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

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R, G, B, Range: 0–1

$$Y = 0.299\times Red + 0.587\times Green + 0.114\times Blue$$

$$U = 0.492111 \times (B - Y) \quad (0.4921110411)$$

$$V = 0.877283 \times (R - Y) \quad (0.8772832199) \quad \text{Phase inverted @ ½H}$$

$$W = -0.509370 \times (R - Y) - 0.194208 \times (B - Y) \Leftarrow [G - Y]$$

(−0.5093696834) (−0.1942078377)

$$I = 0.595901\times Red - 0.274557\times Green - 0.321344\times Blue$$

(0.5959007249) (−0.2745567667) (−0.3213439582)

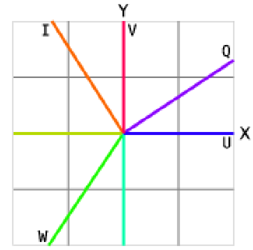
$$Q = 0.211537\times Red - 0.522736\times Green + 0.311200\times Blue$$

(0.2115366883) (−0.5227362571) (0.3111995688)

		HSV Hue
U	#2900FC	249.76°
V	#FF0056	339.76°
W	#1BFA00	113.52°
I	#FC6600	24.29°
Q	#8900FE	272.36°

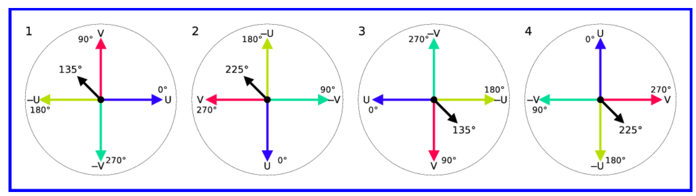
	IRE=1V/140	
Luma (Y) Level:	98	700mV
Sync:	–42	300mV
ColorBurst:	±21	±150mV
Max (Yl & Cy)	130⅔	1.23̅V
Min (Rd & Bl)	–32⅔	66⅔mV

For more information on signal levels, Luma/Chroma matrixing, composite & vector scope images and other info see **NTSC Specifications** .



Rec.709 sRGB Gamut	1931 CIE x	y	nm
Red	0.64	0.33	~607
Green	0.30	0.60	~556
Blue	0.15	0.06	~467
White Point	0.3127	0.329	6504°K
Contrast 2^{12}:1	Gamma 2.4		

PAL On Screen Vector Rotation & V Switch Phases



Colorburst & Carrier

The **PAL** line phase alternation signal for V uses the standard **135°**(+) / **225°**(–) phase toggling of the colorburst. Synchronous detection on a reduced carrier level will increase signal quality. The option of a ½ MHz data channel where the composite signal modulates the **I** channel and the data modulates the **Q** channel is possible.

Claims:

- Using a **3:1** interlace with the **4** phase states of **PAL Chroma** produces a **Luma/Chroma** fine mesh harmonic spacing of ½ the frame rate of **12**Hz and a **2** frame repeat rate like **NTSC**.

- A **3:1** interlace also creates Hanover lines instead of bars within a completed frame that are stationary and do not scroll unlike a **2:1** interlace; i.e. the hue palette phase rotation reverses on alternate lines of a field and a full frame whereas with a **2:1** interlace the rotation reversal is with alternate line pairs of a frame that alternate the hue palette phase rotation for every full frame. This makes any hue error effects twice as fine compared to a **2:1** interlace.

- On a per frame basis the diagonal **Chroma** dot pattern for **U** & **V** is similar to **NTSC** and for axes rotated **45°** away, nearer to **I** & **Q** the pattern is identical.

- A **3:1** interlace offers **24PsF**, **36PsF**, & **72fps** motion refresh. For the faster **36** & **72** refresh rate line interpolation for the missing lines can be used for good quality de-interlaced full frame motion.

3:1 Interlace

Vertical scan is from top to bottom and the field lines shift down ⅓ horizontal field line per field instead of ½ line in a **2:1** interlace. This will produce **2** hammer heads during the vertical blank, offset from the center to each side, or **3** hammer heads separated and centered within the vertical blanking. The vertical sync of the **1ST** field is delayed by **1** horizontal line in relation to the other **2** fields. This is necessary to arrange the on screen **Chroma** dots in a uniform diagonal pattern to facilitate the use of a standard PAL **3** line [diagonal] comb filter for **Luma/Chroma** separation for both field and frame. The **Chroma** dot pattern repeats at a **2** frame interval and complete **Luma/Chroma** separation for static/non-motion areas is realized using an NTSC field comb of **1** frame delay.

PAL-FWVGA

Full Wide VGA Standard Definition

24PsF | **480i72** | **16:9**

+50⅘% NTSC/PAL-M & **+5⅞%** PAL-B/G within a **6**MHz Channel Space
70⅖×39⅗cm ⇒ **80¾**cm/**31⅘"** Diag, **825**µm Line Pitch
3.172MHz **Chroma**

General:			Fair Contrast
Aspect Ratio	16:9		37:24 ≈ 1.5287
Total Picture Pixels (Digital)	854×480 ; 409920 Pixels		734×480 ; 352320
Kell Factor (Analog Resolution)	604×340 ; 204960 Pixels		519×340 ; 176160
Maximum Digital Equiv. @−9dB	880×480 ; 422400 Pixels		622×340 ; 211200

Vertical: Pixel Aspect 1.164:1

Frames Per Second	24Hz
Total Lines Per Frame	526
Fields Per Second	72Hz
Total Lines Per Field	175⅓
Picture Lines	160
Lines Per Blank	15⅓
Blank	1.215ms
Sync	185µs ; 2⅓ Lines

$30^{26}/_{33}$ ScanLines/Inch

Horizontal: Resolution Fair: 518⅞ Max@−9dB:622

Lines Per Second	12.624kHz	
Period (HP)	79.214µs (502½)	
Picture	69.913µs (443½)	OverScan
Total Picture Pixels	538⅞≈1⅔×YBW×(HP−HB) ; (518⅞+20)≈3¾%,2⅗µs	
Viewable Picture Pixels/Line	518⅞ ; 67.312µs (427×2 Dot Clock)	
Blank (HB)	9.301µs (59)	
Front Porch	1.025µs (6½)	
Sync	3.547µs (22½)	
Back Porch	4.729µs (30)	

Chroma Rotary Phase™
with TruColor™
3.162312MHz
501:**250½**:167

Luma & Chroma:

Luma (Y) Bandwidth @−3dB	4⅝MHz, Full Cut 4⅚MHz
Vestigial Sideband	¾MHz, Corner ½MHz
Chroma:	Sub-Sampling 3⁵⁄₆₀:1:1
Sub-Carrier	3.17178MHz ; 8× ⇒ 25.37424MHz
½H Odd Harmonic	502½:**251¼**:167½
U Bandwidth	1½MHz (USB +1½MHz & LSB −1½MHz)
V Bandwidth	1½MHz (USB +1½MHz & LSB −1½MHz)
Color Burst Duration	2.838µs ; 9 cycles 2×(1½+9+4½)=30
Baseband Guard	1½MHz 473/552ns 1.42/1.34µs

MTS Sound: (**L+R**) (**L−R**) (**SAP**)

Sub-Carrier Frequency	4.999104MHz FM ±25kHz, ±25kHz, ±15kHz
H Harmonic	396 ±73kHz Total peak modulation.
L & **R** Frequency Response	50Hz−15kHz
L+R Equalization	75µs Pre-Emphasis
L−R Sub-Carrier	37.872kHz AM 3 ×H DSB-SC
Pilot	18.936kHz 1½×H ±5kHz Deviation (6.85%)
SAP Sub-Carrier	84.600kHz FM 7½×H
Encoding/Compression	Zenith−**dbx** (THAT Corp.)

See **NTSC Specifications**

↓↓ **Chroma** LoR/Freq: 90/⅔kHz, 180/1⅓MHz

854×480
Expanded to
1708
2× HorizSample

378.720kHz
30×12624Hz
(51 Lines)

530.208kHz
42×12624Hz
(71⅜ Lines)

744.816kHz
59×12624Hz
(100¼ Lines)

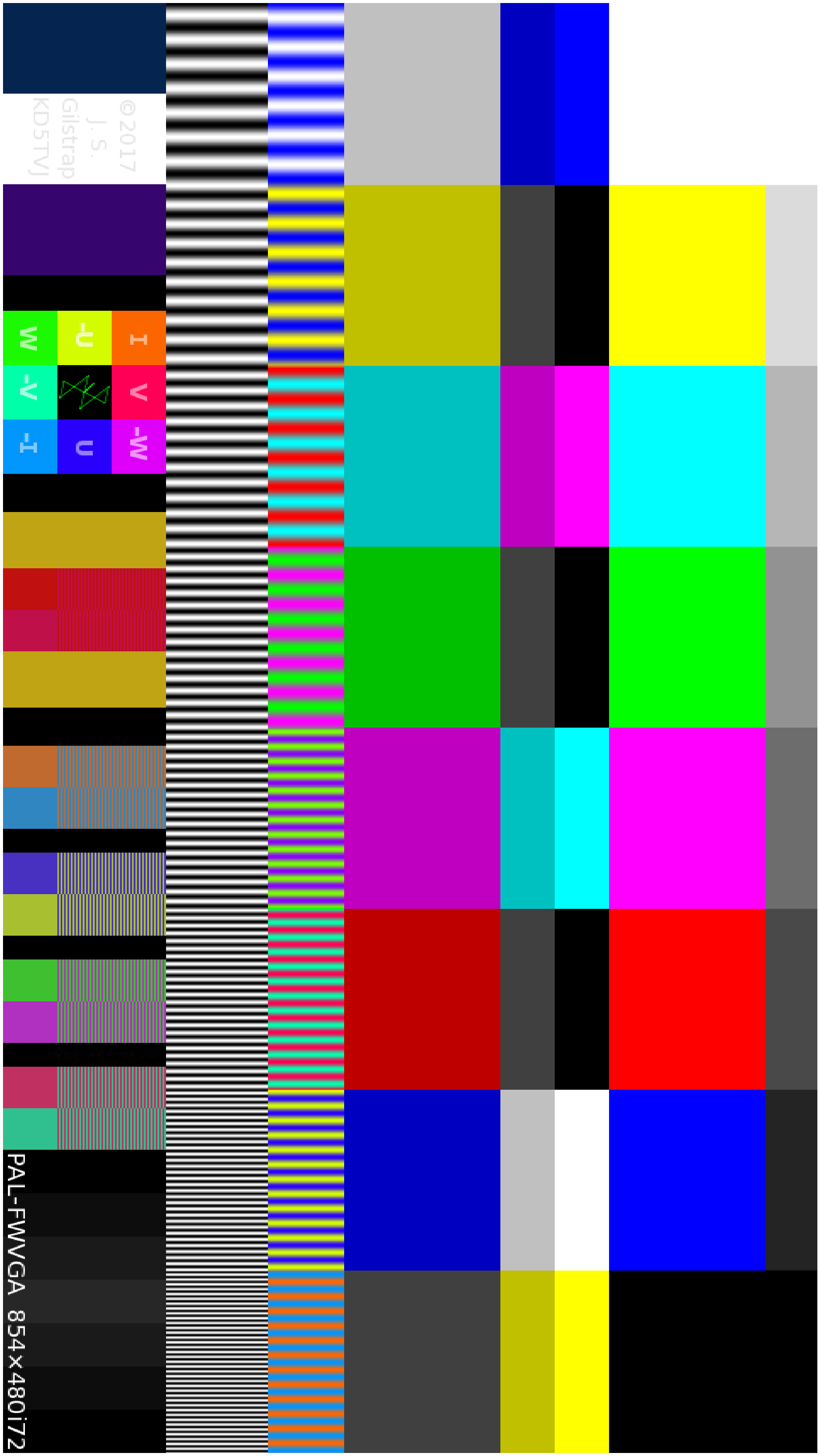
1.060416MHz
84×12624Hz
(142¾ Lines)

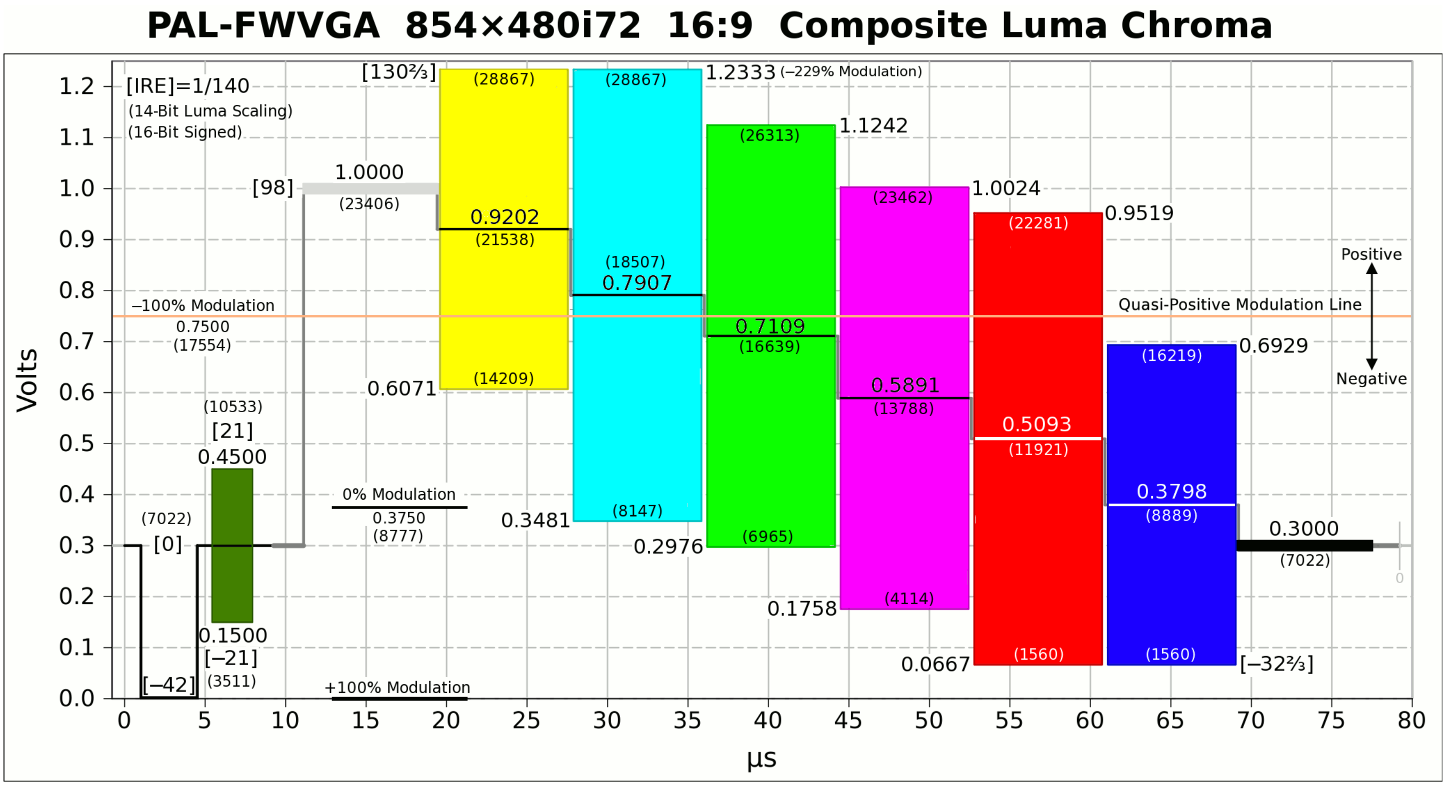
1.489632MHz
118×12624Hz
(200½ Lines)

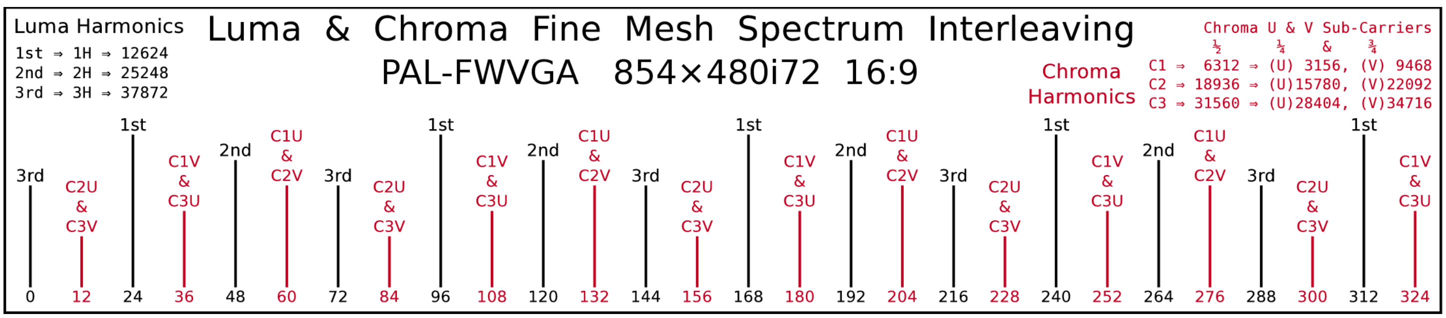
2.120832MHz
168×12624Hz
(285½ Lines)

2.991888MHz
237×12624Hz
(402¾ Lines)

4.229040MHz
335×12624Hz
(569⅓ Lines)

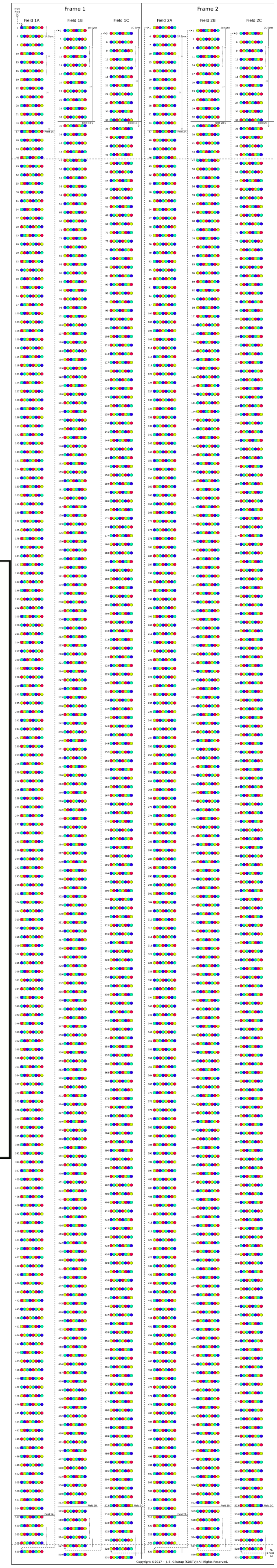




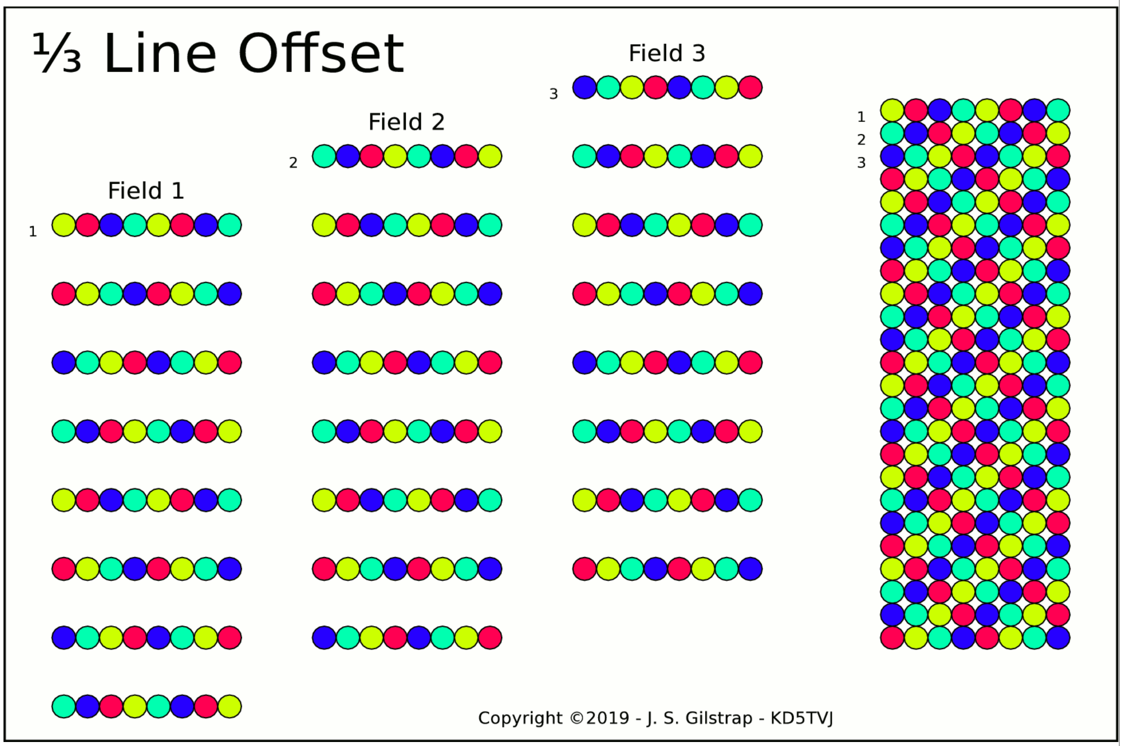


In the image above using a 3:1 interlace the normalized spectrum distribution of Luma with PAL Chroma is shown at the fine mesh level. The 3:1 interlace with a 72Hz field rate ending with ⅓ line causes the Luma and Chroma harmonics to be placed at 24Hz intervals which is also the frame rate. When a 3:1 interlace is used with PAL Chroma the sub-carrier is placed at 3×H×[Integer+½]÷2 (H = Horizontal Sync) so at the coarse mesh level the U & V Chroma clusters will lie on the ¼ & ¾ offsets respectively, in between the Luma Clusters. Having both the Luma and Chroma fine mesh harmonics spaced at 24Hz intervals for cluster triads, the hroma SC being placed on the ¼ mark, and that H/2 is evenly divisible by 24 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 ¼ & ¾ offsets also creates overlapping Chroma harmonics from the U & V channels in a triad configuration of: C1V & C3U, C1U & C2V, and C3V & C2U. 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 a 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 ½FrameRate for both.

To the right is the chroma dot sequence for a **526** line format using a ⅓ 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 the axes close to **I** & **Q** to invert **180°** every **2** lines in a flip-switch manner. The directions that **U** & **V** rotate (shift) on screen will depend on whether the **H/2** multiplier ends with ¼ or ¾ , **625** PAL ends with ¾ while **525** PAL-M & **625** PAL-N ends with ¼ causing chroma dot patterns to be a mirror image of each other. Depending on whether ¼ or ¾ is used, in the image to the right the diagonal representation of the dots for **U** or **V** may or may not be mirror reversed along the vertical.

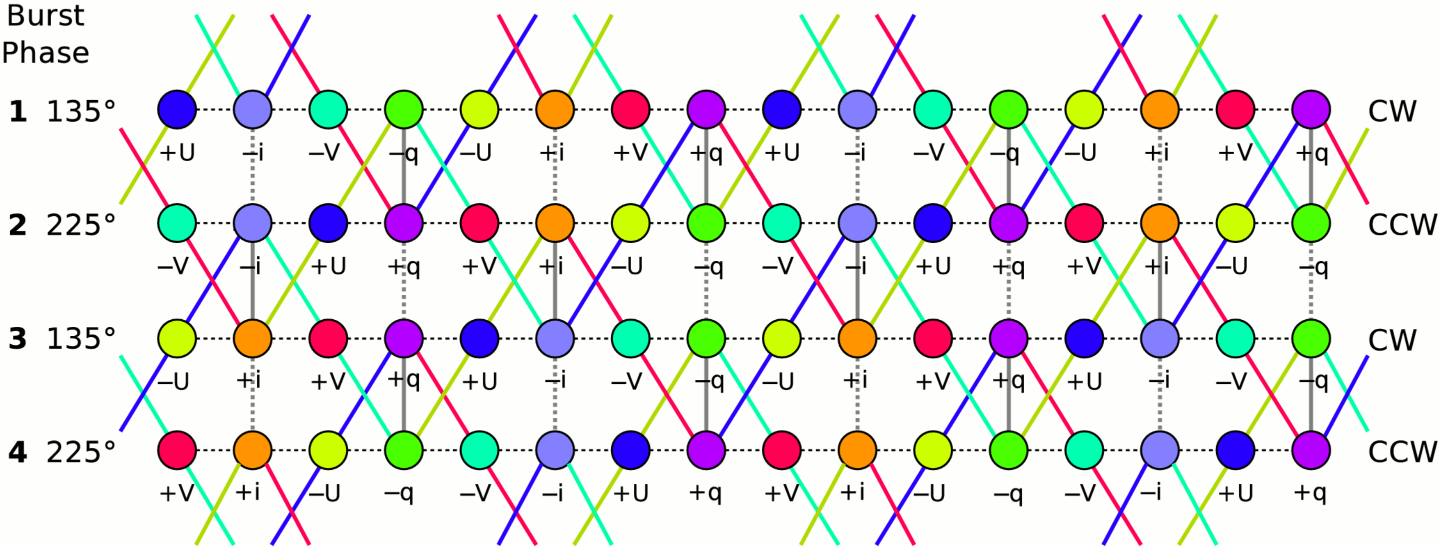


To view the full **526** lines of chroma rotation for **2** frames zoom in on the diagram to the right. You can also highlight the image within the pdf and copy it to the clipboard and then paste it onto an image editor like The GIMP or Photoshop.



In the diagram 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 **1** of a frame, field **2** with line **2**, and field **3** with line **3**. When assembled and properly staggered vertically the pattern on the right is realized.

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



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

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

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

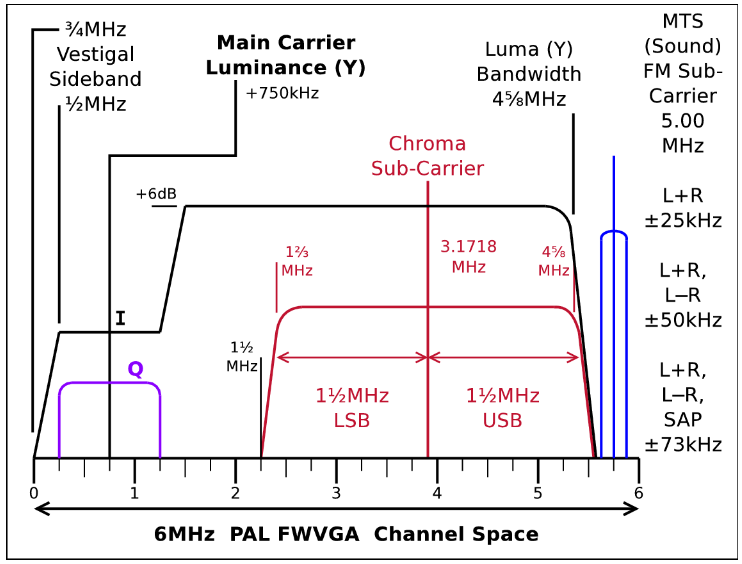
To average out this noise variation between the i & q and U & V sample points the recovered Luma on a line can be a running average of 3 points in a ¼:½:¼ ratio or 5 points in a ⅘×(⅛:¼:½:¼:⅛) ratio. This averaging has minimal effect on sharpness since the sample rate is ~3¾ times the image resolution.

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

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

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

To the right is the channel emission mask. Use of the ½MHz **Q** channel with COFDM modulation, not defined yet, could be used to provide static HF data for HD upscaling and motion vector information for both horizontal and vertical panning. A much higher resolution image could be encoded using this additional data. 5.1 digital surround sound (Opus) could also be an option. Program title and description along with broadcast flags or high quality **CC** with graphics is another option. Using receiver synchronous detection with a partially suppressed carrier and quasi-positive modulation will increase transmitter efficiency and S/N ratio thus providing greater coverage.



The **peach** colored line in the composite video image on page 5 defines where positive modulation begins. This is at ~64% luma level reflecting a DC balance of what an average scene could be although this could vary a great deal. In that case another level should be chosen that would better reflcet the overal actual level. Another option is to use a dynamic carrier level to nominally operate as close to a suppressed carrier as possible as long as the receiver's clamper can compensate for this. In every case PLL driven detectors for both carrier's **I** & **Q** signals are needed with the loop filter operation keyed during horizontal and vertical blanking like the colorburst for the chroma oscillator.

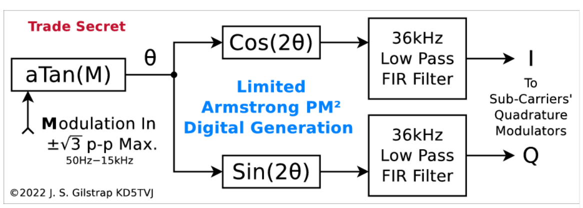
Alternative Narrow Band Sound

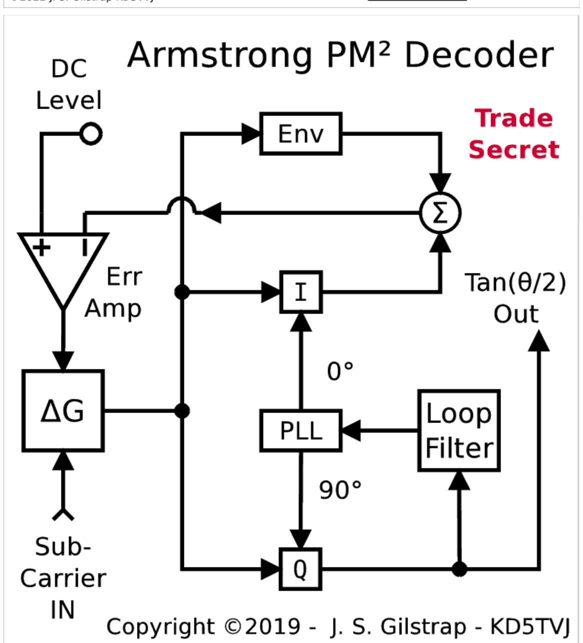
50µs Pre-Emphasis, 13kHz (12¼µs) Pole

2⅔ms Pre-Emphasis 180Hz (884µs) Pole

Harmonic Peak PSNs 2×1ms

2:1 Linear Compression, Attack: 1ms, Decay: 60ms





Sound: Unlimited Armstrong PM²

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X = 1
Y ≤ |±√3|
1 ≤ R ≤ 2
θ ≤ |±60°|
θ=aTan(Y)
R=√(1+Y²)
I=R²×Cos2θ
Q=R²×Sin2θ
I=1–Y²
Q=2Y
Env=R²=1+Y²
2=Env+I
2θ=aTan[2Y÷(1–Y²)]