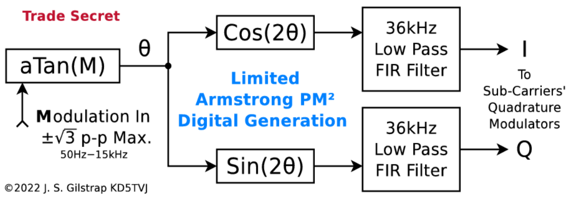


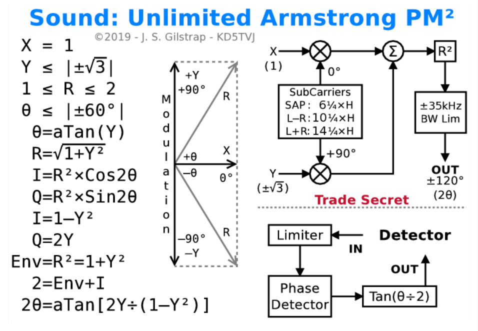


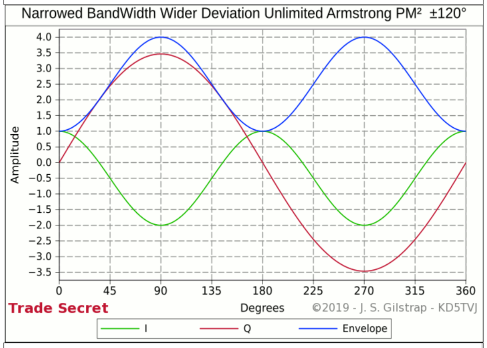
Chroma Rotary Phase™
Digital Encoding
Block Diagram

To the right and below are the generation, wave forms and detection for narrow band sound to be placed on the **Q** channel of the main carrier.

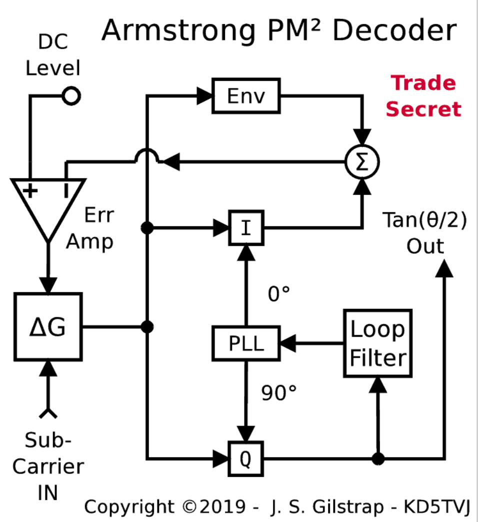








Like the PAL phase switch of the **V** channel CRP™ will need to be corrected also. Both **U** & **V** will need to be de-rotated in the correct direction. There are few ways to do this. By rotating the BFO 90° per line for both **U** & **V** in the direction that de-rotates the **U** channel the **V** channel output is converted to PAL and the typical **V** switch can be used to properly decode the **V** channel as long as the colorburst is aligned with the **I** channel. This also allows the PLL loop circuit to work as it normally would in PAL. This is probably the most foolproof method also. The another option is to de-rotate both **U** & **V** using BFO de-rotation but will complicate PLL phase detection and would facilitate the need to add a **V** switch to the signal for the PLL loop filter. Likewise the de-rotation could also be done post detection but PLL phase tracking would also need some phase detection manipulation also. Detecting on **I** & **Q** axes would need phase switches applied to both **I** & **Q** detectors and could be done using BFO switching for pre detection or a fixed BFO with post detection switching. This would also need PLL loop filter phase manipulation for proper tracking. If special **I** channel processing is needed then this could be an option.



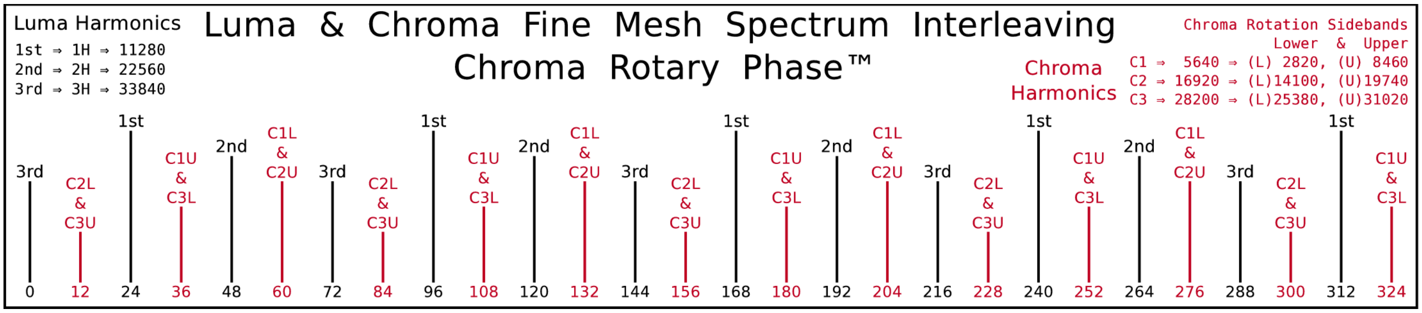
Video Harmonics: Coarse Mesh Cluster & Fine Mesh Interleaving

In PAL with a 2:1 interlace when the Chroma U channel is at the ½ offset as it is in NTSC it does not interfere with the Luma but when the V channel in the same spot is switched at the H/2 rate V is sub-modulated creating a ±H/2 DSB-SC signal. With the sub-modulating carrier of H/2 being in the kHz range and the modulated Chroma sub-carrier bandwidth in the MHz range the upper and lower sidebands of the H/2 sub-modulation almost completely overlap. With the combining of the sidebands along with the U channel if the harmonics overlap they will either reinforce and increase in strength or nullify and create Fukinuki holes. Having the Chroma sub-carrier lie in the ½ center offset between the Luma clusters the V sub-sidebands are displaced at ±H/2 causing the center of the upper and lower sub-sidebands to fall directly on top of the Luma clusters creating direct interference and making them impossible to separate. To eliminate this the Chroma sub-carrier is placed at the ¾ offset instead of the ½ offset and the ±H/2 V sub-sideband centers fall on the ¼ offset or for PAL-M in Brasil the sub-carrier is at the ¼ offset and the ±H/2 V sideband centers fall on the ¾ offset. The ¼‖¾ offset of the U channel sub-carrier does not cause interference with the Luma either.

While this eliminates interference on both the coarse and fine mesh spectrum between the Luma, U & V channels it creates another problem, objectionable on screen standing Chroma dot patterns thus breaking the on screen Chroma dot pattern of NTSC which is designed to be inverted on every other frame averaging out the Luma brightness. To eliminate this on screen pattern problem the Chroma sub-carrier frequency is shifted by the number of cycles in a frame thus causing the on screen dot pattern to invert 180° at the beginning of each field to break up the pattern. Combining this with the 4 unique states of the V switch, odd number of lines per frame and 2:1 interlacing it takes 8 fields or 4 frames before on screen Chroma phasing repeats. Shifting the fine mesh spectra of the Chroma by 1 frame rate does not cause interference to the Luma as the new slots for the Chroma harmonics are also empty, not being occupied by Luma harmonics, but it does make every Luma/Chroma line combination unique for the 4 frame repeat pattern. While this solves the Luma/Chroma interference issues and the on screen dot pattern problems, inverting the Chroma sub-carrier on screen dot pattern by shifting the Chroma sub-carrier frequency by 1 frame rate causes the sub-carrier to creep 1 cycle per frame. This creates additional issues with advanced digital decoding and processing, having way too many more than 4 unique Chroma scan line patterns makes the math all that much more complicated.

While PAL solved the drifting hue issues of NTSC each change created another issue for which another solution was necessary. The V switch feature/bug caused Luma interference which was solved by placing the sub-carrier on a ¼‖¾ offset instead of the ½ offset. The offset feature/bug created the standing on screen dot patterns which was solved by increasing the sub-carrier frequency by 1 frame rate. In the end the Luma/Chroma sub-carrier relationship of PAL is inherently more complex than NTSC and when digital processing with 3 line 3-D comb filters and frame storage came along NTSC with its Luma/Chroma simplicity naturally lent itself to complete Luma/Chroma separation for static images via temporal frame storage and for motion simple 3 line comb filters provided good enough separation. Having enough Luma/Chroma separation the drifting hue issues mostly disappear as it does in S-Video sources since varying Luma levels was the main cause especially with the old tube Chroma decoders. The newer transistor or IC decoders have much better DC tracking in the colorburst loop filter along with some correction signals transmitted during the vertical blank to help minimize hue errors. Multipath signal degradation of NTSC can still cause significant hue errors whereas PAL mostly corrects for this with some loss in color saturation and is one of the the saving graces that PAL still has over NTSC now. With PAL digital processing is less glamorous but still beneficial. More complex algorithms and increased compute power are needed to achieve comparable results although the level achieved with PAL is still not as good as it is with NTSC.

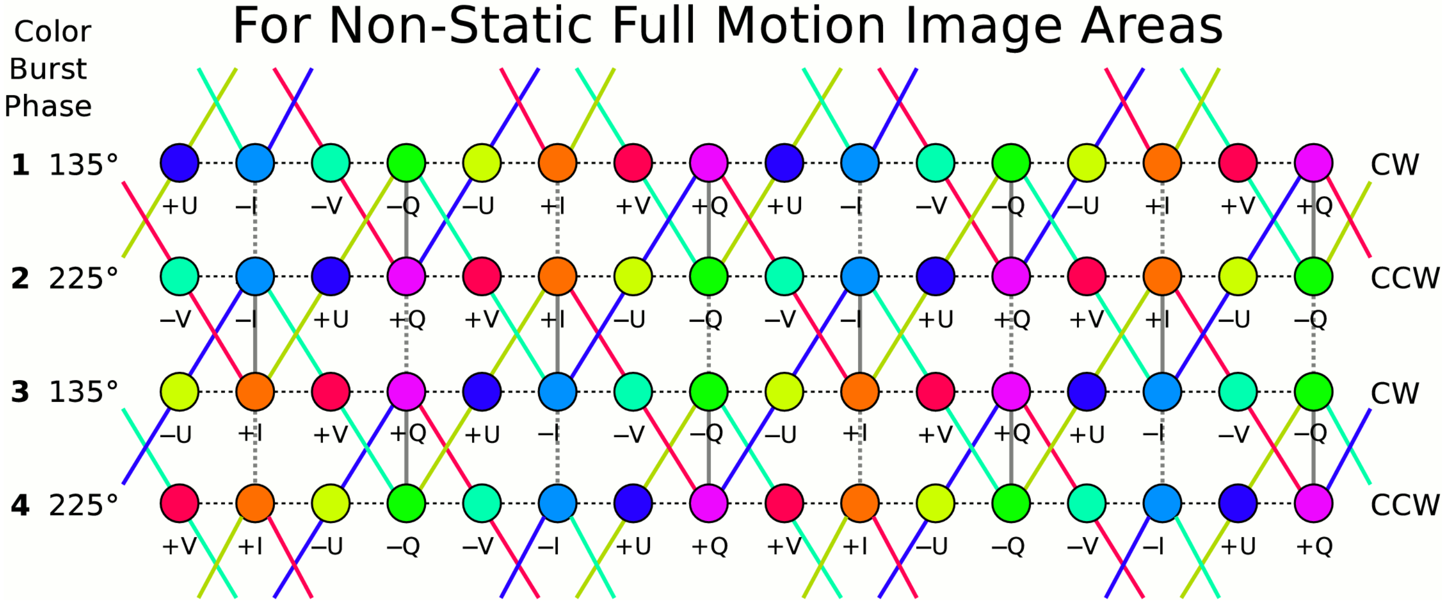
This detour into PAL is a good description with what happens when a Chroma sub-carrier is sub-modulated at a fractional rate of the horizontal frequency, the issues it creates and the solutions used to address them. For a more detailed description many articles about PAL since its inception in the early 1960s are probably available. This description is here since Chroma Rotary Phase™ also uses Chroma sub-carrier sub-modulation but is a more elegant approach than PAL. As with PAL it automatically corrects for hue errors but also eliminates instead of creating Luma/Chroma fine mesh spectral interference when a normal NTSC Chroma modulation is used with a 3:1 interlace. A cleaner implementation avoiding the pitfalls that PAL creates and with the 3:1 interlace Hanover lines are created instead of bars. A balanced solution with an on screen Chroma dot pattern that is more uniform with a natural 2 frame repeat rate. On a per frame basis if the hue falls directly on the U or V axis the Chroma dot pattern is identical to NTSC with line pairs of vertically aligned dots which create a diagonal pattern. Only when the hue falls directly in the middle of the U & V axes is a pure diagonal line of dots created. This predictable dot pattern makes it as simple to process digitally as NTSC.



In the image above using a 3:1 interlace the normalized spectrum distribution of Luma with Chroma Rotary Phase™ is shown at the fine mesh level. The 3:1 interlace with a 72Hz field rate ending with ⅓ line causes the Luma and Chroma harmonics to be placed at 24Hz intervals which is also the frame rate. As with NTSC Chroma the sub-carrier is placed at an odd multiple of ½ horizontal rate so at the coarse mesh level the Chroma clusters will lie in the center between the Luma Clusters. When a conventional NTSC Chroma modulation method is used with a 3:1 interlace the fine mesh Luma and Chroma adjacent cluster harmonics do not interfere with each other but interference does occur 1½ clusters away from each other and then every 3rd cluster after that. Chroma Rotary Phase™ offsets this causing all Chroma harmonics to fall evenly between all Luma harmonics at the fine mesh level in a Luma/Chroma 12Hz interval throughout the combined Luma/ Chroma spectrum. This is because both Chroma channels are sub-modulated at the H/4 rate creating a ±H/4 DSB-SC signal in which the sidebands are centered on the ¼ & ¾ offsets. Having the Luma and Chroma fine mesh harmonics spaced at 24Hz intervals for cluster triads and that H/4 is not evenly divisible by 24 but is divisible by 12 with a quotient that is odd means that all Chroma harmonics are shifted by ±12Hz off center thus moving them away from interference with the Luma and placing them exactly centered in between them. The H/4 modulation also creates overlapping Chroma harmonics from the upper and lower sidebands in a triad configuration of: C1U & C3L, C1L & C2U, and C3U & C2L. This is a repeating 3 cluster pattern even when shifting over 1 cluster at a time. A Fourier spectral analysis has not been done but for the overlapping harmonics it can be assumed that some may be constructive and increase in strength and others may be completely destructive and create Fukinuki holes. The most desirable outcome would be for Chroma harmonics which are from adjacent Chroma clusters and are centered within a Chroma cluster are constructive and those that are centered within the Luma clusters are destructive and are the ones creating the Fukinuki holes. For the Luma the reverse is not true as it is not sub-modulated. For both Luma and Chroma the harmonics for each cluster are spaced 72Hz apart and for a cluster triad there is a 24Hz offset between the 3 so the combined triad of harmonics creates the 24Hz interval. As with a 2:1 interlace the energy in between the Luma clusters is minimal and is where and why the Chroma clusters were placed there originally. The void of strong harmonics in between the Luma clusters for a 3:1 interlace is probably very similar to a 2:1 interlace. Even if the voids are not as defined as a 2:1 interlace the Luma/Chroma fine mesh harmonic separation at the 12Hz interval is as evenly spaced as NTSC's 15Hz interval which is FrameRate/2 for both.

To make all this work seamlessly it is the combination of Chroma Rotary Phase™ with a 3:1 interlace using an even number of scan lines per frame to fit together like puzzle and work synergistically. When the number of lines per frame is evenly divisible by 2 and the quotient is odd then the 4 line Chroma rotation pattern is advanced by 1 line per '½ frame' and over 4 '½ frames' (2 frames) the Chroma rotation pattern evenly repeats. When the number of lines per frame is divided by 3 the lines per field must end with ⅔ line to create the 3:1 interlace. A ⅔ line offset has some advantages over a ⅓ line offset, e.g. scan lines move down the screen but for sequential fields the line groups move up and this may help counteract any visual movement whereas ⅓ line offset causes field lines to sequentially move down the screen accentuating visually the top to bottom scan pattern. This movement is not an issue with a 2:1 interlace as it is an alternate blinking motionless pattern although with the 3:1 interlace the field rate is faster than NTSCi60 at 72Hz so this may help some. For CRTs greater phosphor persistence could be balanced to eliminate visible scan line movement without causing motion blurring. This becomes a non-issue if the image is de-interlaced for CRT progressive scan or is displayed on a flat panel which will be de-interlaced anyway.

Per Field Luma Separation 3 Line Processing
For Non-Static Full Motion Image Areas



For **Luma** samples that fall on **U** or **V** **Chroma** Sample points there are 2 **Luma** samples from **I** & **Q** sample points from adjacent lines on the diagonal that when added together will form the complimentary color to cancel out the **Chroma** on each **Luma** sample. The mapping is shown via the complimentary color lines connected to an **U** or **V** sample and the associated **I** & **Q** samples. The ratio is $(\sqrt{2}:2:\sqrt{2})/(1+\sqrt{2})/2$.

For **Luma** samples that fall on **I** or **Q** sample points **I** or **Q** points directly above or below on adjacent lines are added or subtracted to cancel out **Chroma** on each **Luma** sample point. The mapping is shown via gray lines. Solid lines are additive and dotted lines are subtractive. The ratio is ±¼:½:±¼ .

Since **Luma** sample recovery on **U** or **V** sample points is all additive it provides noise reduction but **Luma** sample recovery on **I** or **Q** sample points have some S/N loss since adjacent lines are subtracted nullifing **Luma** but additive for the complimentary color that cancels out **Chroma** on the current line leaving only the **Luma** from the curent line but also the noise from the adjacent lines.

To average out this noise variation between the **I** & **Q** and **U** & **V** sample points the recovered **Luma** on a line can be a running average of 3 points in a ¼:½:¼ ratio or 5 points in a ⅘×(⅛:¼:½:¼:⅛) ratio. This averaging has minimal effect on sharpness since the sample rate is ~3¾ times the image resolution.

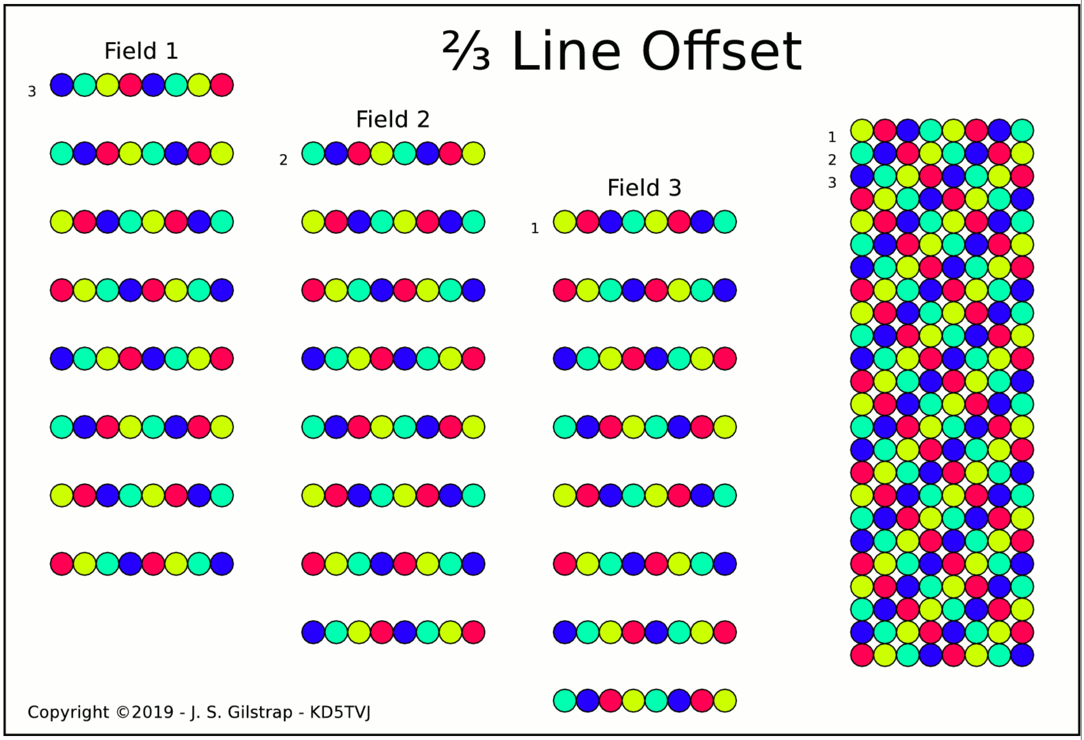
To eliminate **Luma** and obtain **Chroma** it can be as simple as subtracting adjacent lines from the current line as in NTSC with the ¼:½:¼ ratio. Unlike NTSC the adjacent lines do not contribute any to **Chroma** levels but just nullify the **Luma**. The **Chroma** on the adjacent lines are inverted to each other so when they are added together the **Chroma** is nullified. Inverting these 2 summed lines will produce inverted **Luma** which will nullify the **Luma** on the current line Leaving only the quadrature **Chroma** signal to be used for **Chroma** decoding. However this method does not correct for hue phase errors and some lines of **Chroma** resolution are lost nor does it produce the best S/N ratio.

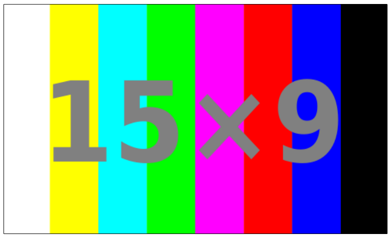
Subtracting one line, above or below from the current line will eliminate the **Luma** and either the **I** or **Q** **Chroma** channel. This method will correct for hue phase errors and produce much better S/N ratio but the **Chroma** lines of resolution will be cut in half. Which **Chroma** channel that will be eliminated and which one will remain will depend on which chroma phase rotation the current line is using. **1**: 1-4 ⇒ +**I**, 1-2 ⇒ +**Q** ; **2**: 2-1 ⇒ —**Q**, 2-3 ⇒ — **I** ; **3**: 3-2 ⇒ +**I**, 3-4 ⇒ +**Q** ; **4**: 4-3 ⇒ —**Q**, 4-1 ⇒ —**I** . For positive values: 1-4 & 3-2 ⇒ + **I** ; 1-2 & 3-4 ⇒ +**Q** and for negative 4-3 & 2-3 ⇒ — **I** ; 2-1 & 4-3 ⇒ —**Q**

Since the **Chroma** sub-carrier is inverted 180° from frame to frame to average out **Luma** brightness two frames can be added or subtracted to obtain the **Luma** or **Chroma** respectively so motion free static image areas will produce full **Luma**/**Chroma** separation without any artifacts. This will produce the highest resolution and best S/N ratio but unless adjacent line **Chroma** information is incorporated with the current line any hue phase errors that exist will not be canceled out but will produce Hanover lines that may be visible and viewer must rely on visual blending for the correct hue.

To the right is the chroma dot sequence for a 470 line format using a ⅔ line offset. It shows the 2 frame repeat rate where the chroma dots are inverted on the even frames and the odd frames are non-inverted, or vice-versa, for an on screen per spot basis. The staggered vertical sync pulses cause the chroma dots to align diagonally on screen to create a uniform pattern. The dots are colored for the U & V axes where they each rotate 90° per line in opposite directions. This also causes I & Q to invert 180° every 2 lines in a flip-switch manner. The directions that U & V rotate will depend on the I & Q flip-switch order within the 4 line chroma repeat pattern. In an alternate application it would be U & V that flip-switch and I & Q would rotate 90° per line in opposite directions and for a vestigial sideband chroma signal I & Q should rotate in the directions that optimizes I's signal integrity if there is a significant difference in quality caused by vector rotation.

To view the full 470 lines of chroma rotation for 2 frames zoom in on the diagram to the right. You can also highlight the image within the pdf and copy it to the clipboard and then paste it onto an image editor like The GIMP or Photoshop. In the diagram below are the 3 fields of chroma dots separated out and also combined revealing the uniform diagonal pattern. In the left half the separated fields are vertically staggered to each other so the 4 line chroma repeat pattern is aligned between the fields. Field 1 starts with line 3 of a frame, field 2 with line 2, and field 3 with line 1. When assembled and properly staggered vertically the pattern on the right is realized.





Standard Definition

WVGA 24PsF 432i72 15:9

w/CRP™ for a **4**MHz Channel Space

Quality**:** +11⅛% NTSC, –22% PAL-B/G

⅔ U.S. Channel Space ($^{4}/_{7}$ EU)

For the vertical scan a 3:1 interlace is used at a field rate of 72 Hz to produce the **F**ilm standard 24 frames per second. For a ⅔ line offset having the 1st field arrive one line early in relation to the other two fields instead of 1 line later as for the ⅓ line offset should properly align the **Chroma** dot pattern diagonally. The full refresh rate will also be at 24 frames per second, 41⅔ms. Using a 3:1 interlace at 72 Hz with 156⅔ lines allows the use of a lower horizontal scan rate providing increased definition of the **Luma** channel with a 3:2 aspect ratio. **Chroma** Rotary Phase™ will be used instead of NTSC **Chroma** since its dot matrix pattern works better with the 3:1 interlace while still offering a two frame repeat pattern but a **2.35**MHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced to ½MHz and the **Luma** corner bandwidth decreased to **3⅓**MHz with cutoff at **3½**MHz to fit within a **4**MHz channel space. The PM sound sub-carriers are on the **Q** channel of the main carrier.

General:	22½×13½ ⇒ 26¼”, 793¾µm LinePitch	Fair Contrast
Aspect Ratio	15:9 = 1⅔	595:432 ≈ 1.3919
Total Picture Pixels (Digital)	720×432 ; 311040 Pixels	601×432 ; 259632
Kell Factor (Analog Resolution)	509×305 ; 155520 Pixels	425×305 ; 129816
Maximum Digital Equiv. @−9dB	721×432 ; 311472 Pixels	510×305 ; 155736
		Pixel Aspect 1:1.197
		16:9 768×432 1:1.280

Vertical:	
Frames Per Second	24Hz
Total Lines Per Frame	470
Fields Per Second	72Hz
Total Lines Per Field	156⅔
Field Picture Lines	144
Lines Per Blank	12⅔
Blank	1.123ms
Sync	207µs ; 2⅓ Lines

$$\begin{array}{ccccc} \text{Aspect Ratio} & & \text{Super Pixel} & & \text{¾ FWVGA Resolution} \\ \begin{bmatrix} 15 \\ 9 \end{bmatrix} & \times & \begin{bmatrix} 48 \\ 48 \end{bmatrix} & = & \begin{bmatrix} 720 \\ 432 \end{bmatrix} \end{array}$$

HD Wide

$$1\tfrac{2}{3} \times \begin{bmatrix} 720 \\ 432 \end{bmatrix} = \begin{bmatrix} 1200 \\ 720 \end{bmatrix}$$

$$2\tfrac{1}{2} \times \begin{bmatrix} 720 \\ 432 \end{bmatrix} = \begin{bmatrix} 1800 \\ 1080 \end{bmatrix}$$

Horizontal:	Resolution Fair: 425⅕ Max@−9dB: 510⅕
Lines Per Second	11.280kHz
Period (Hᴘ)	88.652µs (417)
Picture	79.405µs (373½)
Total Picture Pixels	441⅛ ≈ 1⅔×**λ**ʙᴡ×(Hᴘ−Hʙ) ; (425⅕+15$\underline{9}$)≈3⅗%/2⅞µs OverScan
Viewable Picture Pixels/Line	425⅕ ; 76.534µs (360×2 Dot Clock)
Blank (Hʙ)	9.248µs (43½)
Front Porch	1.063µs (5)
Sync	3.508µs (16½)
Back Porch	4.677µs (22)

Luma & Chroma on **I** Ch. Main Carrier:

			PAL
Luma (λ) Bandwidth @−3dB	**(510)**	3⅓MHz, Full Cut 3½MHz	
		Vestigial ½MHz, Corner ⅜MHz	**PAL**
Chroma:		Sub-Sampling 2:1:1	18.74736MHz (8×)
Sub-Carrier		2.35188MHz ; 8× ⇒ 19.89792MHz	2.34342MHz
½H Odd Harmonic		417:**208½**:139	415½:**207¾**:138½
V Bandwidth	**(255)**	1⅔MHz (USB +1MHz & LSB −1⅔MHz)	
U Bandwidth	**(255)**	1⅔MHz (USB +1MHz & LSB −1⅔MHz)	
Color Burst Duration		2.976µs ; 7 cycles 2×(1+7+3)=22	
Baseband Guard		½MHz **425/531ns 1¼/1.17µs**	

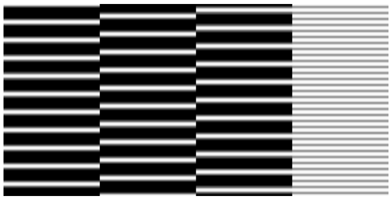
U & **V** rotates in the direction to produce PAL chroma dot pattern.

Sound: Sub-Carrier on **Q** Ch. Main Carrier: PM Deviation: ±⅞π ±2¾R ±157½°

Sub-Carrier Frequency:	**Mono**: 16½×H 186.12kHz. **SAP 141** **L−R 231.24** **L+R 321.48** pg13
	Armstrong PM² Stereo: 12½×H, 20½×H, 28½×H, ±120°
Frequency Response	50Hz−15kHz @−3dB (Harmonic Peak PSNs 2×1ms)
Equalization	50µs Pre-Emphasis, Pole at 13kHz (12¼µs)
	2⅔ms Pre-Emphasis, Pole at 180Hz (884µs)
Processing:	Harmonic Peak PSNs 2×1ms
	2:1 Linear Compression, Attack: 1ms, Decay: 60ms

32 Scan Lines/Inch

Digital: Stereo: MP3 ‖ Vorbis. 5.1 Surround: Opus & SAP



All the advanced processing for both encoding and decoding that has been developed for **PAL** and **NTSC** some of it described in **NTSC Specifications** should be used along with any additional techniques available to improve signal quality, TX/RX robustness e.g. GCR, and image resolution maximization.

720×432
Expanded to
1440
2×HorizSample

282.000kHz
25×11280
(43⅛)

394.800kHz
35×11280
(60¼)

522.720kHz
49×11280Hz
(84⅗)

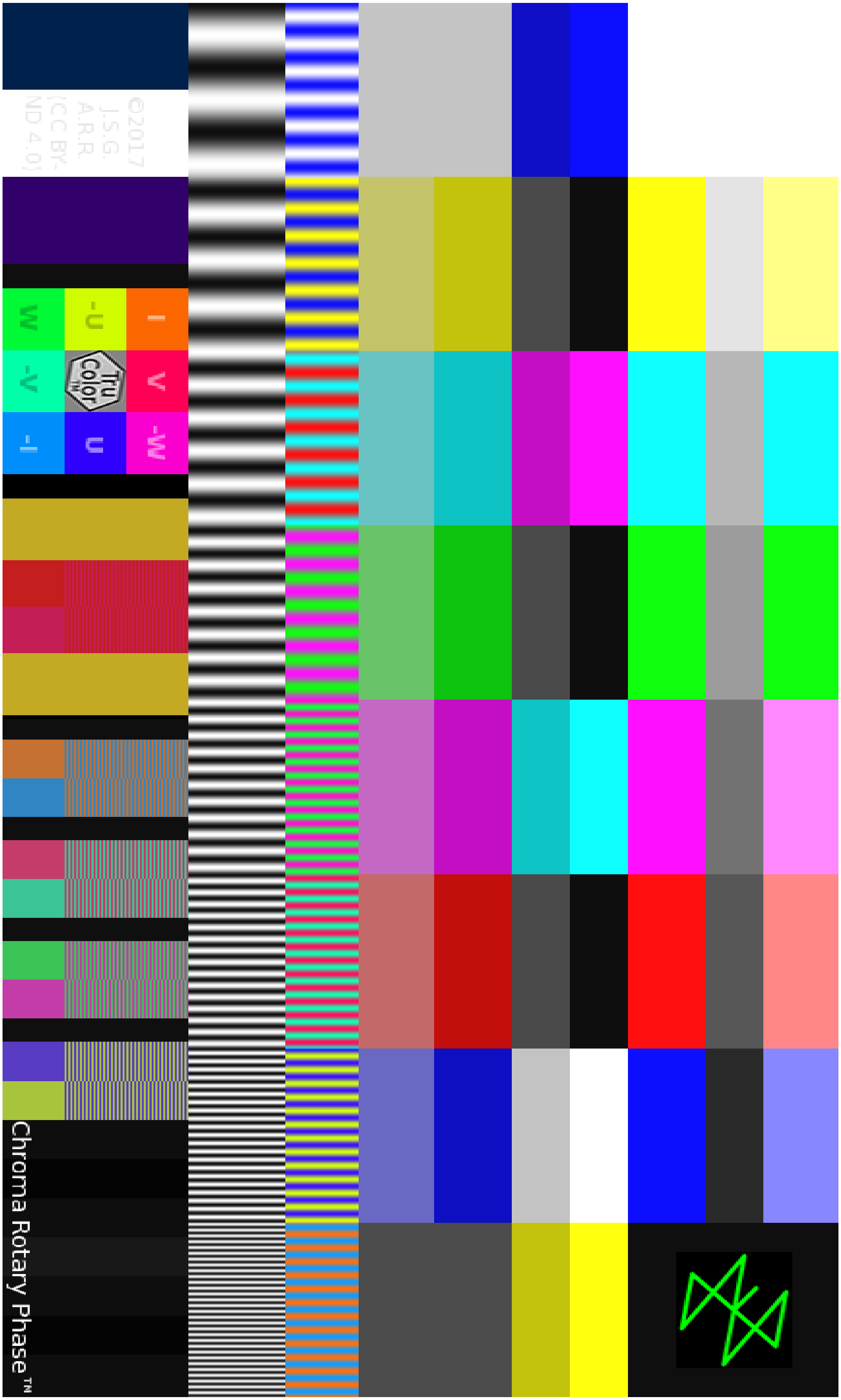
789.600kHz
70×11280Hz
(120⅚)

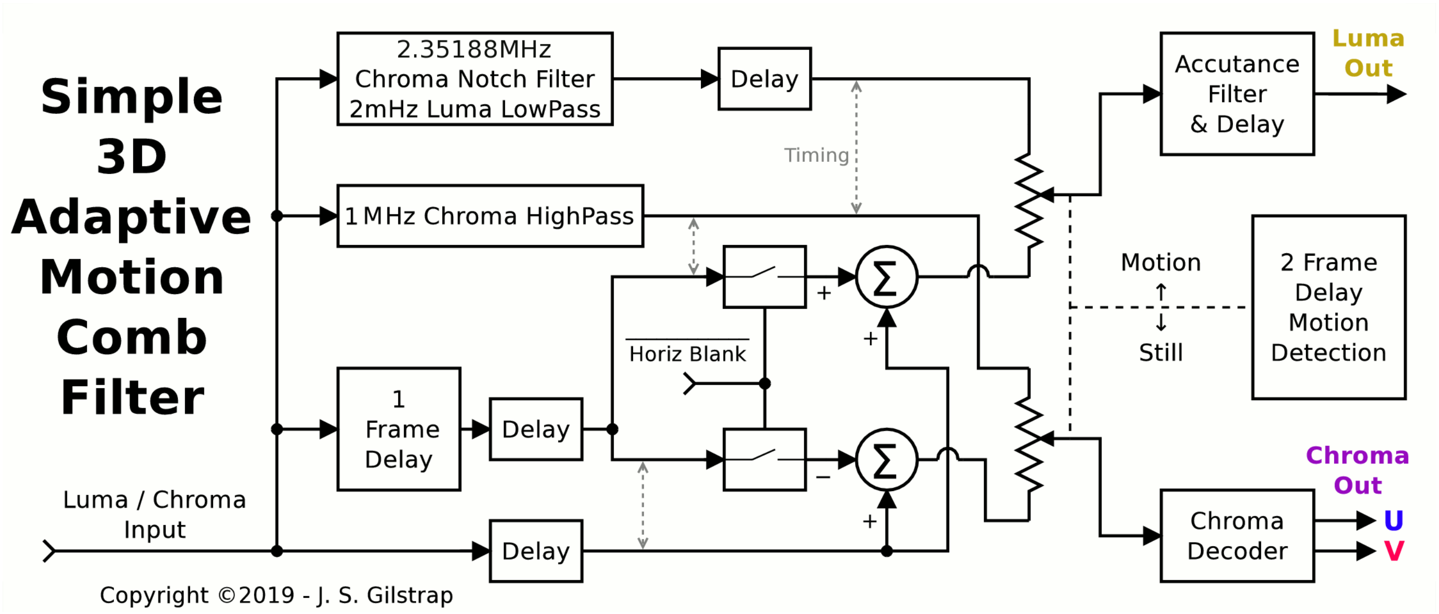
1.105440MHz
98×11280Hz
(69⅕)

1.567920MHz
139×11280Hz
(240)

2.222160MHz
197×11280Hz
(341⅛)

3.135840MHz
278×11280Hz
(480)

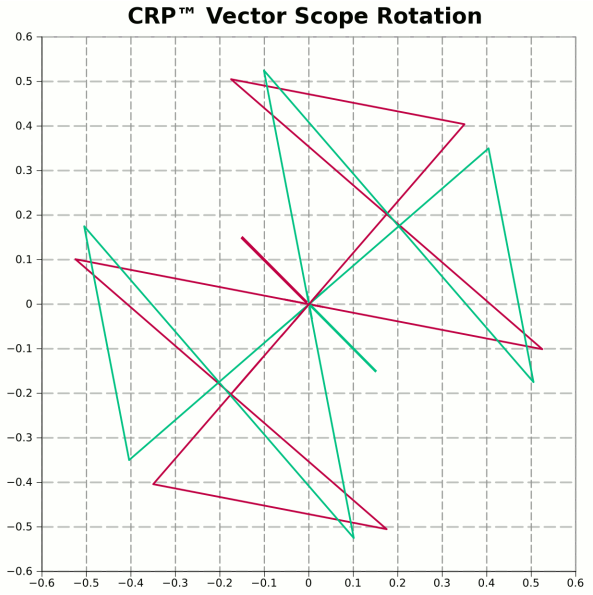




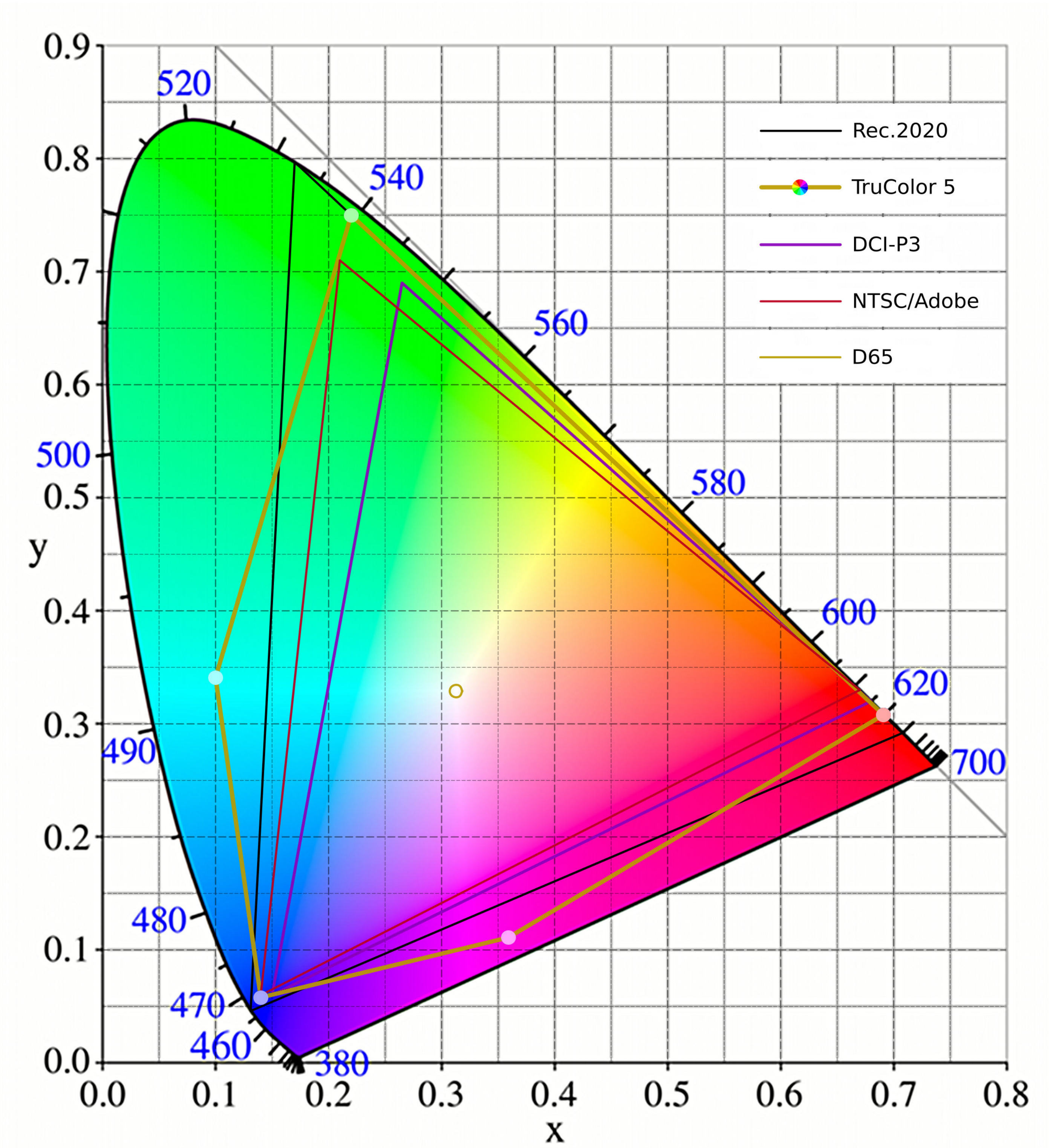
3D Adaptive Motion Comb Filter should use a variable noise floor to control the threshold level and prevent the switch from still to motion being triggered by signal noise. Once above the threshold level the transitional fader wipe should occur over 5–7 pixels to eliminate any hard edges between the still and motion areas. An alternative to an adaptive motion filter is to use the field comb always and pre-process the signal before transmission in much the same way the VHS HQ circuitry does for the 4 line noise reduction so when the 4 lines are added on playback the original 4 lines are produced. In this case the combed motion artifacts are negatively added so upon reception the field comb will cancel them out while also providing high resolution full Luma/Chroma separation in motion areas.

Vertical sync pulse will be similar to an NTSC 2:1 interlace that has a hammer head in the middle of the screen and 2× the number of equalization or VSync pulses per horizontal period. For a 3:1 interlace the number of equalization or VSync pulses per period will be 3× and produce two hammer heads offset from the center to each side on the screen.

To the right is the vector scope representation of **C**hroma **R**otary **P**hase as it rotates through the 4 phases. Unlike PAL in which the pattern mirrors across the **U** axis, in CRP it mirrors across the **I** & **Q** axes. During detection by shifting the PLL Chroma BFO Phase by 90° per horizontal line converts the vector scope image to a PAL scope image, shown in **RED**, that has been **V** switched with the colorburst vector sitting at 135°.



Expanded 5 Color Gamut



Given that both **Red** and **Green** channels can handle negative values, —0.5 and —0¼ respectively, within the composite signal this allows the transmission of increased saturation levels for both **Cyan** and **Magenta** to support a type of **xvYCC** encoding. The approximate values for the colors are **Red** 620nm (0.691, 0.308), **Green** 539nm (0.220, 0.750), **Cyan** 492nm (0.100, 0.341), **Blue** 467nm (0.140, 0.058) and **Magenta** —539nm (0.359, 0.111).

Cable Band Plan ─ 4MHz Channel Spacing

Including Broadcast & Amateur Radio Overlapping Spectrum

Cable must carry Broadcast & Ham Channels.

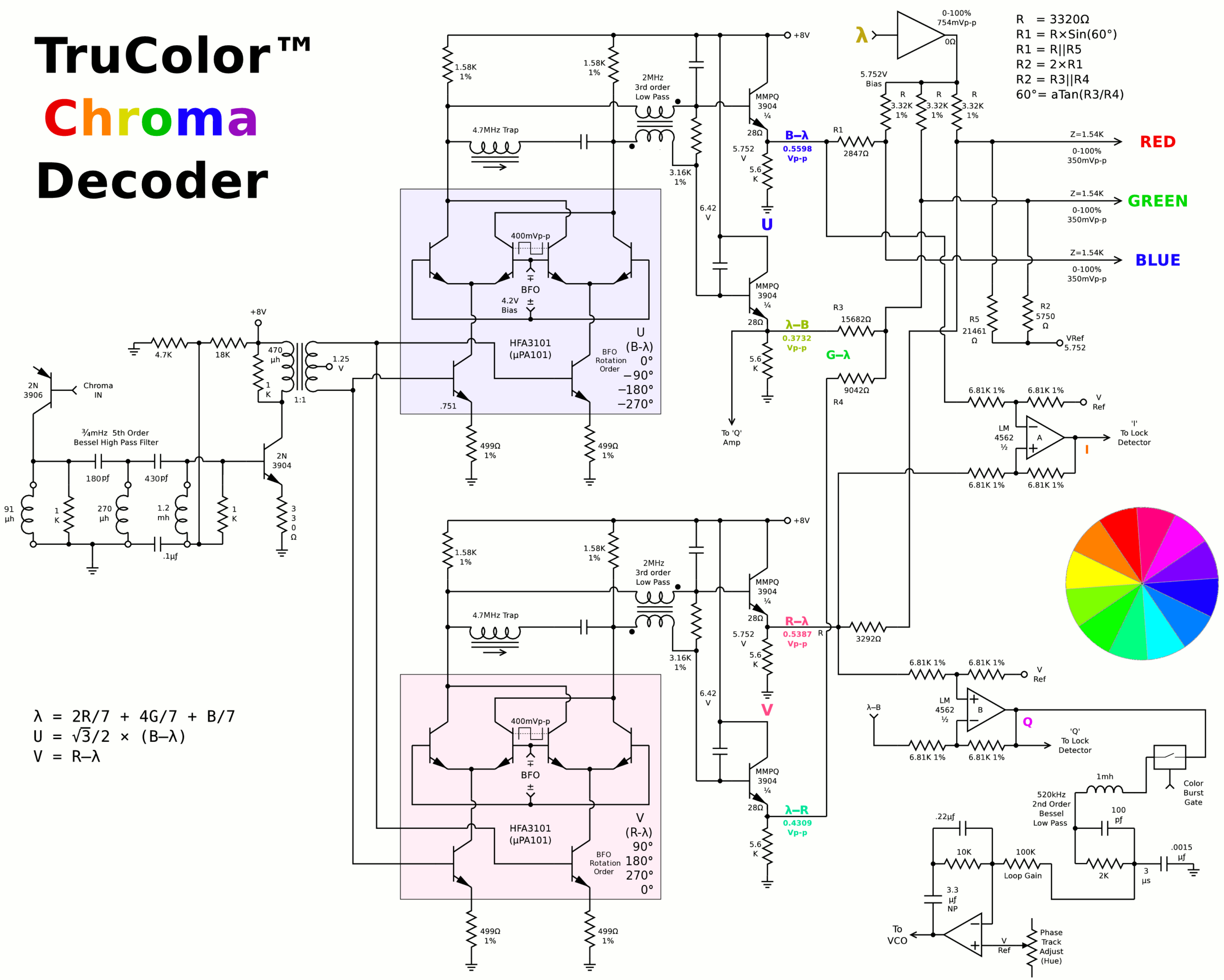
Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable	Broad Cast	Ham
				─────	Channels	─────
Composite Line Input				00		
112	112½	114.85188	116	01		
116	116½	118.85188	120	02		
120	120½	122.85188	124	03		
124	124½	126.85188	128	04		
128	128½	130.85188	132	05		
132	132½	134.85188	136	06		
136	136½	138.85188	140	07		
140	140½	142.85188	144	08		
144	144½	146.85188	148	09		2M 0
148	148½	150.85188	152	0A		
152	152½	154.85188	156	0B		
156	156½	158.85188	160	0C		
160	160½	162.85188	164	0D		
164	164½	166.85188	168	0E		
168	168½	170.85188	172	0F		
172	172½	174.85188	176	10		
176	176½	178.85188	**180**	11	1	
180	180½	182.85188	184	12	2	
184	184½	186.85188	188	13	3	
188	188½	190.85188	**192**	14	4	
192	192½	194.85188	196	15	5	
196	196½	198.85188	200	16	6	VHF2
200	200½	202.85188	**204**	17	7	
204	204½	206.85188	208	18	8	
208	208½	210.85188	212	19	9	
212	212½	214.85188	**216**	1A	10	
216	216½	218.85188	220	1B		
220	220½	222.85188	224	1C		
224	224½	226.85188	228	1D		
228	228½	230.85188	232	1E		
232	232½	234.85188	236	1F		
236	236½	238.85188	240	20		
240	240½	242.85188	244	21		
244	244½	246.85188	248	22		
248	248½	250.85188	252	23		
252	252½	254.85188	256	24		
256	256½	258.85188	260	25		
260	260½	262.85188	264	26		
264	264½	266.85188	268	27		
268	268½	270.85188	272	28		
272	272½	274.85188	276	29		
276	276½	278.85188	280	2A		
280	280½	282.85188	284	2B		
284	284½	286.85188	288	2C		
288	288½	290.85188	292	2D		
292	292½	294.85188	296	2E		
296	296½	298.85188	300	2F		
300	300½	302.85188	304	30		
304	304½	306.85188	308	31		
308	308½	310.85188	312	32		
312	312½	314.85188	316	33		
316	316½	318.85188	320	34		
320	320½	322.85188	324	35		
324	324½	326.85188	328	36		
328	328½	330.85188	332	37		
332	332½	334.85188	336	38		
336	336½	338.85188	340	39		
340	340½	342.85188	344	3A		
344	344½	346.85188	348	3B		
348	348½	350.85188	352	3C		
Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable	Broad Cast Channels	Ham

Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable	Broad Cast	Ham
				─────	Channels	─────
620	620½	622.85188	624	80	48	
624	624½	626.85188	628	81	49	
628	628½	630.85188	632	82	50	
632	632½	634.85188	636	83	51	
636	636½	638.85188	640	84	52	
640	640½	642.85188	644	85	53	
644	644½	646.85188	648	86	54	
648	648½	650.85188	652	87	55	
652	652½	654.85188	656	88	56	
656	656½	658.85188	660	89	57	
660	660½	662.85188	664	8A	58	
664	664½	666.85188	668	8B	59	
668	668½	670.85188	672	8C	60	
672	672½	674.85188	676	8D	61	
676	676½	678.85188	680	8E	62	
680	680½	682.85188	684	8F	63	
684	684½	686.85188	688	90	64	
688	688½	690.85188	692	91	65	
692	692½	694.85188	696	92	66	
696	696½	698.85188	700	93	67	
700	700½	702.85188	704	94	68	
704	704½	706.85188	708	95	69	
708	708½	710.85188	712	96	70	
712	712½	714.85188	716	97	71	
716	716½	718.85188	720	98	72	
720	720½	722.85188	724	99	73	
724	724½	726.85188	728	9A	74	
728	728½	730.85188	732	9B	75	
732	732½	734.85188	736	9C	76	UHF
736	736½	738.85188	740	9D	77	Lost
740	740½	742.85188	744	9E	78	to
744	744½	746.85188	748	9F	79	Chan.
748	748½	750.85188	752	A0	80	Repak
752	752½	754.85188	756	A1	81	
756	756½	758.85188	760	A2	82	
760	760½	762.85188	764	A3	83	
764	764½	766.85188	768	A4	84	
768	768½	770.85188	772	A5	85	
772	772½	774.85188	776	A6	86	
776	776½	778.85188	780	A7	87	
780	780½	782.85188	784	A8	88	
784	784½	786.85188	788	A9	89	
788	788½	790.85188	792	AA	90	
792	792½	794.85188	796	AB	91	
796	796½	798.85188	800	AC	92	
800	800½	802.85188	804	AD	93	
804	804½	806.85188	808	AE	94	
808	808½	810.85188	812	AF	95	
812	812½	814.85188	816	B0	96	
816	816½	818.85188	820	B1	97	
820	820½	822.85188	824	B2	98	
824	824½	826.85188	828	B3	99	
828	828½	830.85188	832	B4	100	
832	832½	834.85188	836	B5	101	
836	836½	838.85188	840	B6	102	
840	840½	842.85188	844	B7	103	
844	844½	846.85188	848	B8	104	
848	848½	850.85188	852	B9	105	
852	852½	854.85188	856	BA	106	
856	856½	858.85188	860	BB	107	
860	860½	862.85188	864	BC	108	
Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable	Broad Cast Channels	Ham

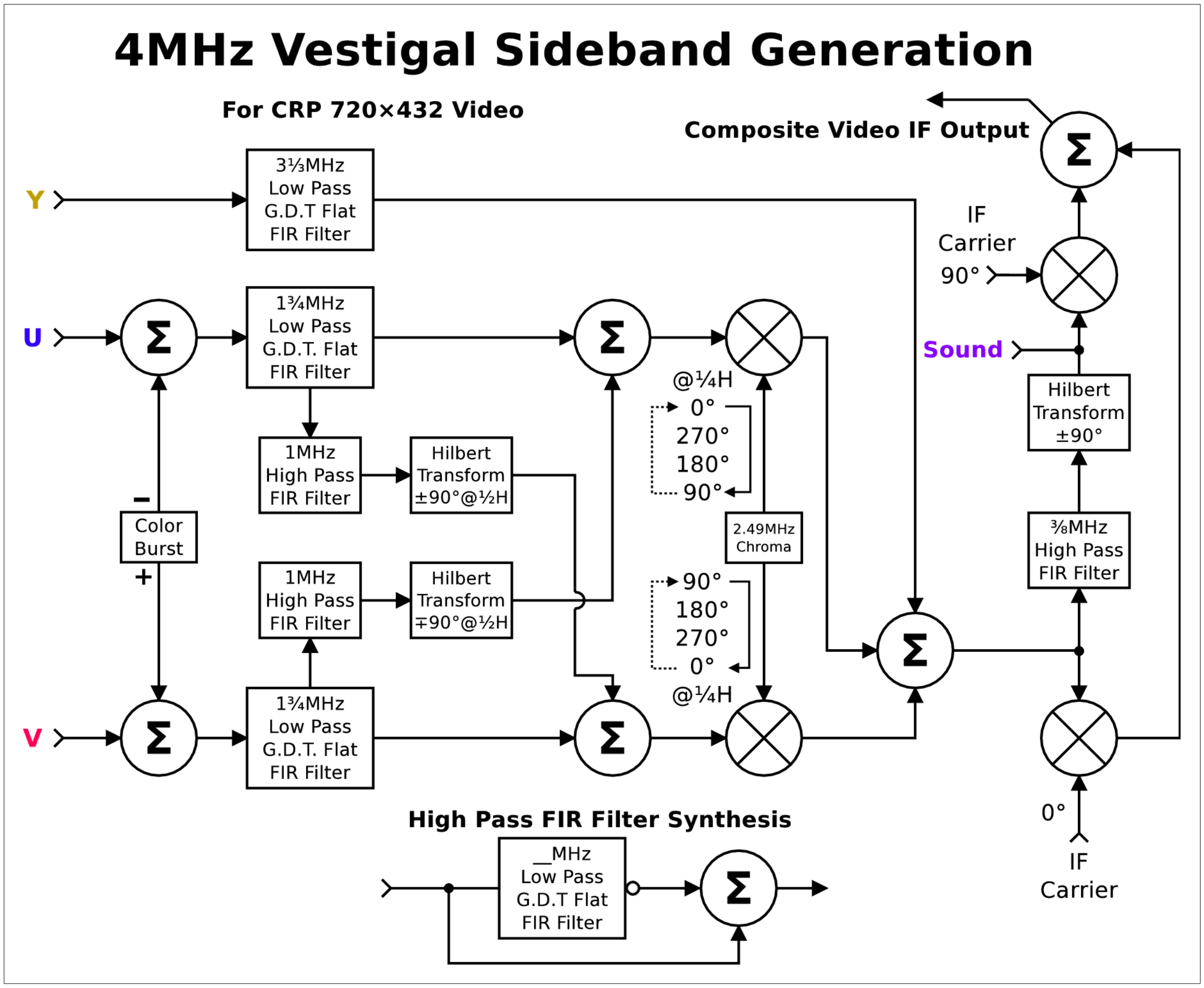
Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable Channels	Broad Cast Channels	Ham Channels
352	352½	354.85188	356	3D		
356	356½	358.85188	360	3E		
360	360½	362.85188	364	3F		
364	364½	366.85188	368	40		
368	368½	370.85188	372	41		
372	372½	374.85188	376	42		
376	376½	378.85188	380	43		
380	380½	382.85188	384	44		
384	384½	386.85188	388	45		
388	388½	390.85188	392	46		
392	392½	394.85188	396	47		
396	396½	398.85188	400	48		
400	400½	402.85188	404	49		
404	404½	406.85188	408	4A		
408	408½	410.85188	412	4B		
412	412½	414.85188	416	4C		
416	416½	418.85188	420	4D		
420	420½	422.85188	424	4E		1
424	424½	426.85188	428	4F		2
428	428½	430.85188	432	50		3
432	432½	434.85188	436	51	70CM	4
436	436½	438.85188	440	52		5
440	440½	442.85188	444	53		6
444	444½	446.85188	448	54		7
448	448½	450.85188	452	55		
452	452½	454.85188	456	56		
456	456½	458.85188	460	57		
460	460½	462.85188	464	58		
464	464½	466.85188	468	59		
468	468½	470.85188	472	5A		
472	472½	474.85188	**476**	5B	11	
476	476½	478.85188	480	5C	12	
480	480½	482.85188	484	5D	13	
484	484½	486.85188	**488**	5E	14	
488	488½	490.85188	492	5F	15	
492	492½	494.85188	496	60	16	
496	496½	498.85188	**500**	61	17	
500	500½	502.85188	504	62	18	
504	504½	506.85188	508	63	19	
508	508½	510.85188	**512**	64	20	
512	512½	514.85188	516	65	21	
516	516½	518.85188	520	66	22	
520	520½	522.85188	**524**	67	23	
524	524½	526.85188	528	68	24	
528	528½	530.85188	532	69	25	
532	532½	534.85188	**536**	6A	26	UHF
536	536½	538.85188	540	6B	27	
540	540½	542.85188	544	6C	28	
544	544½	546.85188	**548**	6D	29	
548	548½	550.85188	552	6E	30	
552	552½	554.85188	556	6F	31	
556	556½	558.85188	**560**	70	32	
560	560½	562.85188	564	71	33	
564	564½	566.85188	568	72	34	
568	568½	570.85188	**572**	73	35	
572	572½	574.85188	576	74	36	
576	576½	578.85188	580	75	37	
580	580½	582.85188	**584**	76	38	
584	584½	586.85188	588	77	39	
588	588½	590.85188	592	78	40	
592	592½	594.85188	**596**	79	41	
596	596½	598.85188	600	7A	42	
600	600½	602.85188	604	7B	43	
604	604½	606.85188	**608**	7C	44	
608	608½	610.85188	**612**	7D	45	
612	612½	614.85188	616	7E	46	
616	616½	618.85188	620	7F	47	
864	864½	866.85188	868	BD	109	
868	868½	870.85188	872	BE	110	
872	872½	874.85188	876	BF	111	
876	876½	878.85188	880	C0	112	
880	880½	882.85188	884	C1	113	
884	884½	886.85188	888	C2	114	
888	888½	890.85188	892	C3		
892	892½	894.85188	896	C4		
896	896½	898.85188	900	C5		
900	900½	902.85188	904	C6		
904	904½	906.85188	908	C7		8
908	908½	910.85188	912	C8		9
912	912½	914.85188	916	C9		10
916	916½	918.85188	920	CA	33CM	11
920	920½	922.85188	924	CB		12
924	924½	926.85188	928	CC		13
928	928½	930.85188	932	CD		
932	932½	934.85188	936	CE		
936	936½	938.85188	940	CF		
940	940½	942.85188	944	D0		
944	944½	946.85188	948	D1		
948	948½	950.85188	952	D2		
952	952½	954.85188	956	D3		
956	956½	958.85188	960	D4		
960	960½	962.85188	964	D5		
964	964½	966.85188	968	D6		
968	968½	970.85188	972	D7		
972	972½	974.85188	976	D8		
976	976½	978.85188	980	D9		
980	980½	982.85188	984	DA		
984	984½	986.85188	988	DB		
988	988½	990.85188	992	DC		
992	992½	994.85188	996	DD		
996	996½	998.85188	1000	DE		
1000	1000½	1002.85188	1004	DF		
1004	1004½	1006.85188	1008	E0		
1008	1008½	1010.85188	1012	E1		
1012	1012½	1014.85188	1016	E2		
1016	1016½	1018.85188	1020	E3		
1020	1020½	1022.85188	1024	E4		
1024	1024½	1026.85188	1028	E5		
1028	1028½	1030.85188	1032	E6		
1032	1032½	1034.85188	1036	E7		
1036	1036½	1038.85188	1040	E8		
1040	1040½	1042.85188	1044	E9		
1044	1044½	1046.85188	1048	EA		
1048	1048½	1050.85188	1052	EB		
1052	1052½	1054.85188	1056	EC		
1056	1056½	1058.85188	1060	ED		
1060	1060½	1062.85188	1064	EE		
1064	1064½	1066.85188	1068	EF		
1068	1068½	1070.85188	1072	F0		
1072	1072½	1074.85188	1076	F1		
1076	1076½	1078.85188	1080	F2		
1080	1080½	1082.85188	1084	F3		
1084	1084½	1086.85188	1088	F4		
1088	1088½	1090.85188	1092	F5		
1092	1092½	1094.85188	1096	F6		
1096	1096½	1098.85188	1100	F7		
1100	1100½	1102.85188	1104	F8		
1104	1104½	1106.85188	1108	F9		
1108	1108½	1110.85188	1112	FA		
1112	1112½	1114.85188	1116	FB		
1116	1116½	1118.85188	1120	FC		
1120	1120½	1122.85188	1124	FD		
1124	1124½	1126.85188	1128	FE		
1128	1128½	1130.85188	1132	FF		

Lower MHz | Carrier MHz | Chroma MHz | Upper MHz | Cable | Broad Cast | Ham Channels

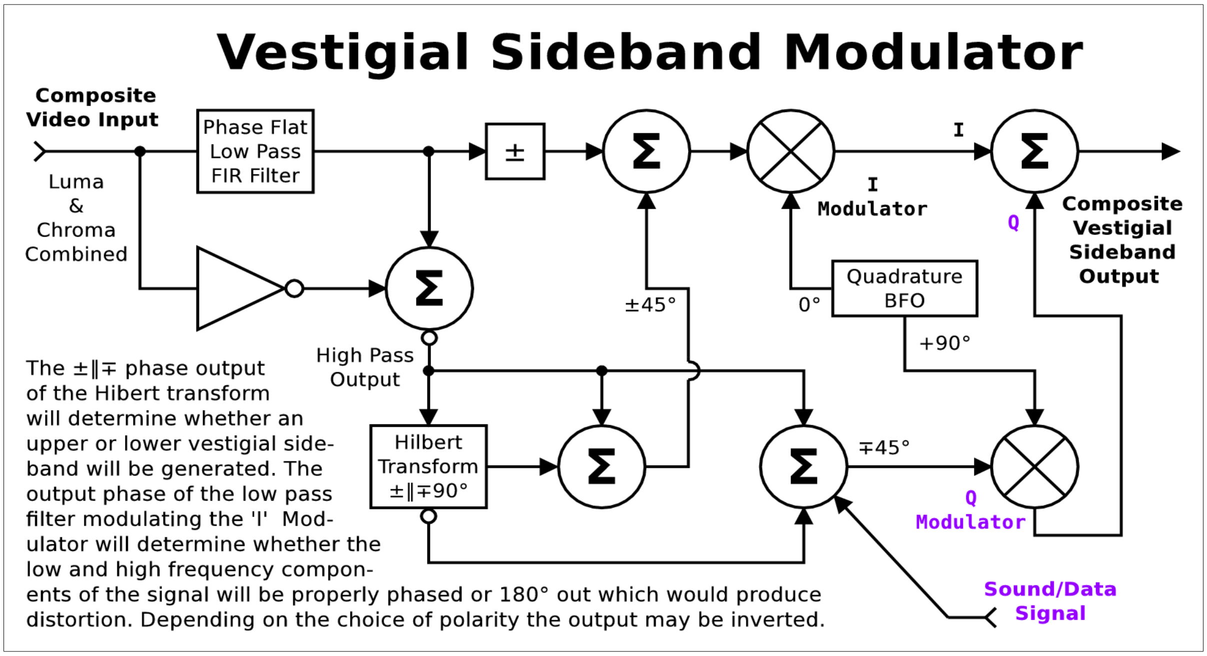
TruColor™ Chroma Decoder



$$\lambda = 2R/7 + 4G/7 + B/7$$
$$U = \sqrt{3}/2 \times (B-\lambda)$$
$$V = R-\lambda$$



Alternative ±45° VSB Offset



The ±‖∓ phase output of the Hibert transform will determine whether an upper or lower vestigial sideband will be generated. The output phase of the low pass filter modulating the 'I' Modulator will determine whether the low and high frequency components of the signal will be properly phased or 180° out which would produce distortion. Depending on the choice of polarity the output may be inverted.

Advanced reading:

1. NTSC and Beyond – Yves Faroudja – IEEE Transactions on Consumer Electronics, Vol.34#1 2/88
2. The Engineer's Guide to Decoding & Encoding – John Watkinson – Snell & Wilcox Handbook Series
3. A Handbook for the Digital Engineer – Keith Jack – Newnes Elsevier
4. Improved Television Systems: NTSC & Beyond – William F. Schreiber
5. Design of FIR Filters – Elena Punskaya