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Hardware (w/ || w/o software): Tucson Arizona Packet Radio TAPR PDF ODT TXT

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Summary of Claims

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 <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** a 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)

Matrixing

Let:

```
R = Red     \
G = Green    Each range from 0 to 1.
B = Blue    /

λ = Matrixed B & W    Luma sub-channel.
U = Matrixed Blue   Chroma sub-channel.
V = Matrixed Red    Chroma sub-channel.
W = Matrixed Green  Chroma sub-channel.
```

Enhanced channels:

```
I = Matrixed Skin   Chroma sub-channel (Hi-Res).
Q = Matrixed Purple Chroma sub-channel (Lo-Res).
```

We have:

$$\lambda = +1/7 \times B \quad +2/7 \times R \quad +4/7 \times G$$
$$B - \lambda = +6/7 \times B \quad -2/7 \times R \quad -4/7 \times G$$
$$R - \lambda = -1/7 \times B \quad +5/7 \times R \quad -4/7 \times G$$
$$G - \lambda = -1/7 \times B \quad -2/7 \times R \quad +3/7 \times G$$
$$G - \lambda = -\tfrac{1}{4} \times (B - \lambda) -\tfrac{1}{2} \times (R - \lambda)$$

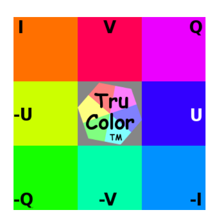
Encode:

```
If:   U(x) = √3/2 × ( B − λ ) ×   0° ┐ Quadrature  _|_
      V(y) =        ( R − λ ) ×  90° ┘ Sub-Carrier  |
Then: W    = √3   × ( G − λ ) @ 240°
```

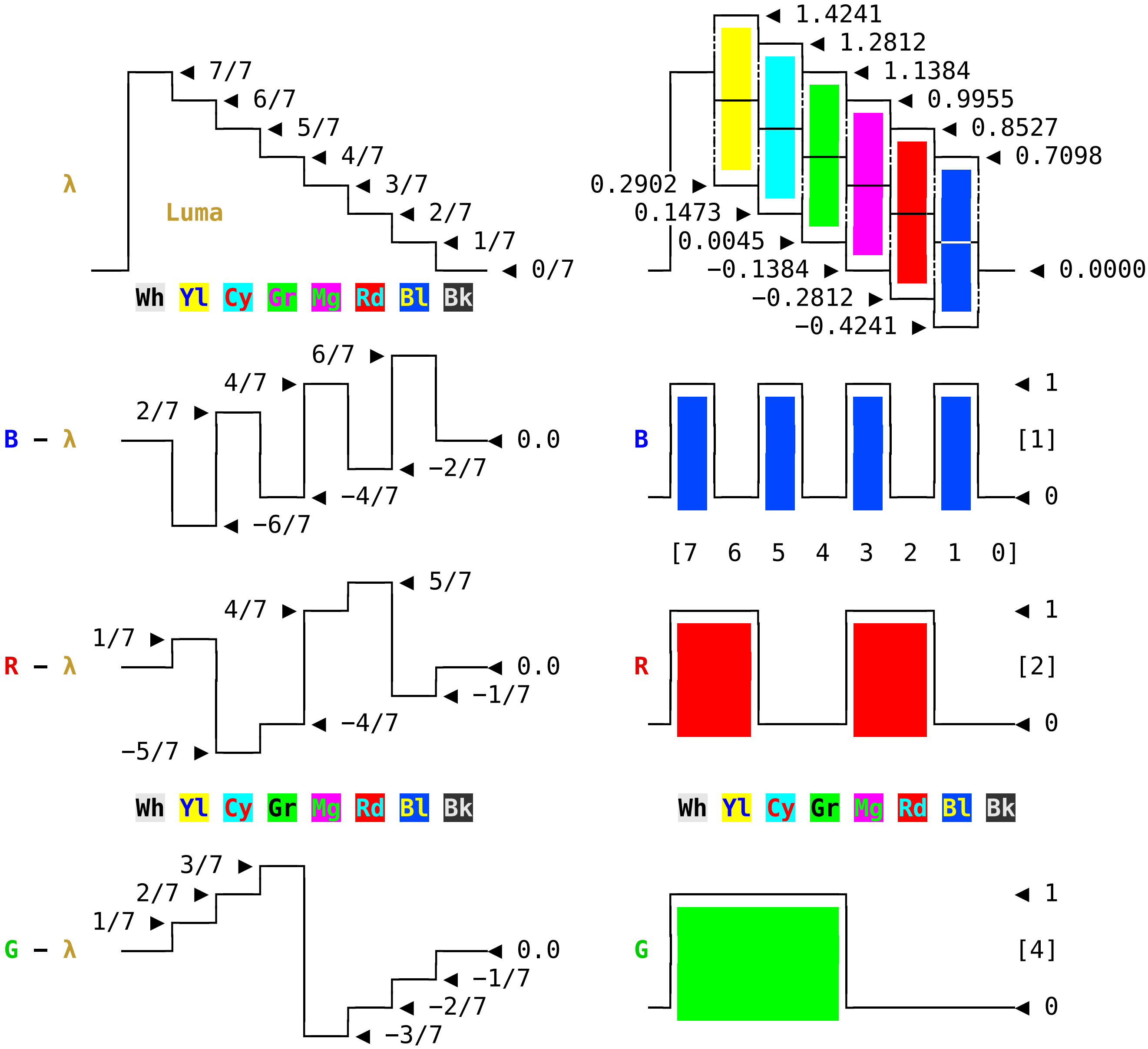
```
Chroma Vector   R = √ U² + V²
Chroma Hue      θ = [ aTan2(V,U) ; If θ < 0 Then θ + 2π ]
```

Decode:

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



100% Color Bars



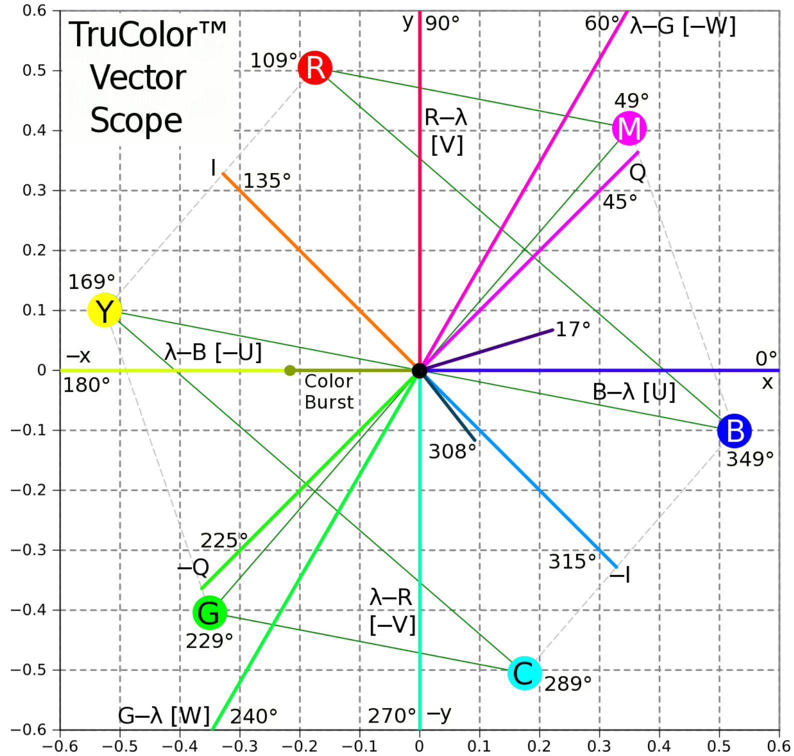
Color Bar	Luma Level	Rectangular Chroma U×√3/2	Levels V	Polar Chroma Hue θ	Chroma Peak Level
White	100.00%	N/A	N/A	N/A	N/A
Yellow	85.71%	−3×√3/7	+1/7	169.11°	2/√7
Cyan	71.43%	+1×√3/7	-5/7	289.11°	2/√7
Green	57.14%	−2×√3/7	-4/7	229.11°	2/√7
Magenta	42.86%	+2×√3/7	+4/7	49.11°	2/√7
Red	28.57%	−1×√3/7	+5/7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

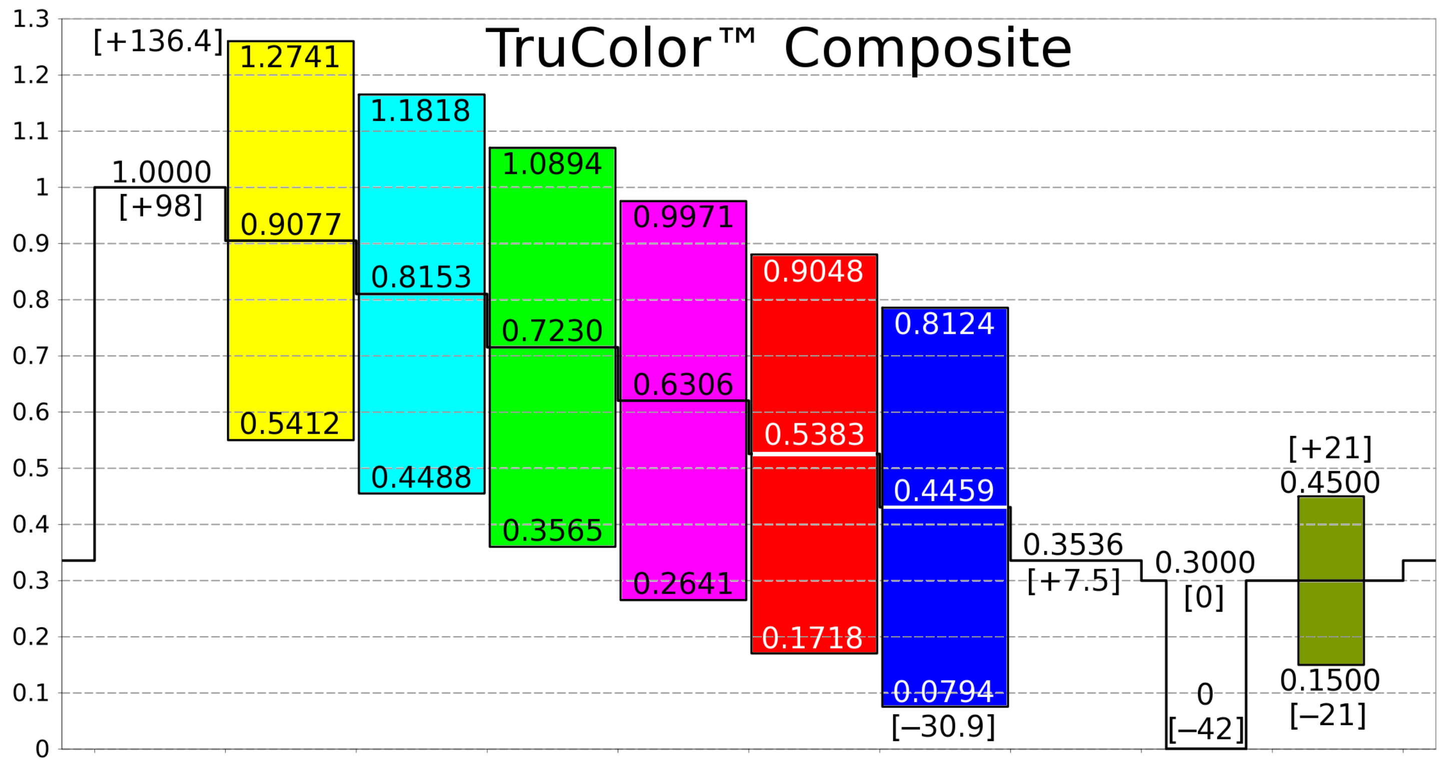
The composite Chroma × ¾ scaling for all colors with full saturation produces a level of **0.5669**pk or **1.134**p-p when modulated. When combined with Luma the Luma + Chroma peak for Yellow is at **142⅖%**, and **Blue** is at **-42⅖%**, slightly more foot room than PAL for **Blue** when composite scaling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

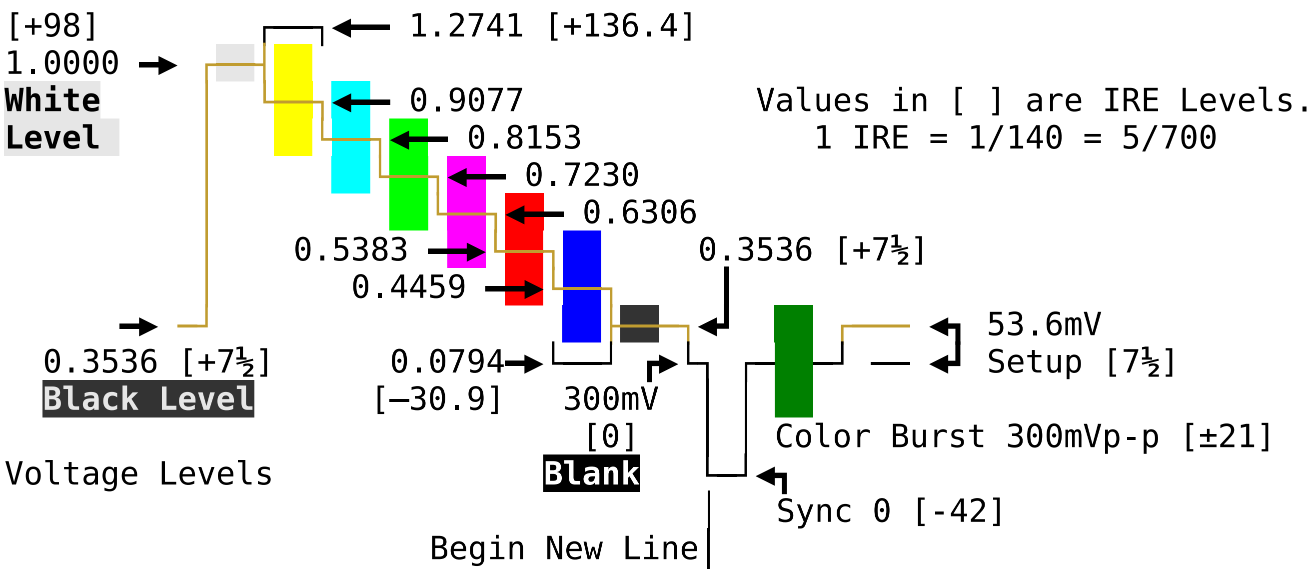
Flesh	(I)	135°	(V − U) ÷ √2
Purple	(Q)	45°	(U + V) ÷ √2





Graphically signal levels in the 2 images above are scaled for Chroma @$\sqrt{2}/2$ for a Luma of 0 to 1. Composite image is scaled with a Luma of [93] (0.6643) & SetUp of [5]. The newer adjusted level labels in the composite are now for a ¾ Chroma scaling for a 0 to 1 Luma of [90½] (0.64643) with a SetUp of [7½]. Sync & Burst levels unchanged.

Analog Scaling



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

Composite = (Luma + Chroma) × 0.64642857 + 0.35357143 (sync + setup [49½]) [90½]

For a 1Vp-p B & W video signal with sync 0.6464 composite scaling is used with a Chroma level of 733mVp-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 $0 \le \lambda \le 1$
12-Bit Scaling = λ × 4095 [Power Factor 2^{12} ; 4096:1 Contrast]

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

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

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 $\sqrt{3}/2$, 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.

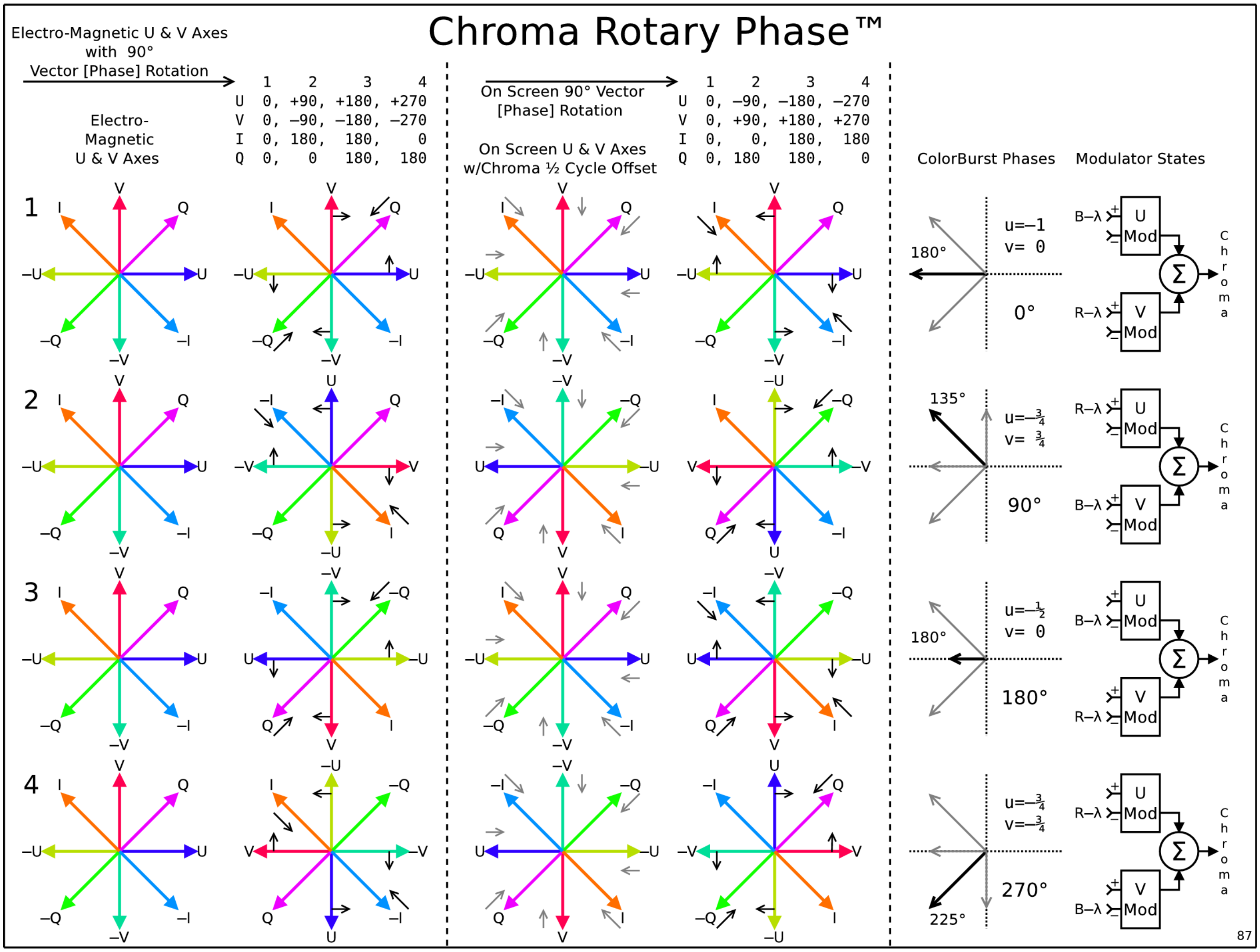
The 'Σ' (Sigma) symbol denotes that this HSλ color space uses a sum/difference method to matrix the **Red**, **Green**, and **Blue** signals into the **Luma** & **Chroma** channels and not a scaling percentage for the **Chroma** saturation.

Chroma Rotary Phase™

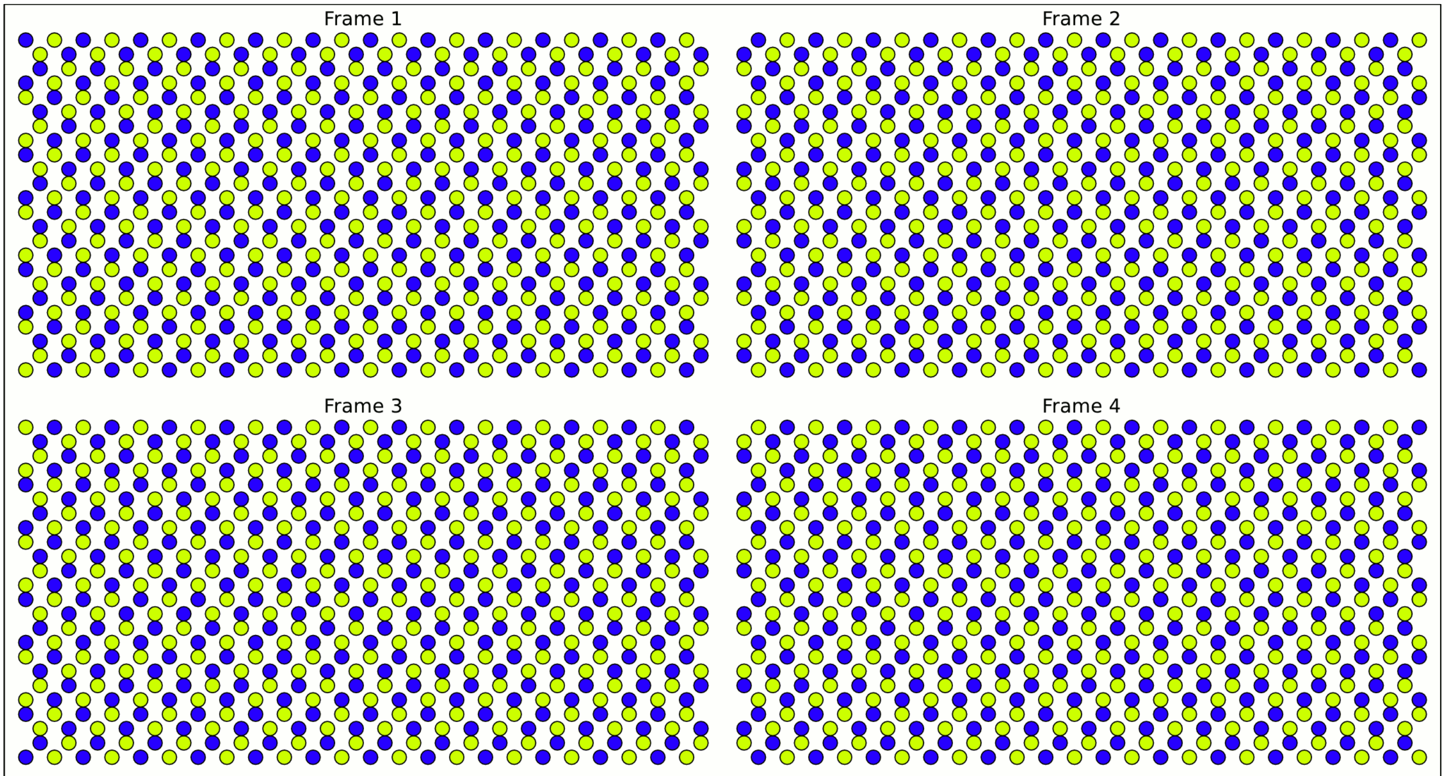
Vector [phase] rotation by **90°** for each horizontal line is a process used in **VHS** video recording for the **Chroma** signal. The lack of signal stability in the tape's higher frequency range is inadequate to record the **Chroma** signal but in the lower frequencies it is minimal but is still present. 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.

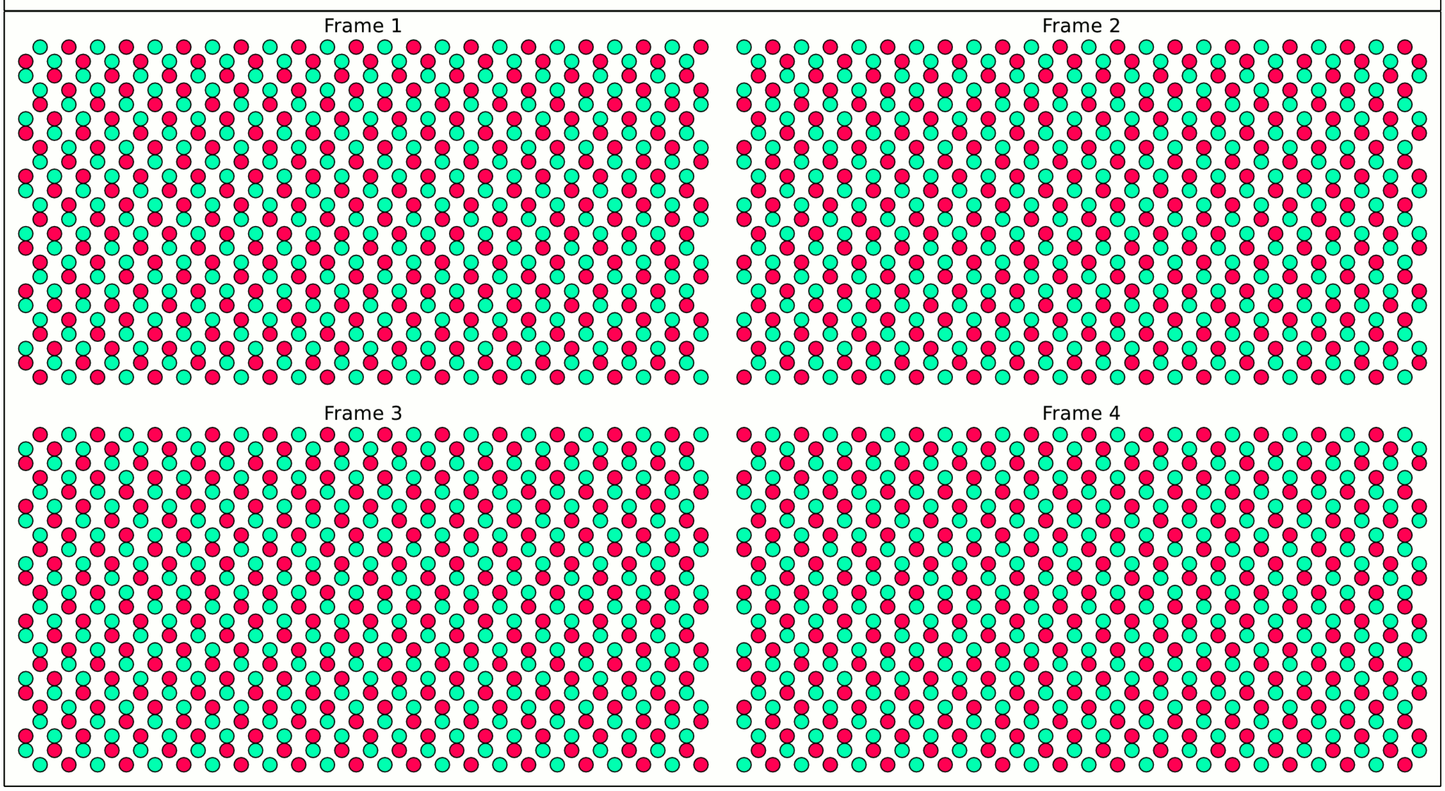
The **Chroma** signal is heterodyned down to 629kHz in a process called color under. During the heterodyning process the mixers use an oscillator with quadrature outputs that rotates the mixer phase by **90°** for each line in opposite directions for each head so the phase will rotate through **360°** 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.

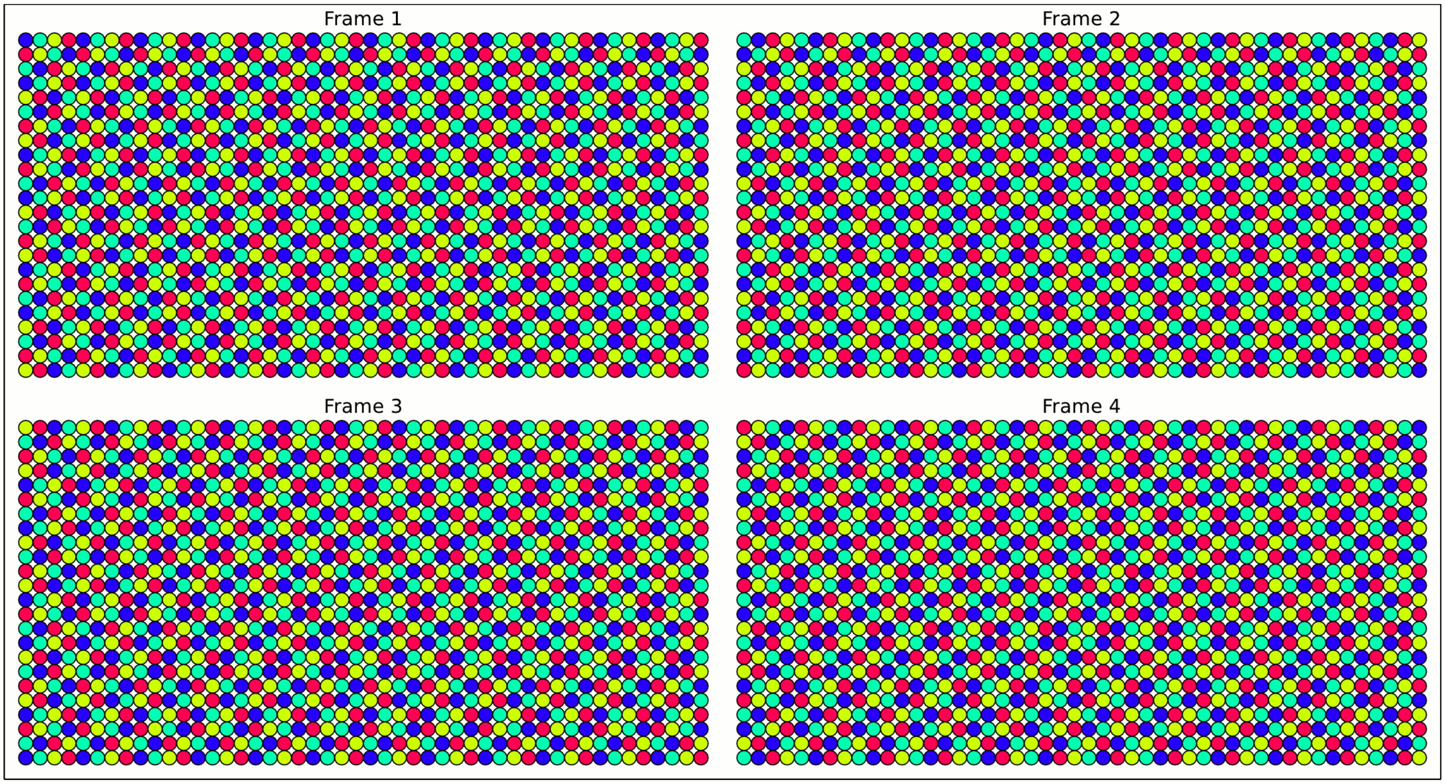


In the image above are 4 video lines labeled **1, 2, 3,** & **4**. The 1st column of vectors are of the **U** & **V** electrical axes. The 2nd column of vectors are of the **U** & **V** electrical axes rotated **90°** per line. The 3rd column of vectors shows the natural phase inversion created by each 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 **U** & **V** modulators and how the modulating signals are applied for each line. Line **1** is normal having the **B–λ** & **R–λ** signals sent to their respective **U** & **V** modulators. In line **2** the signals have swapped modulators and use the **+** inputs. In line **3** the signals are swapped back to their original modulators but use the **–** inputs this time. In line **4** the signals have swapped modulators again but use the **–** inputs instead. The 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.

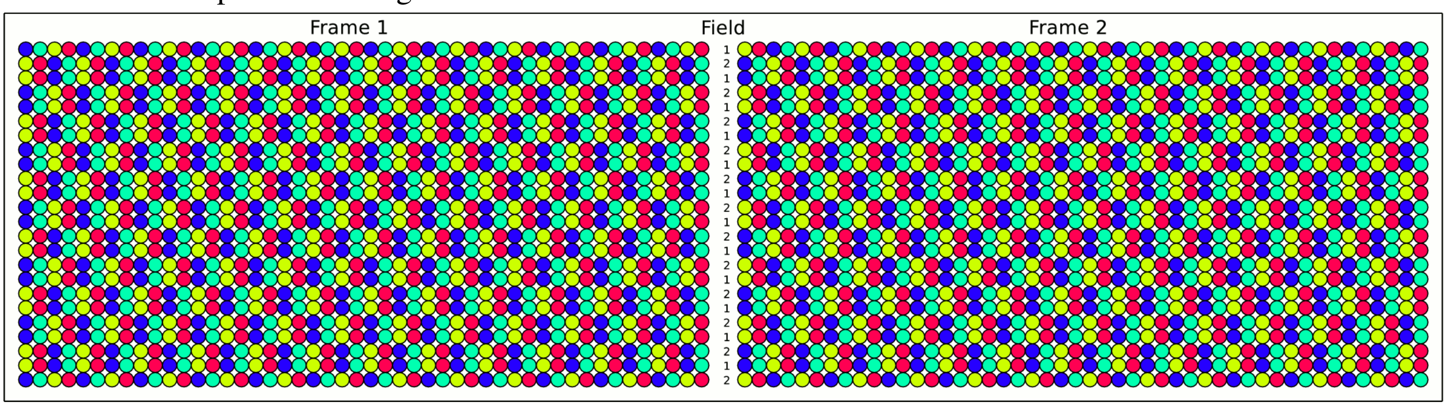




In the images above are the B−λ & R−λ dot patterns separated out into 2 images. These patterns are for an odd number of lines per frame needed for a 2:1 interlace. Since Chroma Rotary Phase™ needs 4 lines to repeat the pattern and the Chroma ends each line with ½ cycle, 4 frames or 8 fields are needed for a 525 line frame for a total of 2100 lines. 525 × 4 = 2100. For a 60Hz field rate the repeat period is 133ms. If the number of lines per frame were even and odd for a field then the repeat rate would be over 2 frames at 67ms as it is in NTSC but this would break the interlace offset created by the odd number of lines per frame. Using an odd number of lines per frame with a 2:1 interlace allows a field to end with ½ of a line causing the lines in each field to sit in between each other on screen. As seen in the image on the next page the pattern is more randomized than it would be for regular NTSC Chroma and this may help compensate for the slower repeat rate of 4 frames instead of 2 or may create other moiré type patterns not seen in regular NTSC Chroma on certain program material if not properly filtered before Chroma generation. Below are the axes as coördinated colored dots as displayed on screen for Chroma Rotary Phase™.

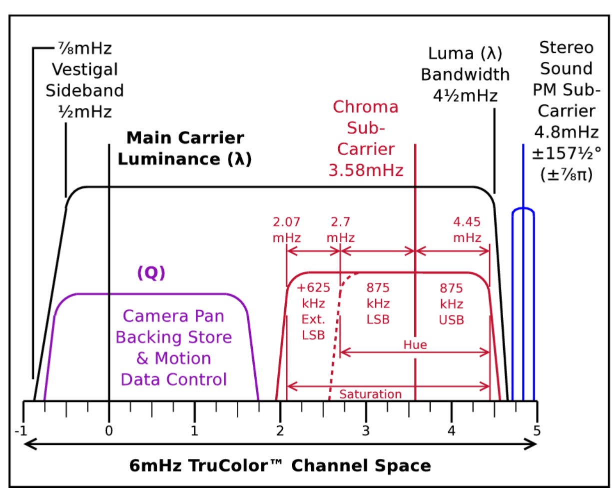


Next are the dot patterns for regular NTSC Chroma.



Wider Screen High Definition WXGA 720i72 / 720p24 CRP™ for a 6mHz Channel Space

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 the horizontal scan a 4:1 pixel interlaced sub-nyquist sampling is used to almost triple the Luma resolution, à la MUSE Hi-Vision. Below is a rough layout of the specification. It takes ⅙ of a second (166ms), 4 full frames (12 fields) to receive the full high definition image. A frame buffer is used to store the 4 frames to assemble a full resolution still picture. For motion the 72 Hz field rate will provide a reduced resolution de-interlaced image with motion blur every $13.\overline{8}$ ms. The sound is on a **4.8** mHz sub-carrier that can handle **3** separate channels of audio, L+R, L−R, and **SAP** or Surround.



Page 16 contains a 1280×720 Test Pattern.

Tru Color Chroma Rotary Phase™

General:

Aspect Ratio	74:45 = 1.6$\overline{4}$
Total Picture Pixels (Digital)	1184×720 ; 852480 Pixels
Kell Factor (Analog Resolution)	837×509 ; 426240 Pixels
Sub-Nyquist(x) & Interlace(y)	296×240 (4:1 & 3:1)

Vertical: [24.0375, +0.1563%]

Frames Per Second	24 Hz [24.0111, +0.0462%]
Total Lines Per Frame	790 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz [72.0333] [72.1125]
Total Lines Per Field	263⅓
Picture Lines	240
Lines Per Blank	23⅓
Blank	1.23 ms
Sync	211 µs ; 4 Lines

Horizontal: Resolution Good:300 Max@-8dB:370

Freq, Period (H_P), Clock Pixel/Line	18.96 kHz, 52.743 µs, [18.968759] [18.989629]
Picture BW Pixels	311≈1⅗×λ_{BW}×(H_P−H_B) ; (296+15)≈4⅚% OverScan
Total Picture Clock ; Period	311 ; 43.51 µs
Blank (H_B)	66 ; 9.233 µs
Front Porch	7 ; 0.979 µs
Sync	25 ; 3.498 µs
Back Porch	34 ; 4.757 µs

Luma & Chroma:

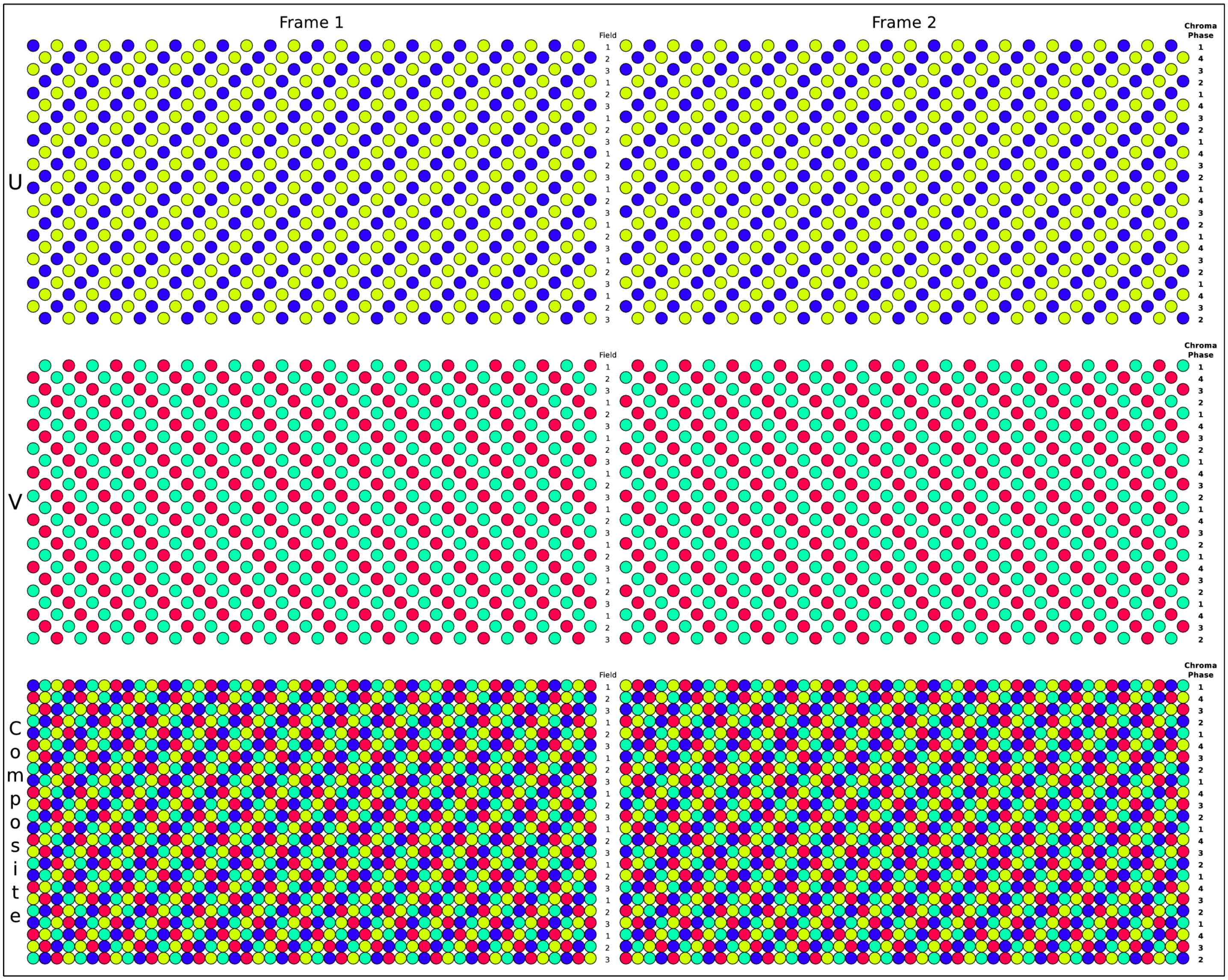
Luma (λ) Bandwidth @-3dB	4½ mHz ; Vestigial ⅞mHz, Corner ½mHz
Chroma:	Sub-Sampling 6⅓:1:½
Sub-Carrier	3.57396 mHz [3.575611 PAL-M]
½H Odd Harmonic	377 (188½) [3.579545 NTSC]
Saturation Bandwidth	2 mHz (USB +⅞mHz & LSB −2mHz)
Hue Bandwidth	⅞ mHz (USB +⅞mHz & LSB −⅞mHz)
Color Burst Duration	2.798 µs ; 10 cycles 2×(2¾+10+4¼)=34
Baseband Guard	1¼ mHz

Stereo Sound:

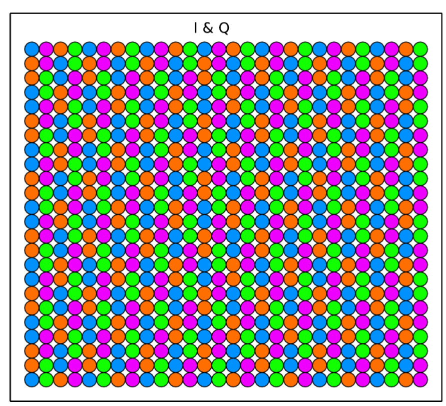
PM SubCarrier ±157½° ±⅞π ±2¾R	4.79688 mHz [4.7990959] [4.804376]
H Harmonic	253
L & R Frequency Response	L+R 50Hz−15kHz, L−R 125Hz−15kHz
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)
L−R Sub-Carrier 2×H	37.92 kHz [37.937517] [37.979257]
Modulation	Unlimited Armstrong PM ±74°, Peak Q:I=3½
	Compander Controlled 'I' Channel

Using a 3:1 interlace with a ⅓ 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 Chroma Rotary Phase™ 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 B−λ & R−λ 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 ⅓ line where the number of lines per frame divided by 3 would produce the number of lines per field ending with ⅓ line. On screen field 2 would start ⅓ line later than field 1 and field 3 would start ⅓ 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 4 instead of line 1 within a frame shifting all the lines in field 1 up by 1 on screen. This will allow the use of the most optimal lines to start the fields within the 4 line

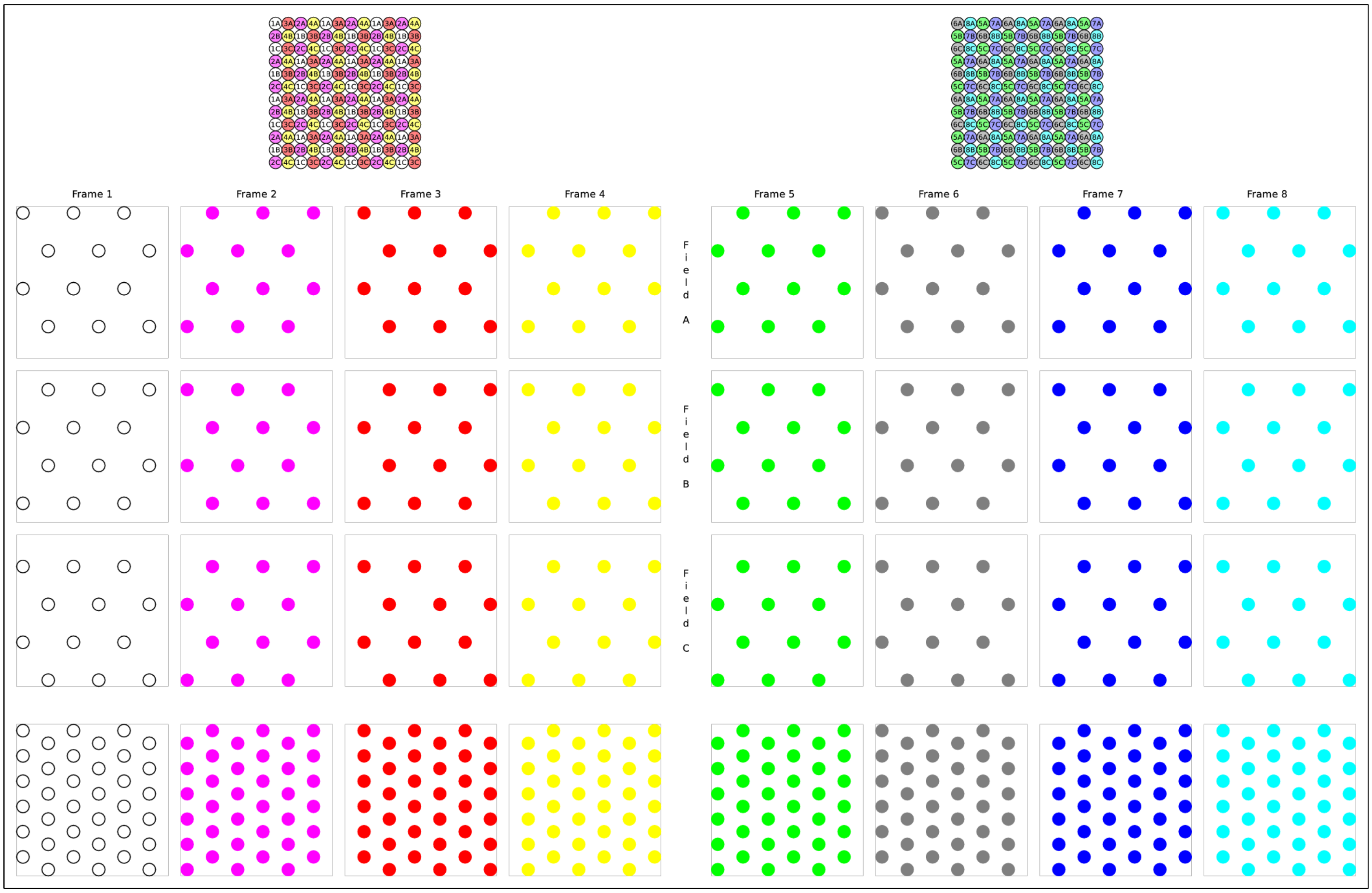
Chroma Rotary Phase™ repeat pattern. The 1st line in the odd frames on screen will start the 4 line Chroma rotation pattern at the beginning and every other frame line will have the U & V Chroma axes swapped as it is in every other field line but the 4 line rotation pattern is reversed from the field rotation direction. The even frames will start the Chroma rotation pattern in the middle to produce the 2 frame repeat rate.



Above are the Composite, B−λ & R−λ 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 4-2-3 pattern that makes the Chroma rotation pattern lay down in this way on screen.



Pixel Interlaced Sub-Nyquist Sampling Patterns



Above are the patterns for 24 fields of sub-nyquist samplings. This is just one method of creating an evenly dispersed pattern that provides effective sequential coverage temporally which seems to meet the requirements. There may be a more optimal arrangement that meets the requirements that offers better artifact concealment. The 8 column 3 row images are for the 3:1 interlaced ones and the bottom row are the 3:1 de-interlaced ones. The odd numbered frame dots are colored White (1), Red (3), Green (5), & Blue (7), and the even numbered frame dots with the same pattern are their complimentary colors Magenta (2), Yellow (4), Dark Gray (6), & Cyan (8). While 12 fields are only needed to complete 4 frames for the 4:1 sub-sampling for full resolution, for the next 4 frames each pixel needs to be sent in the other frame. **Chroma** Rotary Phase™ has a 2 frame repeat pattern where the **Chroma** signal on a per pixel basis is inverted 180° between the 2 frames. This allows for the averaging of the brightness fluctuations caused by the **Chroma** signal being superimposed on the Luma signal even at the fine level for the 4 high resolution pixels contained within a low resolution super pixel. For the high resolution pixels that fall on the first 4 even numbered frames within 8 frames will then fall on the next 4 odd numbered frames within 8 frames and vice-versa. When a frame buffer is used to store each frame for static image areas (without motion), having 8 frames stored will allow complete Luma / **Chroma** separation without using adjacent lines with no loss of high definition detail. When motion is present these portions are updated at the field rate, having the other lines in the other fields interpolated from the current field lines with the **Chroma** information also being separated from the Luma portion using several field lines should provide good separation at a lower resolution. Luma / **Chroma** separation will be incomplete but acceptable for motion areas around Luma intensity & **Hue** / Saturation edge changes. This will be mostly unnoticeable to the eye especially if the motion is fast. If the motion is slow or camera pans present motion vectors can be used in some cases to move high definition pixels instead of using the lower resolution field update mode. Once motion has stopped image processing will switch to static mode where the full high resolution area will be assembled in a shorter time than the eye will mostly notice. Several 8 frame groups can also be averaged into current static areas to provide temporal noise reduction. Adding / subtracting an odd and even frame with the same sample points will will separate the Luma & **Chroma** . Adding a frame from the 1st set of 4 frames with a frame from the 2nd set of 4 where the order in the second set is swapped so **Chroma** can be canceled will allow recovery of each Luma sample point, 1 & 6, 2 & 5, 3 & 8, and 4 & 7 in ⅓ of a second or 333⅓ms.

1280×720

Test Pattern

Wide Screen Enhanced Definition WVGA 432i72 / 432p24 CRP™ for a 6mHz Channel Space

For the vertical scan a 3:1 interlace is used at a field rate of 72 Hz to produce the Film standard 24 frames per second. For the horizontal no sub-sampling will be used and the full refresh rate will also be at 24 frames per second, 41⅔ms. Using a 3:1 interlace at 72 Hz with 159⅓ lines allows the use of a lower horizontal scan rate providing increased definition of the Luma channel and wider aspect ratio than the 4:3 definition image. 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 the old **3.57**mHz Chroma sub-carrier frequency will be used. The vestigial sideband has been reduced by ⅜mHz to increase Luma bandwidth to 4½mHz. This moves the sound to **4.8**mHz having **3** separate channels of audio, L+R, L−R, and **SAP** or Surround.

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General:                                                              Good Contrast
      Aspect Ratio                          16:9   = 1.7̅               97×54  ≈ 1.7963
      Total Picture Pixels  (Digital)      768×432 ; 331776 Pixels     776×432 ; 335232
      Kell Factor (Analog Resolution)      543×305 ; 165888 Pixels     549×305 ; 167616

Vertical:                                         [24.0404, +0.168%]
      Frames Per Second                    24 Hz [24.014, +.0583%]
      Total Lines Per Frame                478   (2 Frame CRP™ Dot Repeat)
      Fields Per Second                    72 Hz [72.042] [72.1212]
      Total Lines Per Field                159⅓
      Picture Lines                        144
      Lines Per Blank                      15⅓
      Blank                                1.34 ms
      Sync                                 261.5 µs ; 3 Lines

Horizontal:                               Resolution  Good:549  Max@-8dB:679
      Lines Per Second                    11.472 kHz [11.478687] [11.491316]
      Period (HP)                          87.169 µs (623)
      Picture                              77.934 µs (557)
      Total Picture Pixels                567≈ϕ×λBW×(HP−HB) ; (549+18)≈3⅙% Over Scan
      Viewable Picture Pixels/Line        549 ; 75.46 µs
      Blank (HB)                             9.235 µs (66)
      Front Porch                            0.979 µs ( 7)
      Sync                                   3.498 µs (25)
      Back Porch                             4.757 µs (34)

Luma & Chroma:
      Luma (λ) Bandwidth @-3dB             4½ mHz ; Vestigial ⅞mHz, Corner ½mHz
      Chroma:                              Sub-Sampling: 3:1:⅝
            Sub-Carrier                   3.573528 mHz [3.579545  NTSC]
            ½H Odd Harmonic               623 (311½)    [3.575611 PAL-M]
            Saturation Bandwidth          1½ mHz  (USB +⅞mHz & LSB −1½mHz)
            Hue Bandwidth                  ⅞ mHz  (USB +⅞mHz & LSB − ⅞mHz)
            Color Burst Duration          2.798 µs ; 10 cycles  2×(2¾+10+4¼)=34
            Baseband Guard                2 mHz

Stereo Sound:
      PM SubCarrier ±157½° ±⅞π ±2¾R       4.795296 mHz [4.7980912] [4.80337]
      H Harmonic                          418
      L & R Frequency Response            L+R 50Hz−12.5kHz, L−R 125Hz−12.5kHz
            Equalization                  75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)
            Harmonic Peak Shifting        65µs & 650µs Phase Shift Networks (Optional)
      L−R Sub-Carrier  3×H                34.416 kHz [34.436061] [34.473949]
            Modulation                     Unlimited Armstrong PM ±74°, Peak Q:I=3½
                                          Compander Controlled 'I' Channel
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Wider Screen Enhanced Definition DVD 480i72 / 480p24 CRP™ for a 6mHz Channel Space

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 the horizontal no sub-sampling will be used and the full refresh rate will also be at 24 frames per second, 41⅔ms. Using a 3:1 interlace at 72 Hz with 175⅓ lines allows the use of a lower horizontal scan rate providing increased definition of the Luma channel and somewhat wider aspect ratio than the 4:3 definition image. 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 the old **3.58**mHz Chroma sub-carrier frequency will be used. The vestigial sideband has been reduced by ⅜mHz to increase Luma bandwidth to 4½mHz. This moves the sound to **4.8**mHz having **3** separate channels of audio, **L+R**, **L−R**, and **SAP** or Surround.

General:		Good Contrast
Aspect Ratio	3:2 = 1½	87:60 = 1.45
Total Picture Pixels (Digital)	720×480 ; 345600 Pixels	696×480 ; 328320
Kell Factor (Analog Resolution)	509×340 ; 172800 Pixels	492×340 ; 164160

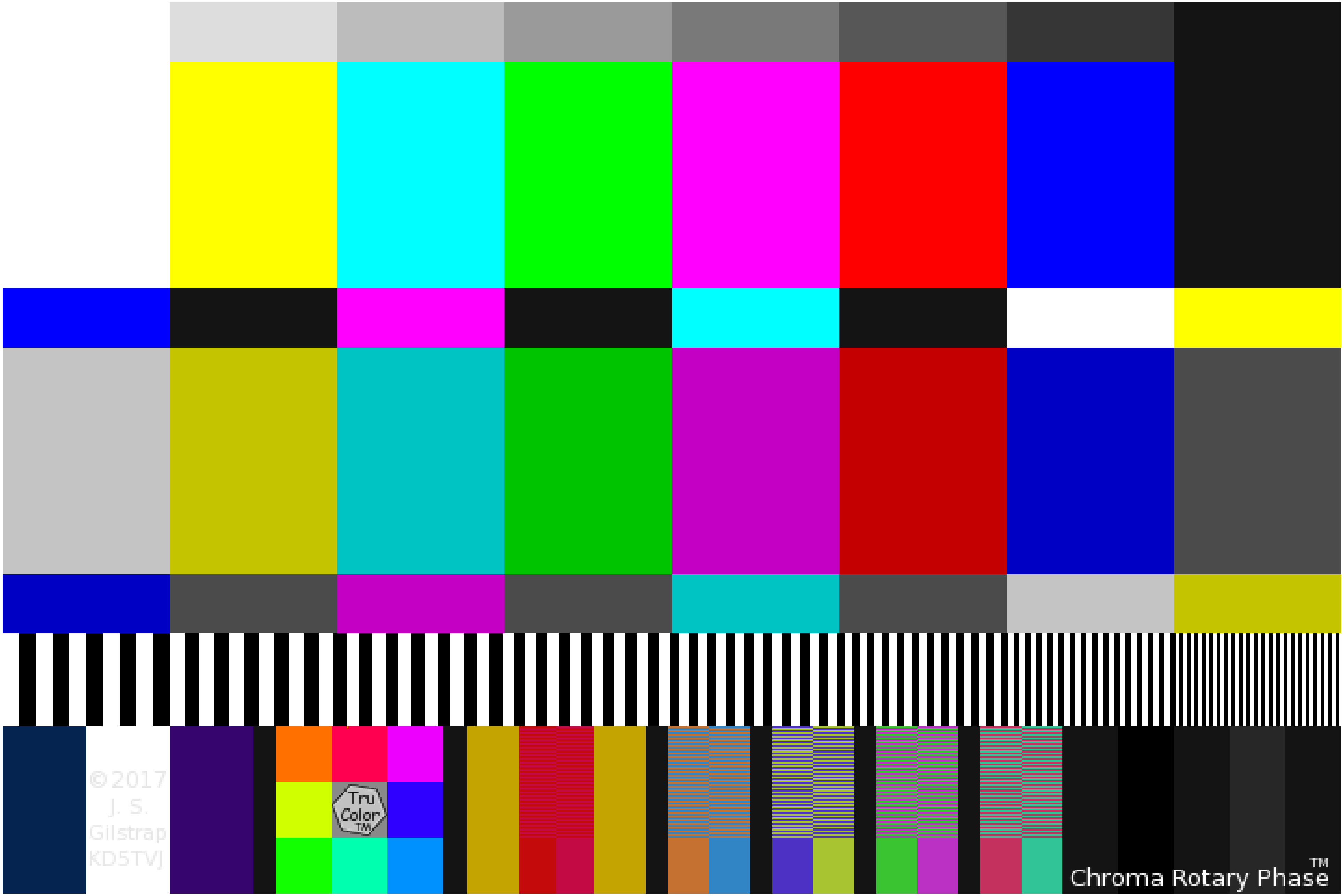
Vertical:	[23.9779, -0.092%]
Frames Per Second	24 Hz [24.0043, +0.018%]
Total Lines Per Frame	526 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz [72.0129] [71.9338]
Total Lines Per Field	175⅓
Picture Lines	160
Lines Per Blank	15⅓
Blank	1.21 ms
Sync	238 µs ; 3 Lines

Horizontal:	Resolution Good:492 Max@−8dB:608
Lines Per Second	12.624 kHz [12.626261] [12.612384]
Period (Hp)	79.214 µs (567)
Picture	69.993 µs (501)
Total Picture Pixels	510≈ϕ×λBW×(Hp−Hb) ; (492+18)≈3½% Over Scan
Viewable Picture Pixels/Line	492 ; 67.523
Blank (Hb)	9.221 µs (66)
Front Porch	0.978 µs (7)
Sync	3.493 µs (25)
Back Porch	4.750 µs (34)

Luma & Chroma:	
Luma (λ) Bandwidth @-3dB	4½ mHz ; Vestigial ⅞mHz, Corner ½mHz
Chroma:	Sub-Sampling: 3:1:⅝
Sub-Carrier	3.578904 mHz [3.579545 NTSC]
½H Odd Harmonic	567 (283½) [3.575611 PAL-M]
Saturation Bandwidth	1½ mHz (USB +⅞mHz & LSB −1½mHz)
Hue Bandwidth	⅞ mHz (USB +⅞mHz & LSB − ⅞mHz) (U:1½ @5⅛)
Color Burst Duration	2.794 µs ; 10 cycles 2×(2¾+10+4¼)=34
Baseband Guard	2 mHz

Stereo Sound:	
PM SubCarrier ±157½° ±⅞π ±2¾R	4.79712 mHz [4.7979792]
H Harmonic	380 [4.7927061]
L & R Frequency Response	L+R 50Hz−15kHz, L−R 125Hz−15kHz
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)
L−R Sub-Carrier 3×H	37.872 kHz [37.837153] [37.878783]
Modulation	Unlimited Armstrong PM ±74°, Peak Q:I=3½ Compander Controlled 'I' Channel

The next page is a 720×480 test pattern.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Tru Color TM
Chroma Rotary Phase TM

Wide Screen High Definition WXGA 672i72 / 672p24 CRP™ for a 6mHz Channel Space

For the vertical scan a 3:1 interlace is used at a field rate of 72 Hz to produce the Film standard 24 frames per second. For the horizontal scan a 4:1 pixel interlaced sub-nyquist sampling is used to almost triple the Luma resolution, à la MUSE Hi-Vision. Below is a rough layout of the specification. It takes $\frac{1}{6}$ of a second (166ms), 4 full frames (12 fields) to receive the full high definition image. A frame buffer is used to store the 4 frames to assemble a full resolution still picture. For motion the 72 Hz field rate will provide a reduced resolution de-interlaced image with motion blur every $13.\overline{8}$ ms. 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 **3.57**mHz Chroma sub-carrier frequency will be used. The vestigial sideband has been reduced by $\frac{3}{8}$mHz to increase Luma bandwidth to $4\frac{1}{2}$mHz. The sound is on a **4.8** mHz sub-carrier that can handle **3** separate channels of audio, **L+R**, **L−R**, and **SAP** or Surround.

General:

Aspect Ratio	53:28 = $1.89\overline{285714}$
Total Picture Pixels (Digital)	1272×672 ; 854784 Pixels
Kell Factor (Analog Resolution)	899×475 ; 427392 Pixels
Sub-Nyquist(x) & Interlace(y)	318×224 (4:1 & 3:1)

Vertical: [24.0608, +0.253%]

Frames Per Second	24 Hz [24.0343, +0.143%]
Total Lines Per Frame	742 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz [72.103] [72.1823]
Total Lines Per Field	$247\frac{1}{3}$
Picture Lines	224
Lines Per Blank	$23\frac{1}{3}$
Blank	1.31 ms
Sync	225 µs ; 4 Lines

Horizontal: Resolution Good:324 Max@−8dB:401

Freq, Period (H_P), Clock Pixel/Line	17.808 kHz, 56.155 µs, 401 [17.833471][17.853092]
Picture BW Pixels	335 ≈ $1\frac{3}{5} \times \lambda_{BW} \times (H_P - H_B)$; (318+17)≈5% OverScan
Total Picture Clock ; Period	335 ; 46.912 µs
Blank (H_B)	66 ; 9.242 µs
Front Porch	7 ; 0.980 µs
Sync	25 ; 3.501 µs
Back Porch	34 ; 4.761 µs

Luma & Chroma:

Luma (λ) Bandwidth @-3dB	$4\frac{1}{2}$ mHz ; Vestigial $\frac{7}{8}$mHz, Corner $\frac{1}{2}$mHz
Chroma:	Sub-Sampling $6\frac{1}{4}$:1:$\frac{1}{2}$
Sub-Carrier	3.570504 mHz [3.575611 PAL-M]
$\frac{1}{2}$H Odd Harmonic	401 ($200\frac{1}{2}$) [3.579545 NTSC]
Saturation Bandwidth	2 mHz (USB +$\frac{7}{8}$mHz & LSB −2mHz)
Hue Bandwidth	$\frac{7}{8}$ mHz (USB +$\frac{7}{8}$mHz & LSB −$\frac{7}{8}$mHz)
Color Burst Duration	2.801 µs ; 10 cycles 2×($2\frac{3}{4}$+10+$4\frac{1}{4}$)=34
Baseband Guard	$1\frac{1}{2}$ mHz

Stereo Sound:

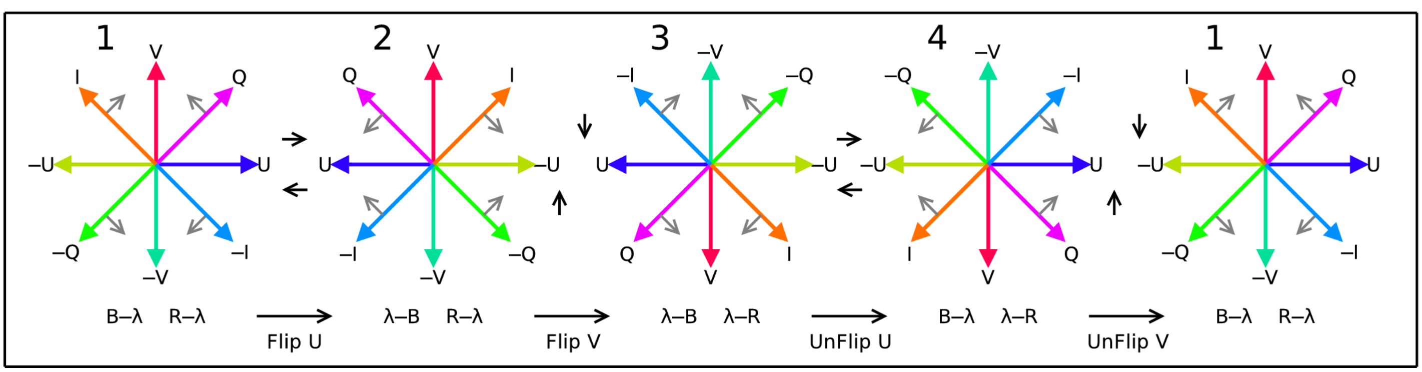
PM SubCarrier ±$157\frac{1}{2}$° ±$\frac{7}{8}$π ±$2\frac{3}{4}$R	4.790352 mHz [4.7972038] [4.8024818]
H Harmonic	269
L & R Frequency Response	**L+R** 50Hz−15kHz, **L−R** 125Hz−15kHz
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz ($12\frac{1}{2}$µs)
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)
L−R Sub-Carrier 2×H	35.616 kHz [35.666943] [35.706185]
Modulation	Unlimited Armstrong PM ±74°, Peak Q:I=$3\frac{1}{2}$
	Compander Controlled 'I' Channel

A Simpler Phase Rotation Method

In referring to the vector chart on page 6 it can be seen that rotating the **U & V** signals by 90° every line causes the **I & Q** signals to flip 180° every other line at half the rate of **U & V** 90° step rotation and the **I & Q** flips are offset by one line to each other. Both **U & V** and **I & Q** signals will rotate a full 360° over 4 lines but **U & V** do it in 4 steps at 90° each whereas **I & Q** do it in 2 steps at 180° each. In a simpler approach to encoding instead of matrixing into **U & V** and rotating both by 90° per line, matrix the **Chroma** into **I & Q** and flip each one every other line. Line A to B flip **I**, line B to C flip **Q**, line C to D unflip **I**, line D to A unflip **Q**. The page 6 chart also shows that subtracting two adjacent lines to eliminate the **Luma** produces **I** or **Q** signals, not **U** or **V**. If high and low bandwidth signals are used for **I & Q** respectively this can be used to an advantage during the encode/decode process.

Originally during NTSC color TV development it was believed that the **I**/**Q** high/low bandwidth scheme was necessary when using a quadrature vestigial sideband signal since both sidebands are needed for full quadrature channel separation. This is true if the two signals are completely independent from each other but the **Chroma** signal characteristics are a polar defined structure of **S**aturation and **Hue** as **R** and **θ** that is represented in the Cartesian coördinate state within the **U & V** signals making them interrelated and in practice full frequency channel separation has not proven to be an issue with a vestigial sideband. Using a vestigial sideband with a quadrature signal in this case can be addressed as the low bandwidth double sideband portion being used for **S**aturation and **Hue** while the higher bandwidth extended lower sideband is used to enhance sharpness for **S**aturation changes. An enhanced version of this could be to take the phase of the lower bandwidth quadrature **Hue** portion of the signal and modulate it to carry the envelope of the full bandwidth quadrature **Chroma** saturation signal supported by the extended lower sideband only much the same way that is used for the vestigial sideband **Luma** signal. Using a differential bandwidth scheme for **I & Q** signals does not provide as great a benefit for the extra complexity required compared to the high/low bandwidth **S**aturation/**Hue** scheme.

With this in mind using a differential bandwidth for **I & Q** signals is not really needed as it once was thought. When the **U & V** signals are the desired output from line combining then swapping **I & Q** for **U & V** respectively in using the 180° flip process will output **U & V** when lines are combined and would be the preferable method. Line A to B flip **U**, line B to C flip **V**, line C to D unflip **U**, line D to A unflip **V**. This also causes the **I & Q** signals to rotate 90° per line in opposite directions not **U & V** as in the previous method. Rotation may also produce some sideband asymmetry and if this is significant it would be desirable to have '**I**' rotate in the direction that would produce stronger lower sideband energy. The chart below shows this alternate method in the electrical domain, but not on screen. On screen **I & Q** will rotate in opposite directions in relation to the electrical domain when the **Chroma** sub-carrier ends each line with ½ cycle.
The previous ColorBrurst signaling phases can be used or a more sophisticated method where the ColorBurst phase is aligned with the '**+I**' vector and would rotate a full 360° through the 4 states of phase rotation. This would also require a

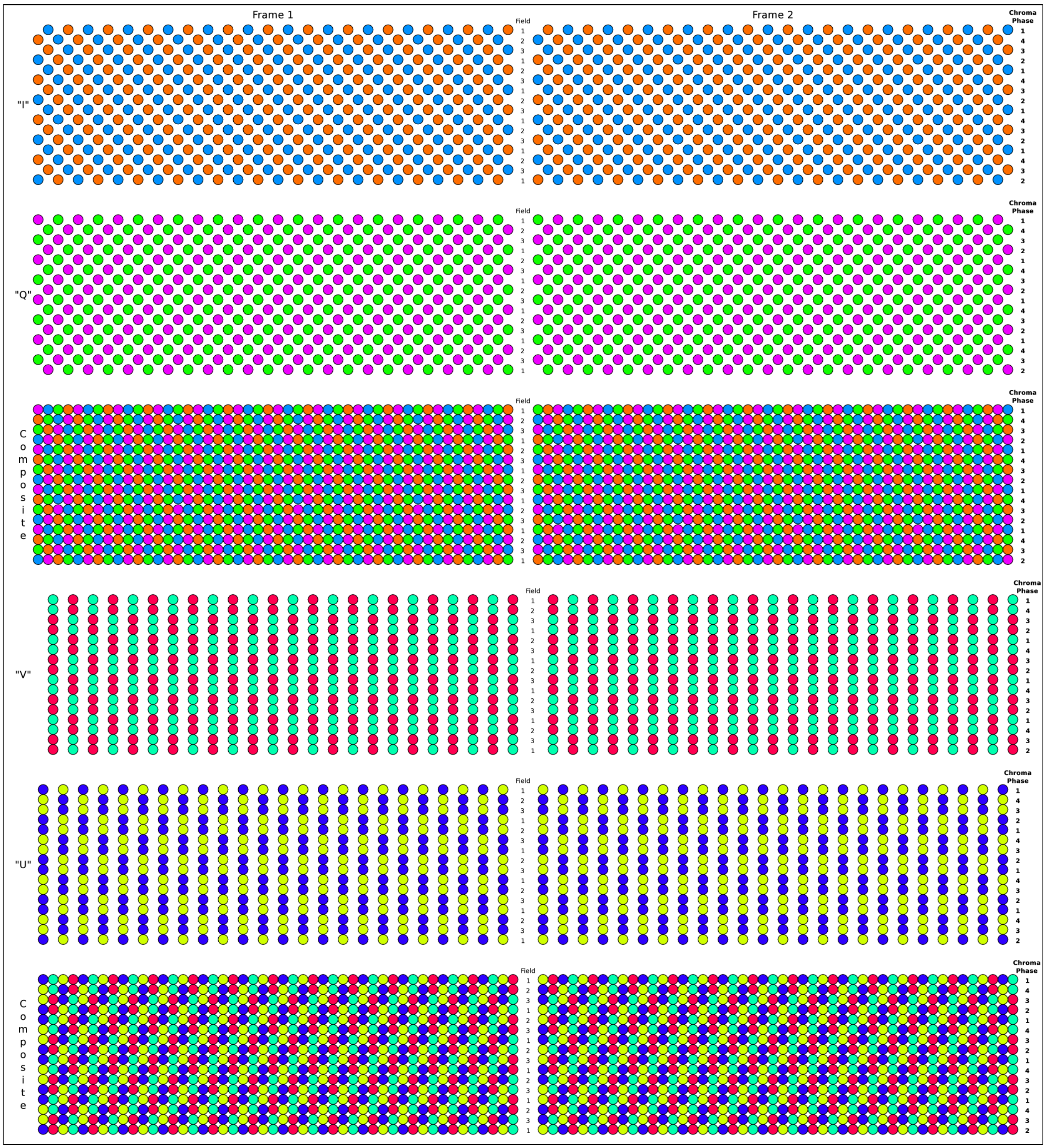


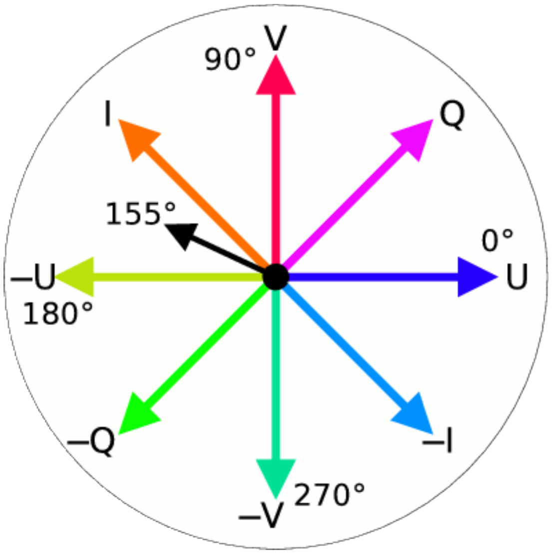
more sophisticated switching PLL loop filter that would compensate for the rotation. A better approach would be a 4 angle ColorBurst signal with easy PLL tracking that would also identify proper switch states for both **U & V** axes, one with separate switching signals from the ColorBurst signal on each of the **U & V** axes, e.g. 1:155°, 2:125°, 3:235°, 4:205°.

The 180° axes flip that produces indirect instead of using direct 90° vector rotation is similar to PAL but both axes are flipped electrically, (PAL 2.0™, PAL²™, PAL 2×™ or DualPAL™ anyone?), producing both electrical and on screen vector rotation while still using the ½ cycle/line offset maintaining a dot pattern similar to NTSC. PAL (Der System Bruch) using $\frac{3}{4}$‖$\frac{1}{4}$ cycle/line offset to shift both axes 90° on screen also incorporated phase creep to fix the broken **Chroma** dot pattern that the $\frac{1}{2}$ cycle/line 180° offset NTSC created. This 90° shift per line on screen of both **U** **&** **V** vectors is in the same direction but switching **V**'s polarity at the H/2 rate reverses its rotational shift in relation to **U** on screen. As a result in relation to the beginning of each line on screen both **U** **&** **V** shift 90° per line in opposite directions which causes **U** **&** **V** to swap axes. Any hue phase errors will be in the opposite direction on alternate lines canceling out any errors.

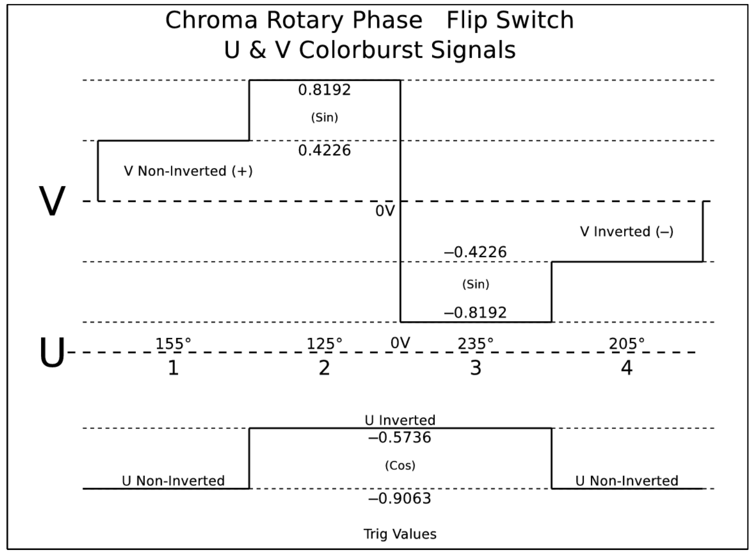
With this alternative method the on screen **Chroma** color dot patterns on page 10 will swap colors between **U** **&** **V** and **I** **&** **Q** positions respectively. In the electrical domain with both rotating clockwise '**I**' will swap with '**V**' and rotating counter-clockwise '**Q**' will swap with '**U**', swapping Orange and Red, CyanBlue and Cyan, Magenta and Blue, Green and Yellow.

I, **Q**, **V**, **U**, & **Composite** flip switch dot patterns.

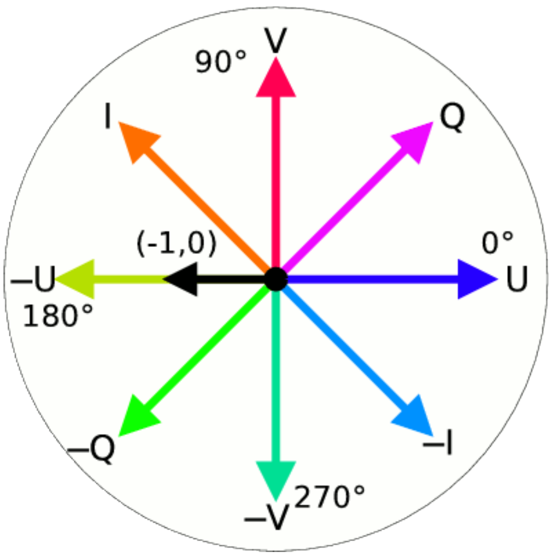




Chroma Rotary Phase
U & V Flip Switch Animation

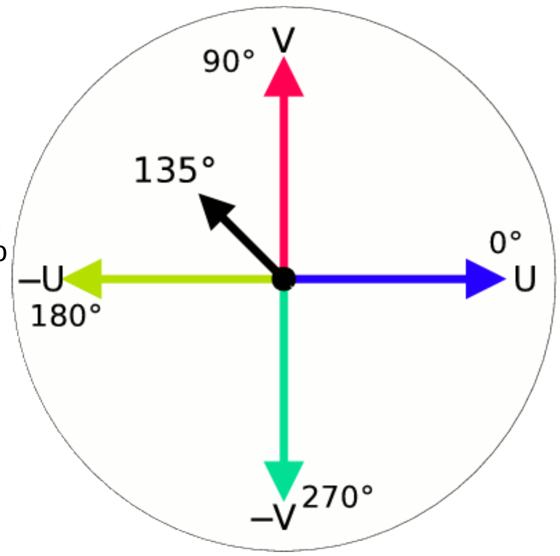


U & V Flip Switch Colorburst signaling.



Chroma Rotary Phase
U & V Vector Rotation Animation

This document being in PDF format does not support animated images. For access to these and other live animations in ODT format please follow this link below.
NATV Animations



PAL On Screen Vector Rotation & Vswitch Animation

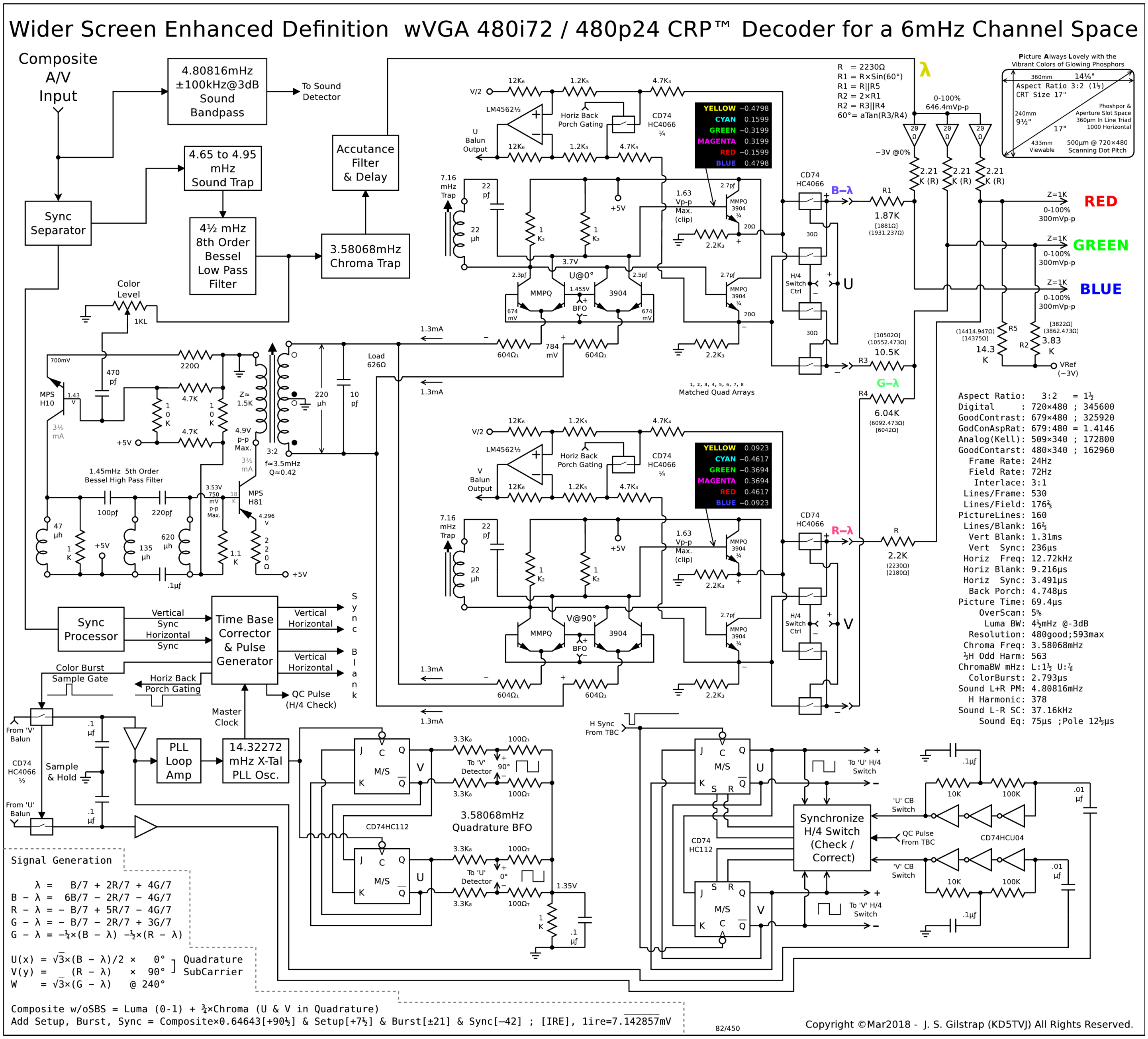
For transmission using a fully suppressed carrier for the composite video, not including sync (zero carrier modulation by Luma at 50% gray or another fixed level that minimizes carrier level on average program material), or a content variable level carrier to maximize carrier suppression on a per frame 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. Carrier Burst tracking will happen during the sync pulses with a 0° phase angle, the same way the ColorBurst does. The 'Q' channel can contain control data for full motion field line interpolation de-interlacing, backing (re)store during(after) motion, static multiple frame storage averaging for noise reduction, various other data, and digital sound.

Studio Quality 4:3 Aspect 480i72 / 480p24 CRP™@3.58mHz NTSC–F72/3 6mHz Channel

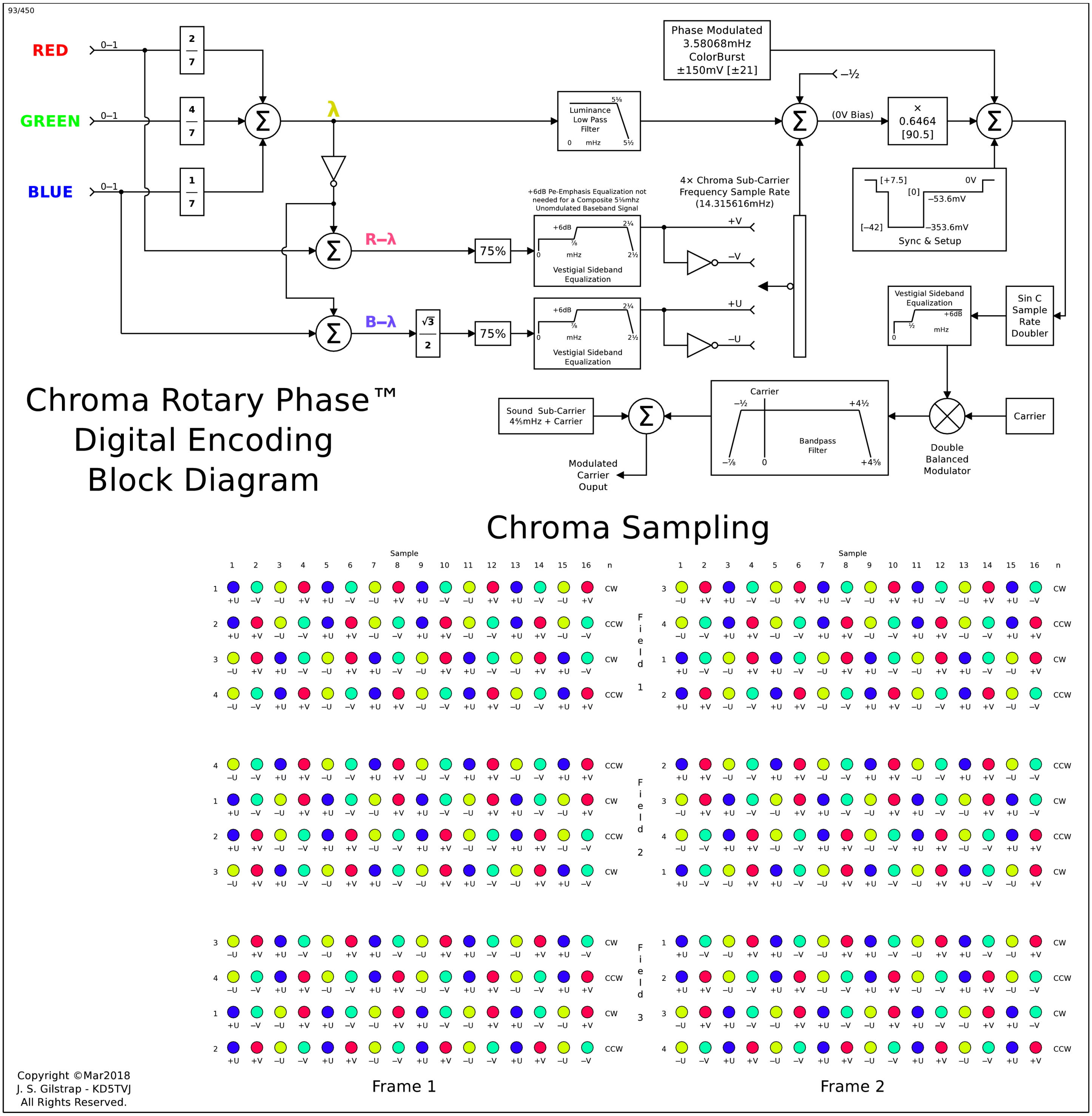
For the vertical scan a 3:1 interlace is used at a field rate of 72 Hz to produce the **F**ilm standard 24 frames per second. For the horizontal no sub-sampling will be used and the full refresh rate will also be at 24 frames per second, 41⅔ms. Using a 3:1 interlace at 72 Hz with 175⅓ lines allows the use of a lower horizontal scan rate providing increased definition of the **Luma** channel and the normal aspect ratio of 4:3 is used. **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 and the **3.58**mHz **Chroma** sub-carrier frequency will be used. The sound is at **4.5**mHz having **3** separate channels of audio, **L+R**, **L–R**, & **S**urround.

General:	
Aspect Ratio	4:3 = 1⅓
Total Picture Pixels (Digital)	640×480 ; 307200 Pixels
Kell Factor (Analog Resolution)	452×340 ; 153600 Pixels
Broadcast	434×340 ; 147362 Pixels
Vertical:	
Frames Per Second	24.0043 Hz, +0.018% (24)
Total Lines Per Frame	526 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72.0129 Hz (72)
Total Lines Per Field	175⅓
Picture Lines	160
Lines Per Blank	15⅓
Blank	1.214 ms
Sync	238 µs ; 3 Lines
Horizontal:	Resolution Good:434 Max@–8dB:536
Lines Per Second	12.626261 kHz (12624)
Period (HP)	79.2 µs
Picture Period	68.305 µs
Total Picture Pixels	464≈ϕ×λBW×(HP–HB) ; (434+30)≈ 6½% OverScan
Total Clock Pixels Per Line	567
Blank (HB)	10.895 µs (78)
Front Porch	1.397 µs (10)
Sync	4.61 µs (33)
Back Porch	4.889 µs (35)
Luma & Chroma:	
Luma (λ) Bandwidth @-3dB	4⅕ mHz ; Vestigial 1¼mHz, Corner ¾mHz
Chroma:	Sub-Sampling 2⅘:1:⅖
Sub-Carrier	3.579545 mHz [NTSC] (3.578904)
½H Odd Harmonic	567 (283½)
I Bandwidth	1½ mHz (USB +⅗mHz & LSB –1½mHz)
Q Bandwidth	⅗ mHz (USB +⅗mHz & LSB – ⅗mHz)
Color Burst Duration	2.794 µs ; 10 cycles 2×(3+10+4½)=35
Baseband Guard	2 mHz
Stereo Sound:	(4.494144)
FM SubCarrier	4.494949 mHz ±25kHz, ±50kHz, ±73kHz
H Harmonic	356 L+R, add L–R, add SAP
L & R Frequency Response	L+R 50Hz–15kHz, L–R 125Hz–15kHz
Equalization	75µs Pre-Emphasis
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)
L–R Sub-Carrier 3×H	37.878784 (37872)
Modulation	Double Sideband Suppressed Carrier AM
Encoding	dbx

While the above specifications are for an NTSC version using 24Fps/72fps, 3:1 interlace, and **Chroma** Rotary Phase™, the schematic below is for a 720×480 resolution (3:2 aspect ratio) and optimized for increased **Luma** bandwidth. It is also specified on page 18 & 32 although chroma and horizontal frequencies vary somewhat from drawing.



2 frame 526 line **Chroma** Rotary Phase™ dot repeat pattern with sync alignment. This is for **U** & **V** axes rotating 90° every line in opposite directions which also causes **I** & **Q** axes to flip 180° every other line but their flips are offset by one line from each other. The schematic above flips **U** & **V** axes 180° alternately every other line thus causing **I** & **Q** axes to rotate 90° on every line.



Sin C or Cubic sample doubling may not provide high enough accuracy to faithfully create the Chroma sub-carrier signal. For better accuracy use the higher sample rate of 28.64mHz which is 8 times the Chroma in 45° steps instead of 4 times at 14.32mHz in 90° steps for a 3.58mHz Chroma sub-carrier frequency. This higher sample rate is required if a Sub-Nyquist sampling scheme is used since 8 Luma samples are generated per Chroma cycle.

X × Y	Diagonal			X × Y	Diagonal		
Cm×Cm	Cm	In		Cm×Cm	Cm	In	
27×18	32½	12⅘	✓13”	45×30	54	21¼	
30×20	36	14⅕		48⅗×32⅖	58⅖	23	✓23”
33×22	39⅔	15⅗		51×34	61⅓	24⅛	
36×24	43¼	17	✓17”	54×36	64⅞	25½	✓25+”
39×26	46⅞	18½		57×38	68½	27	✓27”
42×28	50½	19⅞	✓20”	60×40	72⅛	28⅖	

Chroma Rotary Phase™ 8× Sampling

Frame 1

Field		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	n
Field 1	1	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	CW
	2	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	CCW
	3	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	CW
	4	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	CCW
Field 2	4	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	CCW
	1	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	CW
	2	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	CCW
	3	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	CW
Field 3	3	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	CW
	4	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	CCW
	1	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	CW
	2	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	CCW

Sample (columns 1–16)

Frame 2

Field		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	n
Field 1	3	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	CW
	4	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	CCW
	1	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	CW
	2	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	CCW
Field 2	2	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	CCW
	3	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	CW
	4	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	CCW
	1	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	CW
Field 3	1	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	CW
	2	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	CCW
	3	−U	+I	+V	+Q	+U	−I	−V	−Q	−U	+I	+V	+Q	+U	−I	−V	−Q	CW
	4	−U	−Q	−V	−I	+U	+Q	+V	+I	−U	−Q	−V	−I	+U	+Q	+V	+I	CCW

Sample (columns 1–16)

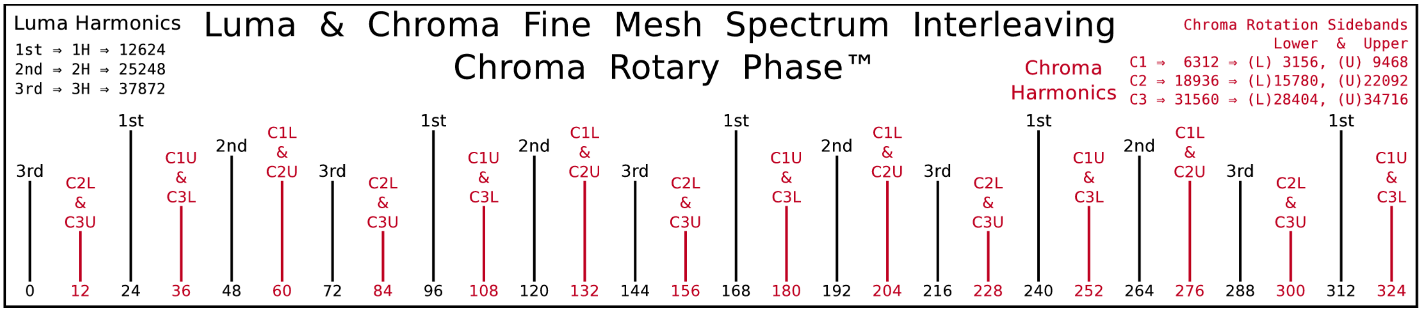
Video Harmonics: Coarse Mesh Cluster & Fine Mesh Interleaving

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 fracturing 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 rapidly enough for every spot on screen making the dot pattern invert more like NTSC. 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.

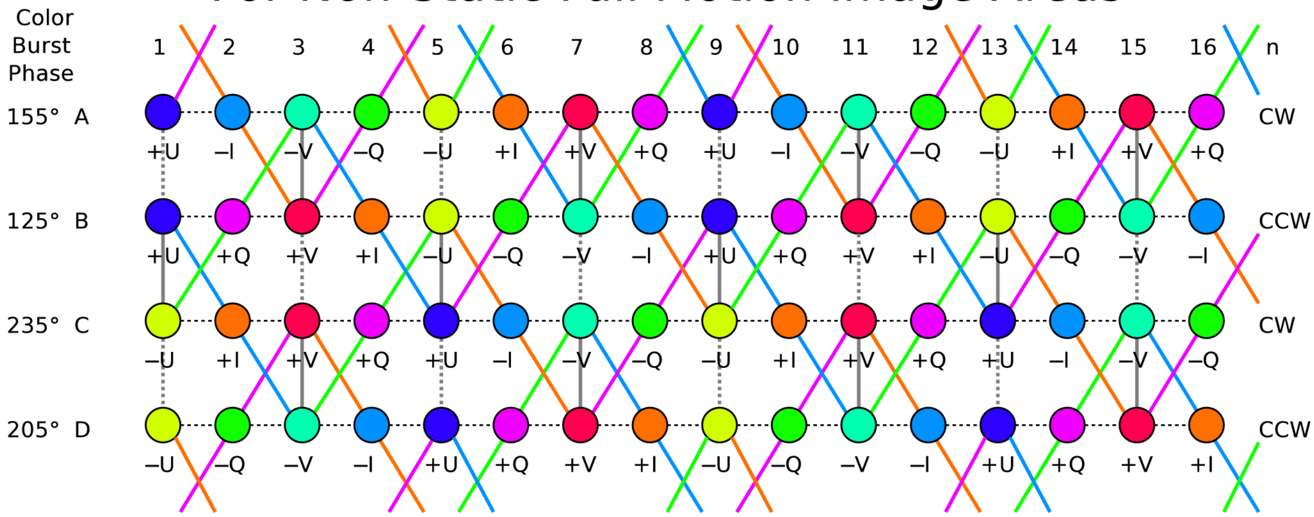
This detour into PAL is a good description with what happens when a Chroma sub-carrier is sub-modulated at a fractional rate of the horizontal frequency, the issues it creates and the solutions used to address them. For a more detailed description many articles about PAL since its inception in the early 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 ⅓ line to create the 3:1 interlace. It is also possible to end with ⅔ line and have a 3:1 interlace but this may be less optimal as it may take a greater staggering of the vertical sync pulse to create the uniform on screen Chroma dot pattern as illustrated earlier when ⅓ line is used. However if it is determined that a ⅔ line offset has distinct advantages and does not introduce any un-resolvable conflicts then it should be used instead, 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 persistance 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 I or Q Chroma Sample points there are 2 Luma samples from U & V 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 cpmplimentary color lines connected to an I or Q sample and the associated U & V samples. The ratio is (√2:2:√2)/(1+√2)/2 .

For Luma samples that fall on U or V sample points U or V 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 (±1:2:±1)/2 .

Since Luma sample recovery on I or Q sample points is all additive it provides noise reduction but Luma sample recovery on U or V 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 (1:2:1)/4 ratio or 5 points in a (1:2:4:2:1)/10 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 (1:2:1)/4 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 U or V 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.
A: a-d ⇒ +U, a-b ⇒ –V ; B: b-a ⇒ +V, b-c ⇒ +U ; C: c-b ⇒ –U, c-d ⇒ +V ; D: d-c ⇒ –V, d-a ⇒ –U .
For positive values: a-d & b-c ⇒ +U ; b-a & c-d ⇒ +V and for negative d-a & c-b ⇒ –U ; a-b & d-c ⇒ –V.

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.

Wider Screen High Definition WXGA 720i72 / 720p24 CRP™ for a 6mHz Channel Space

For the vertical scan a 3:1 interlace is used at a field rate of 72 Hz with 260⅔ lines to produce the Film 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. For the horizontal scan a 4:1 pixel interlaced sub-nyquist sampling is used to almost triple the Luma resolution, à la MUSE Hi-Vision. Below is a rough layout of the specification. It takes ⅙ of a second (166ms), 4 full frames (12 fields) to receive the full high definition image. A frame buffer is used to store the 4 frames to assemble a full resolution still picture. For motion the 72 Hz field rate will provide a reduced resolution de-interlaced image with motion blur every $13.\overline{8}$ ms. Chroma Rotary Phase™ with a **3.58** mHz sub-carrier frequency will be used since its dot matrix pattern works better with the 3:1 interlace while still offering a two frame repeat pattern. The sound is on a **4.8** mHz sub-carrier that can handle **3** separate channels of audio, **L+R**, **L−R**, and **SAP** or Surround.

```
General:                                                     Stretch to:
     Aspect Ratio                      5:3   = 1.6̅           16:9   = 1.7̅
     Total Picture Pixels  (Digital)  1200×720 ; 864000 Pixels   1280×720 ; 921600
     Kell Factor (Analog Resolution)   832×509 ; 432000 Pixels    905×509 ; 460800
     Sub-Nyquist(x) & Interlace(y)     300×240  (4:1 & 3:1)

Vertical:                                   [24.0285, +0.1186%]
     Frames Per Second                 24 Hz [24.0021, +0.0086%]
     Total Lines Per Frame             782 (2 Frame CRP™ Dot Repeat)
     Fields Per Second                 72 Hz [72.0062] [72.0854]
     Total Lines Per Field             260⅔
     Picture Lines                     240
     Lines Per Blank                   20⅔
     Blank                             1.1 ms
     Sync                              195 µs ; 3⅔ Lines

Horizontal:                               Resolution  Good:321  Max@−8dB:396
     Freq, Period (HP), Clock Pixel/Line  18.768 kHz, 53.282 µs, [18.769612]
     Picture BW Pixels                    315≈1⅗×λBW×(HP−HB) ; (300+15)≈5% OverScan
     Total Picture Clock ; Period         315 ; 44.052 µs        [18.790262]
     Blank (HB)                            66 ;  9.23  µs
     Front Porch                            7 ;  0.979 µs
     Sync                                  25 ;  3.496 µs
     Back Porch                            34 ;  4.755 µs

Luma & Chroma:
     Luma (λ) Bandwidth @-3dB          4½ mHz ; Vestigial ⅞mHz, Corner ½mHz
     Chroma:                           Sub-Sampling 5⅚:1:½
          Sub-Carrier                 3.575304 mHz [3.575611 PAL-M]
          ½H Odd Harmonic             381 (190½)    [3.579545 NTSC]
          Saturation Bandwidth        2 mHz  (USB +⅞mHz & LSB −1⅛mHz)
          Hue Bandwidth               ⅞ mHz  (USB +⅞mHz & LSB − ⅞mHz)
          Color Burst Duration        2.797 µs ; 10 cycles  2×(2¾+10+4¼)=34
          Baseband Guard              1½ mHz

Stereo Sound:
     PM SubCarrier ±157½° ±⅞π ±2¾R    4.804608 mHz [4.8050206] [4.8103072]
     H Harmonic                        256
     L & R Frequency Response          L+R 50Hz−15kHz, L−R 125Hz−15kHz
          Equalization                75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)
          Harmonic Peak Shifting      65µs & 650µs Phase Shift Networks (Optional)
     L−R Sub-Carrier  2×H             37.536 kHz [37.539223] [37.580249]
          Modulation                  Unlimited Armstrong PM ±74°, Peak Q:I=3½
                                      Compander Controlled 'I' Channel
```

Wider Screen Enhanced Definition **DVD 480i72 / 480p24 w/CRP™** for a **6**mHz Channel Space

Better than **NTSC/PAL-M** Broadcast Resolution (+52%) using 1 U.S. Channel Space

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 the horizontal no sub-sampling will be used and the full refresh rate will also be at 24 frames per second, 41⅔ms. 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. Using a 3:1 interlace at 72 Hz with 172⅔ lines allows the use of a lower horizontal scan rate providing increased definition of the **Luma** channel and somewhat wider aspect ratio than 4:3 at 3:2. **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 **3.1**mHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced by ½mHz to increase **Luma** bandwidth to 4½mHz. This moves the sound to **4.9**mHz having **2** separate channels of audio, **L+R** & **L−R**.

Optimal screen size 24” diagonal, (20”×13⅓”), 61cm diagonal, (50⅘×33⅞cm), 706µm line pitch.

General:		Good Contrast
Aspect Ratio	3:2 = 1½	177:120 = 1.475
Total Picture Pixels (Digital)	720×480 ; 345600 Pixels	708×480 ; 339840
Kell Factor (Analog Resolution)	509×340 ; 172800 Pixels	500×340 ; 169920
Maximum Digital Equiv. @−8dB	874×480 ; 419520 Pixels	618×340 ; 209760

Vertical:	
Frames Per Second	24 Hz
Total Lines Per Frame	518 (2 Frame **CRP™** Dot Repeat)
Fields Per Second	72 Hz
Total Lines Per Field	172⅔
Picture Lines	160
Lines Per Blank	12⅔
Blank	1.02 ms
Sync	188 µs ; 2⅓ Lines

With this low number of scan lines using a line doubler will increase this to 960. The ~1½ mbps QAM/COFDM data stream located on the Q channel of the main carrier will then carry the high frequency Luma difference information and widen the 3:2 aspect to 1440 pixels for all 960 lines. The high resolution pixel dot clock will be 8× the Chroma frequency. The number of dot clock pixels for normal resolution of active picture area is 852. Doubling this would give 1704 and with 960 lines would provide a 16:9 aspect ratio. This data will contain mostly zeros which will be eliminated and only the sharpest edge enhancement details will be retained which should compress well using modern video data compression algorithms. It should be possible to have full resolution at the 72i/24p rate. Video digitization, decoding and frame storage must be used and this high resolution mode is best suited for a larger flat screen set of up to 60" while still providing good sharpness. If data streams are lost line line doubling will still occur but an analog style edge enhancement/accutance filter will help sharpen the edges.

Horizontal:	Resolution Good:500 Max@−8dB:618
Lines Per Second	12.432 kHz
Period (Hᴘ)	80.438 µs (499)
Picture	71.249 µs (442) Over Scan
Total Picture Pixels	518¾ ≈ ϕ ×λBW×(Hᴘ−Hʙ) ; (500+18¾)≈3⅝%
Viewable Picture Pixels/Line	500 ; 68.67 µs (426 ×2 Dot Clock)
Blank (Hʙ)	9.188 µs (57)
Front Porch	0.967 µs (6)
Sync	3.546 µs (22)
Back Porch	4.675 µs (29)

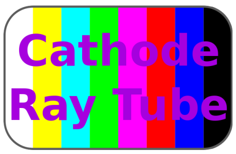
Luma & Chroma:	
Luma (λ) Bandwidth @-3dB	4½ mHz ; Vestigial ¾mHz, Corner ⅜mHz
Chroma:	Sub-Sampling 3:1:1
Sub-Carrier	3.101784 mHz
½H Odd Harmonic	499 (249½)
U Bandwidth	1½ mHz (USB +1½mHz & LSB −1½mHz)
V Bandwidth	1½ mHz (USB +1½mHz & LSB −1½mHz)
Color Burst Duration	2.579 µs ; 8 cycles 2×(2½+8+4)=29
Baseband Guard	¾ mHz

Stereo Sound:	−1.000776 mHz 80½×H (VSB Side)
PM SubCarrier ±157½° ±⅞π ±2¾R	4.898208 mHz
H Harmonic	394
L & R Frequency Response	**L+R** 50Hz−15kHz, **L−R** 100Hz−15kHz
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)
L−R Sub-Carrier 3×H	37.296 kHz
Modulation	Unlimited Armstrong PM ±74°, Peak Q:I=3½ Compander Controlled 'I' Channel

Standard Definition **wVGA 432i72 / 432p24 w/CRP™** for a **5**mHz Channel Space

Better than **NTSC/PAL-M** Broadcast Resolution (+35%) using ⅚ U.S. Channel Space

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 **1^{st}** 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. For the horizontal no sub-sampling will be used and 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 the **Golden Aspect Ratio ϕ**, 13:8 . **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 **2½**mHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced to ¾mHz and the **Luma** corner bandwidth decreased to **4**mHz with cutoff at **4¼**mHz to fit within a **5**mHz channel space. The PM sound sub-carriers are on the 'Q' channel of the main carrier. Note: **#̲** below represents a decimal.



24 ″ diagonal, (20½″×12⅗″),	61 cm diagonal, (52 ×32 cm),	741µm line pitch.
19 ″ diagonal, (16¼″×10 ″),	48¼cm diagonal, (41¼×25⅖cm),	588µm line pitch.
15¼″ diagonal, (13 ″× 8 ″),	38¾cm diagonal, (33 ×20⅓cm),	470µm line pitch.
12⅘″ diagonal, (10⅖″× 6⅖″),	31 cm diagonal, (26⅗×16¼cm),	376µm line pitch.

General:

		Good Contrast
Aspect Ratio	13:8 = 1⅝, ~ϕ	13:8 = 1⅝
Total Picture Pixels (Digital)	702×432 ; 303264 Pixels	702×432 ; 303264
Kell Factor (Analog Resolution)	497×305 ; 151632 Pixels	497×305 ; 151632
Maximum Digital Equiv. @–8dB	869×432 ; 375408 Pixels	614×305 ; 187704

Vertical:

Frames Per Second	24 Hz [24.0142, +0.0592%]
Total Lines Per Frame	470 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz [72.0426]
Total Lines Per Field	156⅔
Picture Lines	144
Lines Per Blank	12⅔
Blank	1.123 ms
Sync	207 µs ; 2⅓ Lines

Horizontal: Resolution Good:497 Max@–8dB:614

Lines Per Second	11.280 kHz [11.286682]
Period (Hᴘ)	88.652 µs (443)
Picture	79.647 µs (398) Over Scan
Total Picture Pixels	515½ ≈ ϕ×λʙᴡ×(Hᴘ–Hʙ) ; (497+18½)≈3⅗%
Viewable Picture Pixels/Line	497 ; 76.845 µs (384×2 Dot Clock)
Blank (Hʙ)	9.005 µs (45) [9.0]
Front Porch	1.001 µs (5) [1.0]
Sync	3.302 µs (16½) [3.3]
Back Porch	4.703 µs (23½) [4.7]

Luma & Chroma:

Luma (λ) Bandwidth @-3dB	4 mHz ; Vestigial ¾mHz, Corner ⅜mHz
Chroma:	Sub-Sampling 2⅔:1:1
Sub-Carrier	2.49852 mHz [2.5]
½H Odd Harmonic	443 (221½)
U Bandwidth	1⅓ mHz (USB +1⅓ mHz & LSB –1⅓mHz)
V Bandwidth	1⅓ mHz (USB +1⅓ mHz & LSB –1⅓mHz)
Color Burst Duration	2.802 µs ; 7 cycles 2×(1¾+7+3)=23½
Baseband Guard	¾ mHz

With this low number of scan lines using a line doubler will increase this to 864. The ~1½ mbps data stream located on the Q channel will then carry the high frequency Luma difference information to widen the resolution to 1404 pixels for all 864 lines. The high resolution pixel dot clock will be 8× the Chroma frequency. The number of dot clock pixels for normal resolution of active picture area is 768. Doubling this would give 1536 and with 864 lines would provide a 16:9 aspect ratio. This data will contain mostly zeros which will be eliminated and only the sharpest edge enhancement details will be retained which should compress well using modern video data compression algorithms. It should be possible to have full resolution at the 72i/24p rate. Video digitization, decoding and frame storage must be used and this high resolution mode is best suited for a larger flat screen set of up to 50" while still providing good sharpness. A lower deviation/fidelity mono sound channel will be used along with a digitized stereo, 5.1 channel surround and/or SAP mixed in with the data stream. If data streams are lost and not decodeable then the analog PM mono sound with a lower fidelity wil still be receiveable. Also under these conditions line doubling will still occur along with the use of a conventional edge enhancement/accutance filter to enhance Luma detail. The sound data channel should use a more robust carrier so loss is less likely using Opus as the encoding system.

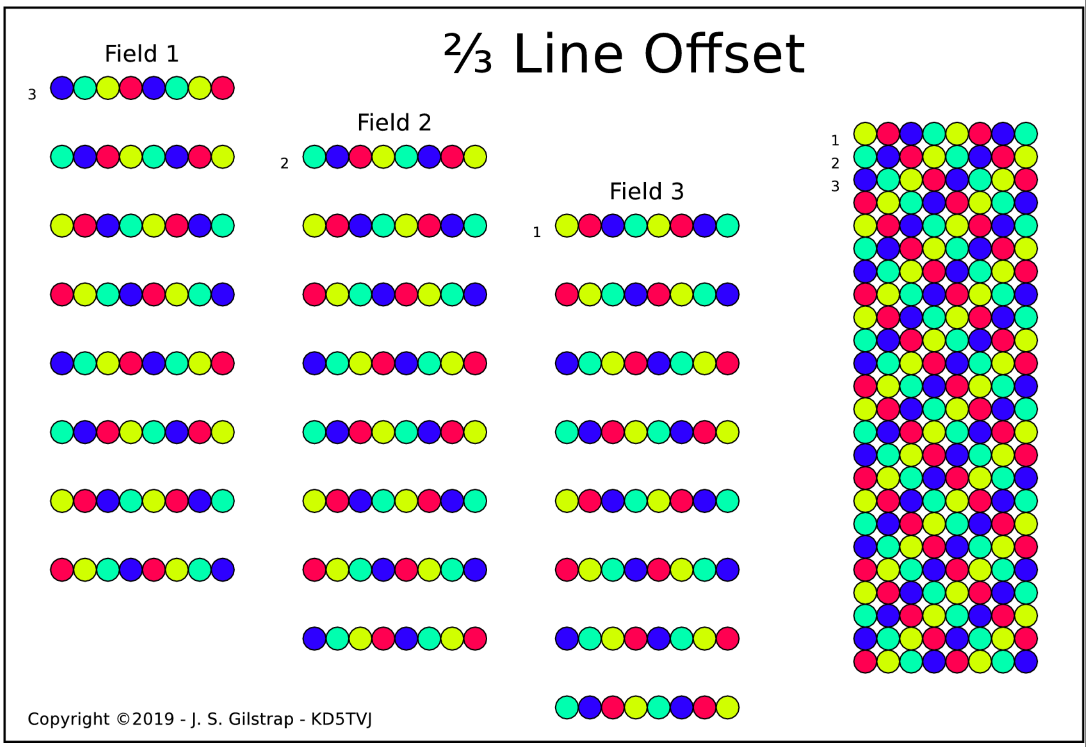
Sound: Sub-Carriers on 'Q' Channel of Main Carrier. PM Deviation: ±⅞π ±2¾R ±157½°

Sub-Carrier Frequencies:	**L+R**: 8½×H 95.88kHz [95.936795]	5½×H 62.04kHz ±1R ±573̲°
	L–R: 25½×H 287.64kHz [287.810384]	(50Hz–12½kHz Mono Only)
Frequency Response	50Hz–15kHz @ –3dB	(Digital Data/Sound;~20 QAM/COFDM Slots @5kHz)
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)	(≤1½mbps)
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)	

702×432
Expanded to
768 Wide
for Dot Clock

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. In application it will be U & V that will flip-switch and I & Q will rotate 90° per line in opposite directions. The directions that I & Q rotate will depend on the U & V flip-switch order within the 4 line chroma repeat pattern. 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. The diagram uses the U & V colored dots because they are easier to view. As shown in previous diagrams dot colors for composite I & Q arrangements are hard to look at.

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. The same should be done for the image on bottom of page 30 for the 526 line format with a ⅓ line offset to rotate it 90° clockwise if you don't want to look at it sideways.



In the diagram above 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.

A Minimalist NeoRetro™ Analog Color Television Standard

Standard Definition **VGA** **432i72/432p24** **w/CRP™** for a **4**mHz Channel Space

On Par with **NTSC-M/PAL-M** Broadcast Resolution (+9½%) using ⅔ U.S. Channel Space (½ **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. For the horizontal no sub-sampling will be used and 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 4:3 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**mHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced to ½mHz and the **Luma** corner bandwidth decreased to **3¼**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. ↓↓ 576×432 test pattern expanded to 618 wide for dot clock. ↓↓

24 ″ diagonal, (20 ″×13⅓″), 61 cm diagonal, (50⅘×33⅞cm), 784μm line pitch. 3:2
19⅚″ diagonal, (16½″×11 ″), 50½cm diagonal, (42 ×28 cm), 648μm line pitch. 3:2
17 ″ diagonal, (13⅗″×10⅕″), 43⅕cm diagonal, (34½×25⁹cm), 600μm line pitch. 4:3

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General:                                                      Good Contrast
      Aspect Ratio                      4:3   = 1⅓           287:216 ≈ 1.3287
      Total Picture Pixels  (Digital)   576×432 ; 248832 Pixels     574×432 ; 247968
      Kell Factor (Analog Resolution)   407×305 ; 124416 Pixels     406×305 ; 123984
      Maximum Digital Equiv. @-8dB      709×432 ; 306288 Pixels     501×305 ; 153144
                (Test Pattern page 46)  648×432                  1.0035:1 Pixel Aspect
Vertical:                                 3:2   = 1½             1.1315:1 Pixel Aspect
      Frames Per Second                 24 Hz [23.9736 -0.1099%]
      Total Lines Per Frame             470   (2 Frame CRP™ Dot Repeat)
      Fields Per Second                 72 Hz [71.9209]
      Total Lines Per Field             156⅔
      Picture Lines                     144
      Lines Per Blank                   12⅔
      Blank                             1.123 ms
      Sync                              207 μs ; 2⅓ Lines

Horizontal:                            Resolution  Good:406  Max@-8dB:501
      Lines Per Second                  11.280 kHz [11.267606]
      Period (HP)                       88.652 μs (355) [88¾]          (373)
      Picture                           79.662 μs (319) [79¾]  79.502 (334½)
      Total Picture Pixels             419 ≈ ϕ×λBW×(HP-HB) ; (406+13)≈3⅛% Over Scan
                                       418 ≈ ϕ×λBW×(HP-HB) ; (405+13)
      Viewable Picture Pixels/Line     406 ; 77.165 μs (309×2 Dot Clock) [77¼]
                                       405 ; 77.006 μs (324×2 Dot Clock)
      Blank (HB)                         8.990 μs (36) [9 ]  9.151 (38½)
      Front Porch                        0.999 μs ( 4) [1 ]  1.07  (4½)
      Sync                               3.246 μs (13) [3¼]  3.327 (14)
      Back Porch                         4.745 μs (19) [4¾]  4.754 (20)

Luma & Chroma:
      Luma (λ) Bandwidth @-3dB          3¼ mHz ; Vestigial ½mHz, Corner ¼mHz
      Chroma:                           Sub-Sampling 2½:1:⅚
            Sub-Carrier                 2.0022 mHz  [2] (2.10372)
            ½H Odd Harmonic             355 (177½)  373 (186½)
            I Bandwidth                 1⅓ mHz  (USB +1⅛mHz & LSB -1⅓mHz)
            Q Bandwidth                 1⅛ mHz  (USB +1⅛mHz & LSB -1⅛mHz)
            Color Burst Duration        2.497 μs ; 5 cycles  2×(2+5+2½)=19
            Baseband Guard              ½ mHz                2×(2+5+3 )=20

Sound: Sub-Carrier on 'Q' Channel of Main Carrier.  PM Deviation: ±⅞π  ±2¾R  ±157½°
      Sub-Carrier Frequency:           Mono: 8½×H  95.88kHz [95.774648]  (×3½ & ×8½)
      Frequency Response               50Hz-12½kHz @ -3dB (Harmonic Peak PSNs 2×1ms)
      Equalization                     75μs Pre-Emphasis, Shelf at 12.73kHz (12½μs)
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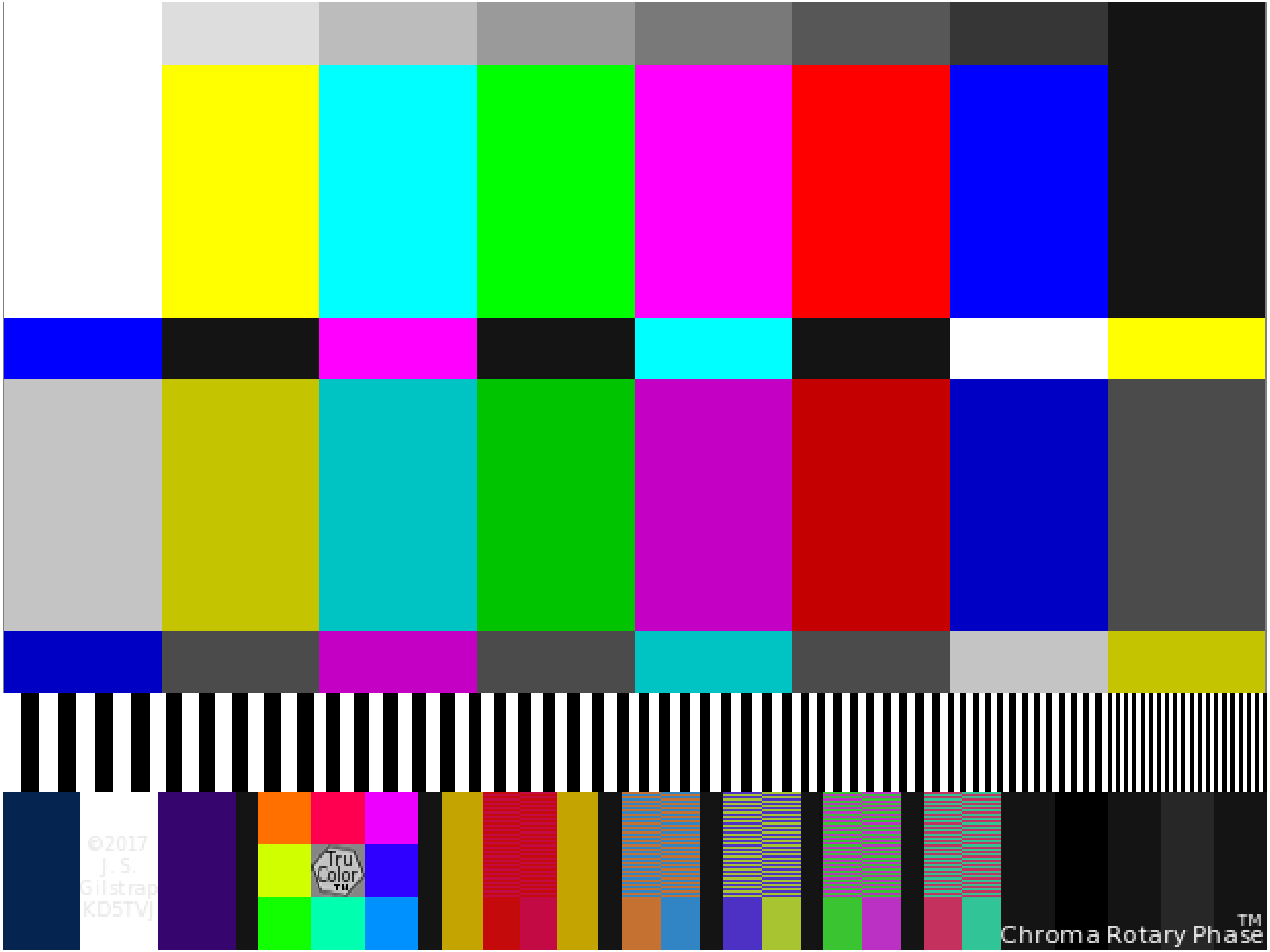
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Tru Color TM
Chroma Rotary Phase TM

Standard 4:3 Screen Sizes vs Dot Pitch

X Y	Diag	X Y	Diag	Line Pitch 432	**480**	528	**576**
20 ″×15 “	25“	50⅘×38⅛cm	63½cm	882µm	794µm	722µm	662µm
19⅕“×14⅖″	24“	48¾×36½cm	61 cm	847µm	762µm	714µm	635µm
18⅖″×13⅘“	23“	46¾×35 cm	58⅖cm	811µm	730µm	685µm	606µm
17⅗“×13⅕“	22“	44⅔×33½cm	55⅞cm	776µm	698µm	655µm	582µm
16⅘“×12⅗“	21“	42⅔×32 cm	53⅓cm	741µm	667µm	606µm	556µm
16 “×12 “	20″	40⅝×30½cm	50⅘cm	706µm	635µm	595µm	529µm
15⅕“×11⅖″	19″	38⅗×29 cm	48¼cm	670µm	603µm	566µm	503µm
14⅖″×10⅘“	18″	36⅗×27⅖cm	45¾cm	635µm	572µm	536µm	476µm
13⅗“×10⅕“	17“	34½×25⅞cm	43⅛cm	600µm	540µm	491µm	450µm
12⅘“× 9⅗“	16″	32½×24⅜cm	40⅔cm	564µm	506µm	476µm	423µm
12 “× 9 “	15″	30½×22⅚cm	38⅟cm	529µm	476µm	446µm	397µm
11⅕“× 8⅖″	14″	28½×21⅓cm	35½cm	494µm	445µm	417µm	370µm
10⅖″× 7⅘“	13″	26⅖×19⅘cm	33 cm	459µm	413µm	375µm	344µm

Golden Aspect Ratio ϕ Screen Sizes vs Dot Pitch

1,2,3,5,8,13,21,34,55,89,144,233,377,610,987,1597,2584,4181,6765,10946...

$\phi = (1+\sqrt{5}) \div 2 \approx 1.618033988749895...$

X Y	Diag	X Y	Diag	Line Pitch 432	**480**	528	**576**
72 ″×44½″	84⅝″	182⅞×113cm	215 cm	2616µm	2355µm	2141µm	1962µm
56⅔″×35 ″	66⅔″	144 ×89 cm	169¼cm	2060µm	1854µm	1686µm	1545µm
44½″×27½″	52⅓″	113 ×69⅞cm	132⅞cm	1617µm	1455µm	1323µm	1213µm
35 ″×21⅔″	41⅕″	89 ×55 cm	104⅝cm	1273µm	1146µm	1042µm	955µm
27½″×17 ″	32⅓″	69⅞×43⅙cm	82⅛cm	1000µm	900µm	818µm	750µm
21⅔″×13⅜″	25½″	55 ×34 cm	64⅔cm	787µm	708µm	644µm	590µm
17 ″×10½″	20 ″	43⅙×26⅔cm	50¾cm	617µm	556µm	505µm	463µm
13⅜″× 8¼″	15¾″	34 ×21 cm	40 cm	486µm	438µm	398µm	365µm
10½″× 6½″	12⅜″	26⅔×16½cm	31⅜cm	382µm	344µm	313µm	287µm
8¼″ × 5⅛″	9¾″	21 ×13 cm	24⅔cm	301µm	271µm	246µm	226µm

X Y	Diag	X Y	Diag	Line Pitch 624	672	**720**	768
72 ″×44½″	84⅝″	182⅞×113cm	215 cm	1811µm	1682µm	1570µm	1472µm
56⅔″×35 ″	66⅔″	144 ×89 cm	169¼cm	1426µm	1324µm	1236µm	1159µm
44½″×27½″	52⅓″	113 ×69⅞cm	132⅞cm	1119µm	1039µm	970µm	910µm
35 ″×21⅔″	41⅕″	89 ×55 cm	104⅝cm	881µm	818µm	764µm	716µm
27½″×17 ″	32⅓″	69⅞×43⅙cm	82⅛cm	692µm	643µm	600µm	562µm
21⅔″×13⅜″	25½″	55 ×34 cm	64⅔cm	545µm	506µm	472µm	443µm
17 ″×10½″	20 ″	43⅙×26⅔cm	50¾cm	428µm	397µm	370µm	347µm
13⅜″× 8¼″	15¾″	34 ×21 cm	40 cm	337µm	313µm	292µm	273µm
10½″× 6½″	12⅜″	26⅔×16½cm	31⅜cm	265µm	246µm	229µm	215µm
8¼″ × 5⅛″	9¾″	21 ×13 cm	24⅔cm	208µm	193µm	181µm	169µm

X Y	Diag	X Y	Diag	Line Pitch 816	864	912	960
72 ″×44½″	84⅝″	182⅞×113cm	215 cm	1385µm	1308µm	1239µm	1177µm
56⅔″×35 ″	66⅔″	144 ×89 cm	169¼cm	1091µm	1030µm	976µm	927µm
44½″×27½″	52⅓″	113 ×69⅞cm	132⅞cm	856µm	808µm	766µm	728µm
35 ″×21⅔″	41⅕″	89 ×55 cm	104⅝cm	674µm	637µm	603µm	573µm
27½″×17 ″	32⅓″	69⅞×43⅙cm	82⅛cm	529µm	500µm	473µm	450µm
21⅔″×13⅜″	25½″	55 ×34 cm	64⅔cm	417µm	394µm	373µm	354µm
17 ″×10½″	20 ″	43⅙×26⅔cm	50¾cm	327µm	309µm	292µm	278µm
13⅜″× 8¼″	15¾″	34 ×21 cm	40 cm	257µm	243µm	230µm	219µm
10½″× 6½″	12⅜″	26⅔×16½cm	31⅜cm	202µm	191µm	181µm	172µm
8¼″ × 5⅛″	9¾″	21 ×13 cm	24⅔cm	159µm	150µm	143µm	135µm

Enhanced Definition **VGA+ 528i72/528p24 w/CRP™** for a **6**mHz Channel Space

Better than **NTSC/PAL-M** Broadcast Resolution (+63%) using 1 U.S. Channel Space (¾ **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. For the horizontal no sub-sampling will be used and the full refresh rate will also be at 24 frames per second, 41⅔ms. Using a 3:1 interlace at 72 Hz with 192⅔ lines allows the use of a lower horizontal scan rate providing increased definition of the **Luma** channel with a 4:3 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 **3.56**mHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced to ¾mHz and the **Luma** corner bandwidth increased to **5**mHz with cutoff at **5**¼mHz to fit within a **6**mHz channel space. The PM sound sub-carriers are on the 'Q' channel of the main carrier. ↓↓ 704×528 test pattern expanded to 858 wide for dot clock. ↓↓

27″ diagonal, (21⅗″×16⅕″), 68⅗cm diagonal, (54⅞×41⅙cm), 779µm line pitch.
22″ diagonal, (17⅗″×13⅕″), 53⅓cm diagonal, (42⅔×32 cm), 635µm line pitch.
18″ diagonal, (14⅕″×10⅘″), 43⅛cm diagonal, (34½×25⅞cm), 520µm line pitch.
14″ diagonal, (11⅕″× 8⅗″), 35 cm diagonal, (28 ×21 cm), 404µm line pitch.

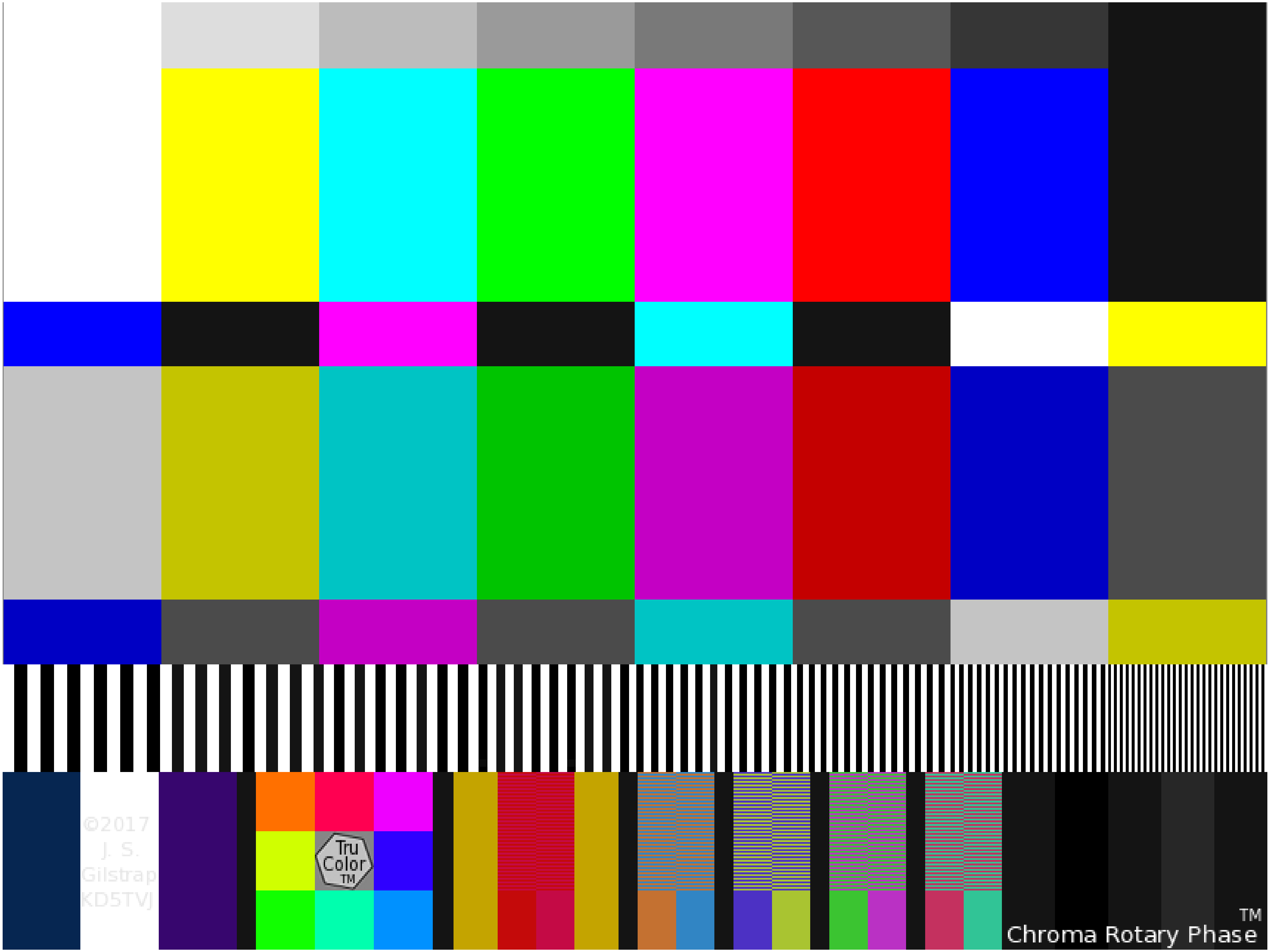
		Good Contrast
General:		
Aspect Ratio	4:3 = 1⅓	345:264 = 1.307
Total Picture Pixels (Digital)	704×528 ; 371712 Pixels	690×528 ; 364320
Kell Factor (Analog Resolution)	498×373 ; 185856 Pixels	488×373 ; 182160
Maximum Digital Equiv. @−8dB	852×528 ; 449856 Pixels	603×373 ; 224928
		1.0203:1 Pixel Aspect

Vertical:	
Frames Per Second	24 Hz
Total Lines Per Frame	578 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz
Total Lines Per Field	192⅔
Picture Lines	176
Lines Per Blank	16⅔
Blank	1.201 ms
Sync	192 µs ; 2⅔ Lines
Horizontal:	Resolution Good: 488 Max@−8dB:603
Lines Per Second	13.872 kHz
Period (HP)	72.088 µs (513)
Picture	62.954 µs (448) OverScan
Total Picture Pixels	$509\underline{3}$ ≈ ϕ×λBW×(HP−HB) ; ($487\underline{7}$+$21\underline{6}$)≈4¼%
Viewable Picture Pixels/Line	$487\underline{7}$; 60.284 µs (429×2 Dot Clock)
Blank (HB)	9.134 µs (65)
Front Porch	0.984 µs (7)
Sync	3.302 µs (23½)
Back Porch	4.707 µs (33½)
Luma & Chroma:	
Luma (λ) Bandwidth @-3dB	5 mHz ; Vestigial ¾mHz, Corner ⅜mHz
Chroma:	Sub-Sampling 27/9:1:7/9
Sub-Carrier	3.558168 mHz
½H Odd Harmonic	513 (256½)
Saturation Bandwidth	1⅘ mHz (USB +1⅖mHz & LSB −1⅘mHz)
Hue Bandwidth	1⅖ mHz (USB +1⅖mHz & LSB −1⅖mHz)
Color Burst Duration	2.529 µs ; 9 cycles 2×(3¼+9+4½)=33½
Baseband Guard	¾ mHz

With this low number of scan lines using a line doubler will increase this to 1056. The ~1½ mbps data stream located on the Q channel will then carry the high frequency Luma difference information and widen the resolution to 1408 pixels for all 1056 lines. The high resolution pixel dot clock will be 8× the Chroma frequency. The number of dot clock pixels for normal resolution of active picture area is 858. Doubling this would give 1716 and with 1056 lines would provide a 13:8 aspect ratio. This data will contain mostly zeros which will be eliminated and only the sharpest edge enhancement details will be retained which should compress well using modern video data compression algorithms. It should be possible to have full resolution at the 72i/24p rate. Video digitization, decoding and frame storage must be used and this high resolution mode is best suited for a larger flat screen set of up to 60" while still providing good sharpness. A lower deviation/fidelity mono sound channel will be used along with a digitized stereo, 5.1 channel surround and/or SAP mixed in with the data stream. If data streams are lost and not decodeable then the analog PM mono sound with a lower fidelity wil still be receiveable. Also under these conditions line doubling will still occur along with the use of a conventional edge enhancement/accutance filter to enhance Luma detail. The sound data channel should use a more robust carrier so loss is less likely using Opus as the encoding system.

Sound: Sub-Carriers on 'Q' Channel of Main Carrier. PM Deviation: ±⅞π ±2¾R ±157½°

Sub-Carrier Frequencies:	**L+R**: 7½×H 104.040kHz	4½×H 62.424kHz	±½π	±1⅗R	±90°
	L−R: 20½×H 284.376kHz	(50Hz−12½kHz Mono Only)			
Frequency Response	50Hz−15kHz @ −3dB	(Digital Data/Sound;~15 QAM/COFDM Slots @6⅞kHz)			
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)				
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)				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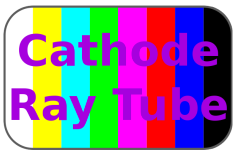
Wide Definition **WVGA 480i72 / 480p24 w/CRP™** for a **6**mHz Channel Space

Better than **NTSC/PAL-M** Broadcast Resolution (+68%) using 1 U.S. Channel Space.

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. For the horizontal no sub-sampling will be used and the full refresh rate will also be at 24 frames per second, 41⅔ms. Using a 3:1 interlace at 72 Hz with 172⅔ lines allows the use of a lower horizontal scan rate providing increased definition of the **Luma** channel with the **Golden Aspect Ratio ϕ**, 13:8. **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 and a **3.1**mHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced to ¾mHz and the **Luma** corner bandwidth increased to **5**mHz with cutoff at **5¼**mHz to fit within a **6**mHz channel space. The PM sound sub-carriers are on the 'Q' channel of the main carrier. Note: # below represents decimal.



30 ″ diagonal, (25⅗″×15¾″), 76⅓cm diagonal, (65 ×40 cm), 833µm line pitch.
24 ″ diagonal, (20½″×12⅗″), 61 cm diagonal, (52 ×32 cm), 667µm line pitch
19 ″ diagonal, (16¼″×10 ″), 48½cm diagonal, (41¼×25⅗cm), 529µm line pitch.
15¾″ diagonal, (13⅗″× 8¼″), 40 cm diagonal, (34⅛×21 cm), 437µm line pitch.

General:		Good Contrast
Aspect Ratio	13:8 = 1⅝, ~ϕ	131:80 = 1.6375
Total Picture Pixels (Digital)	780×480 ; 374400 Pixels	786×480 ; 377280
Kell Factor (Analog Resolution)	552×340 ; 187200 Pixels	555×340 ; 188640
Maximum Digital Equiv. @−8dB	971×480 ; 466080 Pixels	687×340 ; 233040

Vertical:	
Frames Per Second	24 Hz
Total Lines Per Frame	518 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz
Total Lines Per Field	172⅔
Picture Lines	160
Lines Per Blank	12⅔
Blank	1.02 ms
Sync	188 µs ; 2⅓ Lines

Horizontal:	Resolution Good:555½ Max@−8dB:687
Lines Per Second	12.432 kHz
Period (Hᴘ)	80.438 µs (499)
Picture	71.408 µs (443) OverScan
Total Picture Pixels	577¾ ≈ ϕ ×λBW×(Hᴘ−Hʙ) ; (555½+22¼)≈3⅚%
Viewable Picture Pixels/Line	555½ ; 68.67 µs (426×2 Dot Clock)
Blank (Hʙ)	9.027 µs (56)
Front Porch	1.048 µs (6½)
Sync	3.224 µs (20)
Back Porch	4.755 µs (29½)

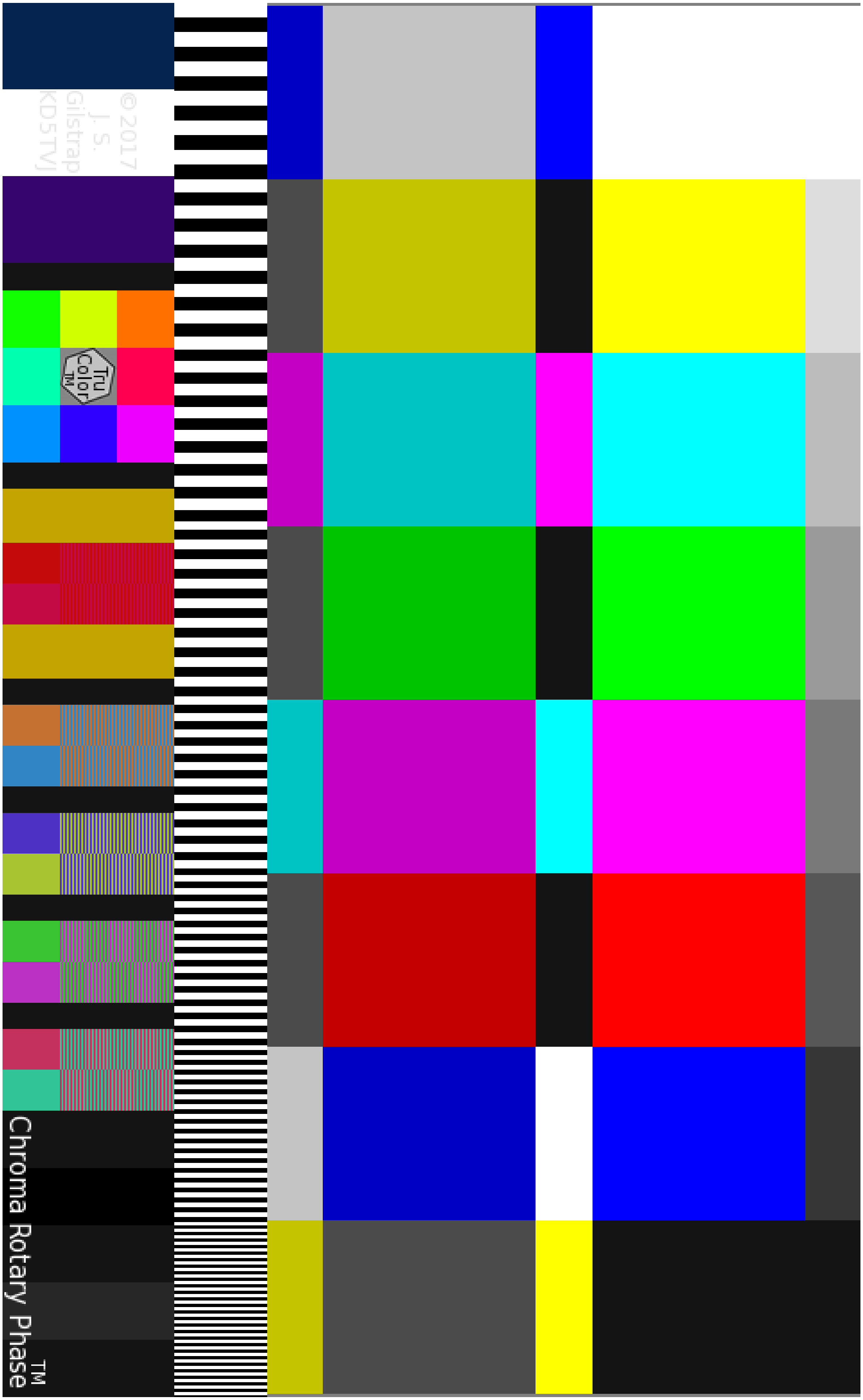
Luma & Chroma:	
Luma (λ) Bandwidth @-3dB	5 mHz ; Vestigial ¾mHz, Corner ⅜mHz
Chroma:	Sub-Sampling 2⅔:1:1
Sub-Carrier	3.101784 mHz
½H Odd Harmonic	499 (249½)
Saturation Bandwidth	1⅞ mHz (USB +1⅞mHz & LSB −1¾mHz)
Hue Bandwidth	1¾ mHz (USB +1¾mHz & LSB −1¾mHz)
Color Burst Duration	2.579 µs ; 8 cycles 2×(2¾+8+4)=29½
Baseband Guard	¾ mHz

Sound: Sub-Carriers on 'Q' Channel of Main Carrier. PM Deviation: ±⅞π ±2¾R ±157½°

Sub-Carrier Frequencies:	L+R: 7½×H 93.24kHz	4½×H 55.944kHz ±1 R ±57⅓°
	L−R: 22½×H 279.72kHz	(50Hz−12½kHz Mono Only)
Frequency Response	50Hz−15kHz @ −3dB (Digital Data/Sound;~18 QAM/COFDM Slots @6kHz)	
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)	
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)	

With this low number of scan lines using a line doubler will increase this to 960. The ~1½ mbps data stream located on the Q channel will then carry the high frequency Luma difference information to widen the resolution to 1560 pixels for all 960 lines. The high resolution pixel dot clock will be 8× the Chroma frequency. The number of dot clock pixels for normal resolution of active picture area is 852. Doubling this would give 1704 and with 960 lines would provide a 16:9 aspect ratio. This data will contain mostly zeros which will be eliminated and only the sharpest edge enhancement details will be retained which should compress well using modern video data compression algorithms. It should be possible to have full resolution at the 72i/24p rate. Video digitization, decoding and frame storage must be used and this high resolution mode is best suited for a larger flat screen set of up to 55" while still providing good sharpness. A lower deviation/fidelity mono sound channel will be used along with a digitized stereo, 5.1 channel surround and/or SAP mixed in with the data stream. If data streams are lost and not decodeable then the analog PM mono sound with a lower fidelity wil still be receiveable. Also under these conditions line doubling will still occur along with the use of a conventional edge enhancement/accutance filter to enhance Luma detail. The sound data channel should use a more robust carrier so loss is less likely using Opus as the encoding system.

780×480
Expanded to
852 Wide
for Dot Clock



Standard Definition **VGA 480i72 / 480p24 w/CRP™** for a **5**mHz Channel Space

Studio Quality NTSC-Film (i72/3) Better than **NTSC/PAL-M** Broadcast (+35%) using ⅚ U.S. Channel Space.

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. For the horizontal no sub-sampling will be used and the full refresh rate will also be at 24 frames per second, 41⅔ms. Using a 3:1 interlace at 72 Hz with 172⅔ lines allows the use of a lower horizontal scan rate providing increased definition of the **Luma** channel with the aspect ratio of 4:3. **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 **2.5**mHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced to ¾mHz and the **Luma** corner bandwidth decreased to **4**mHz with cutoff at **4¼**mHz to fit within a **5**mHz channel space. The PM sound sub-carriers are on the 'Q' channel of the main carrier. Note: # below represents a decimal.

25″ diagonal, (20″×15″), 63½cm diagonal, (50⅘×38⅒cm), 794µm line pitch.
20″ diagonal, (16″×12″), 50⅘cm diagonal, (40⅝×30½cm), 635µm line pitch.
15″ diagonal, (12″× 9″), 38⅒cm diagonal, (30½×22⅚cm), 476µm line pitch.
10″ diagonal, (8″× 6″), 25⅖cm diagonal, (20⅓×15¼cm), 318µm line pitch.

General: — Good Contrast

Aspect Ratio	4:3 = 1⅓	21:16 = 1⁵/₁₆
Total Picture Pixels (Digital)	640×480 ; 307200 Pixels	630×480 ; 302400
Kell Factor (Analog Resolution)	452×340 ; 153600 Pixels	446×340 ; 151200
Maximum Digital Equiv. @−8dB	780×480 ; 374400 Pixels	551×340 ; 187200

Vertical: — 1.0159:1 Pixel Aspect

Frames Per Second	24 Hz [24.0711 +0.2962%]
Total Lines Per Frame	518 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz [72.2133]
Total Lines Per Field	172⅔
Picture Lines	160
Lines Per Blank	12⅔
Blank	1.02 ms
Sync	188 µs ; 2⅓ Lines

Horizontal: — Resolution Good:446 Max@−8dB:551

Lines Per Second	12.432 kHz [12.468828]
Period (HP)	80.438 µs (401)
Picture	71.411 µs (356)
Total Picture Pixels	462 ≈ ϕ ×λBW×(HP−HB) ; (446+16)≈3½% Over Scan
Viewable Picture Pixels/Line	446 ; 68.911 µs (2×343½ Dot Clock)
Blank (HB)	9.027 µs (45) [9.0]
Front Porch	0.979 µs (5) [1.0]
Sync	3.310 µs (16½) [3.3]
Back Porch	4.714 µs (23½) [4.7]

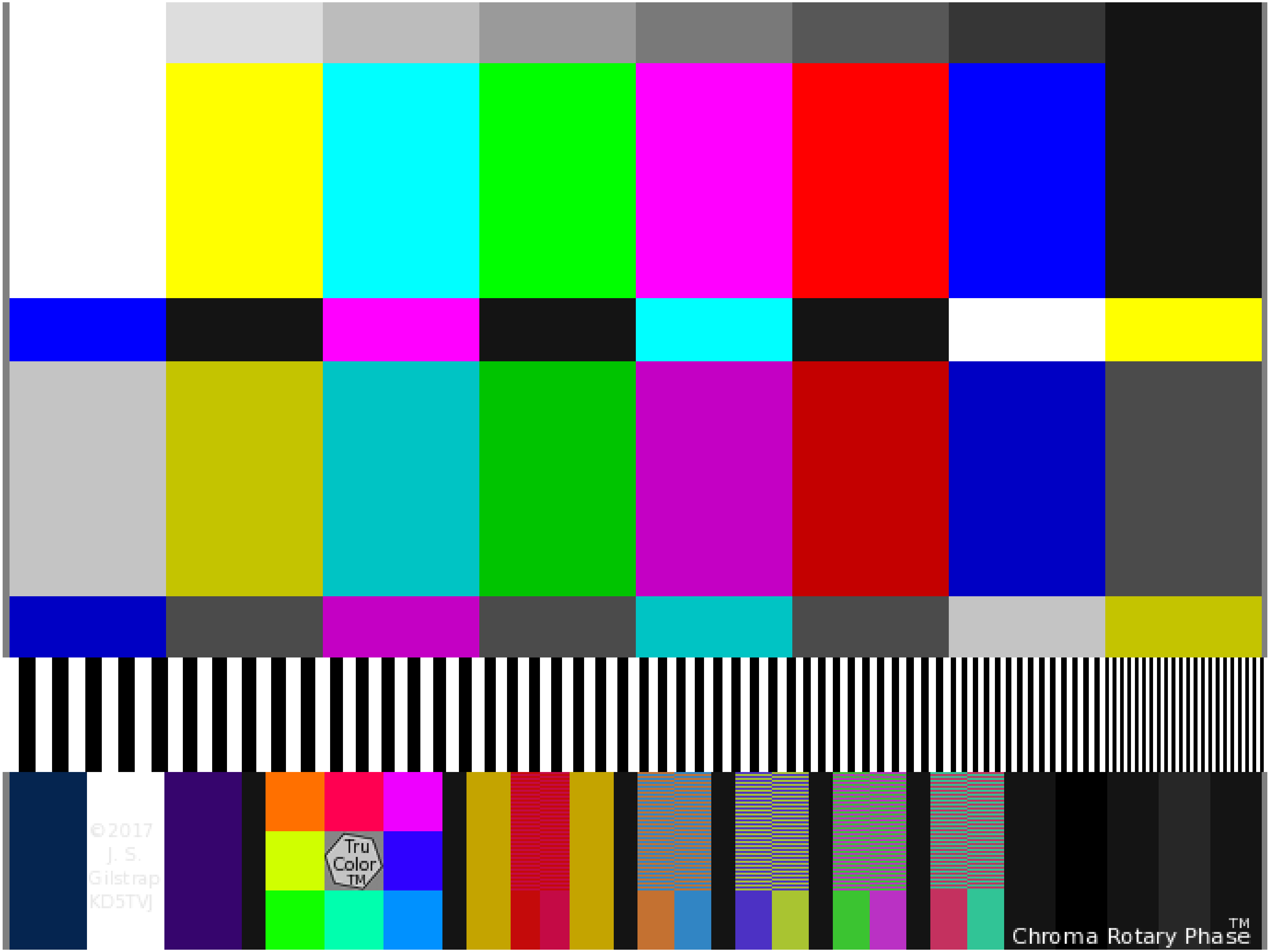
Luma & Chroma:

Luma (λ) Bandwidth @-3dB	4 mHz ; Vestigial ¾mHz, Corner ⅜mHz
Chroma:	Sub-Sampling 2⅔:1:1
Sub-Carrier	2.492616 mHz [2.5]
½H Odd Harmonic	401 (200½)
U Bandwidth	1½ mHz (USB +1½mHz & LSB −1½mHz)
V Bandwidth	1½ mHz (USB +1½mHz & LSB −1½mHz)
Color Burst Duration	2.41 µs ; 6 cycles 2×(2¼+6+3½)=23½
Baseband Guard	¾ mHz

Sound: Sub-Carriers on 'Q' Channel of Main Carrier. PM Deviation: ±⅞π ±2¾R ±157½°

Sub-Carrier Frequencies:	L+R: 7½×H 93.24kHz	4½×H 55.944kHz ±1R ±57⅓°
	L−R: 22½×H 279.72kHz	(50Hz−12½kHz Mono Only)
Frequency Response	50Hz−15kHz @ −3dB	(5.1 Digital;~18 QAM/COFDM Slots @6kHz)
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)	
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)	

↓↓ 640×480 Test Pattern Expanded to 687 Wide for Dot Clock. ↓↓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A Minimalist NeoRetro™ Analog Color Television Standard

Wider Definition wVGA 432i72/432p24 w/CRP™ for a 4½mHz Channel Space

Better than **NTSC/PAL-M** Broadcast Resolution (+22%) using ¾ U.S. Channel Space (**9/16 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. For the horizontal no sub-sampling will be used and 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 **2.1**mHz **Chroma** sub-carrier frequency will be used. The vestigial sideband has been reduced to ¾mHz and the **Luma** corner bandwidth decreased to **3⅝**mHz with cutoff at **3⅞**mHz to fit within a **4½**mHz channel space. The PM sound sub-carriers are on the 'Q' channel of the main carrier. ↓↓ 648×432 test pattern. ↓↓

24 ″ diagonal, (20″×13⅓″), 61 cm diagonal, (50⅘×33⅞cm), 784µm line pitch.
18 ″ diagonal, (15″×10 ″), 45⅘cm diagonal, (38½×25⅖cm), 588µm line pitch.
14⅖″ diagonal, (12″× 8 ″), 36⅝cm diagonal, (30½×20⅓cm), 470µm line pitch.
10⅘″ diagonal, (9″× 6 ″), 27½cm diagonal, (22⅞×15¼cm), 353µm line pitch.

General:		Good Contrast
Aspect Ratio	3:2 = 1½	213:144 ≈ 1.4792
Total Picture Pixels (Digital)	648×432 ; 279936 Pixels	639×432 ; 276048
Kell Factor (Analog Resolution)	453×305 ; 139968 Pixels	452×305 ; 138024
Maximum Digital Equiv. @−8dB	789×432 ; 340848 Pixels	558×305 ; 170424
		1.014:1 Pixel Aspect

Vertical:	
Frames Per Second	24 Hz
Total Lines Per Frame	470 (2 Frame CRP™ Dot Repeat)
Fields Per Second	72 Hz
Total Lines Per Field	156⅔
Picture Lines	144
Lines Per Blank	12⅔
Blank	1.123 ms
Sync	207 µs ; 2⅓ Lines

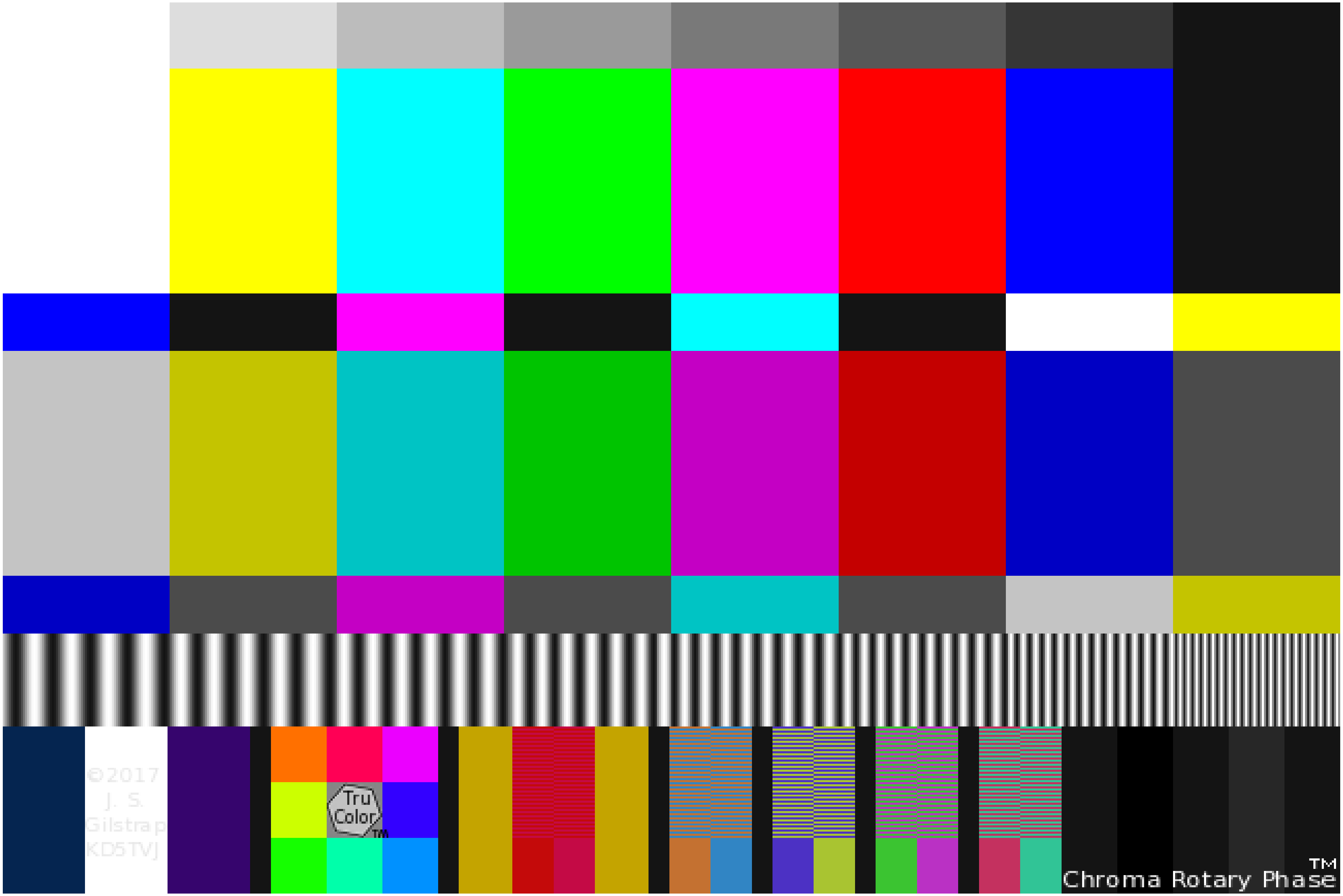
Horizontal:	Resolution Good:452 Max@−8dB:558
Lines Per Second	11.28 kHz
Period (HP)	88.652 µs (373)
Picture	79.502 µs (334½) OverScan
Total Picture Pixels	466 ≈ ϕ×λBW×(HP−HB) ; (452+14)≈3%
Viewable Picture Pixels/Line	452 ; 77.006 µs (324×2 Dot Clock)
Blank (HB)	9.151 µs (38½)
Front Porch	1.07 µs (4½)
Sync	3.327 µs (14)
Back Porch	4.754 µs (20)

Luma & Chroma:	
Luma (λ) Bandwidth @-3dB	3⅝ mHz ; Vestigial ⅝mHz, Corner ⅓mHz
Chroma:	Sub-Sampling 2⅖:1:⅔
Sub-Carrier	2.10372 mHz
½H Odd Harmonic	373 (186½)
Saturation Bandwidth	1½ mHz (USB +1½mHz & LSB −1mHz)
Hue Bandwidth	1 mHz (USB +1 mHz & LSB −1mHz)
Color Burst Duration	2.376 µs ; 5 cycles 2×(2+5+3)=20
Baseband Guard	⅝ mHz

With this low number of scan lines using a line doubler will increase this to 864. The >1 mbps data stream located on the Q channel will then carry the high frequency Luma difference information to widen the resolution to 1296 pixels for all 864 lines. The high resolution pixel dot clock will be 8× the Chroma frequency. This data will contain mostly zeros which will be eliminated and only the sharpest edge enhancement details will be retained which should compress well using modern video data compression algorihms. It should be possible to have full resolution at the 72i/24p rate. Video digitization, decoding and frame storage must be used and this high resolution mode is best suited for a larger flat screen set of up to 50" while still providing good sharpness. A lower deviation/fidelity mono sound channel will be used along with a digitized stereo, 5.1 channel surround and/or SAP mixed in with the data stream. If data streams are lost and not decodeable then analog PM mono sound with a lower resolution wil still be received. Also under these conditions line doubling will still occur along with the use of a conventional edge enhancement/accutance filter to enhance Luma detail. The sound data channel should use a more robust carrier so loss is less likely using Opus as the encoding system.

Sound: Sub-Carrier on 'Q' Channel of Main Carrier. PM Deviation: ±2¾R ±157½° ±⅞π

Sub-Carrier Frequency:	**Mono**: 8½×H 95.88kHz	6½×H 73.32kHz ±2 R ±114⅗°, −3dB@12½kHz
Frequency Response	50Hz−15kHz@−3dB	(Digital Data/Sound; ~18 QAM/COFDM Slots @5½kHz)
Equalization	75µs Pre-Emphasis, Shelf at 12.73kHz (12½µs)	(≤1½mbps)
Harmonic Peak Shifting	65µs & 650µs Phase Shift Networks (Optional)	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