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

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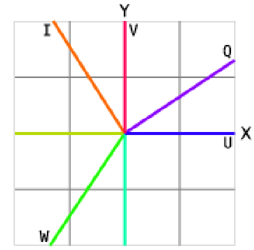
R, G, B, Range: 0–1

		HSV Hue
Y = 0.299×Red + 0.587×Green + 0.114×Blue		
U = 0.492111 × (B – Y) (0.4921110411)	U #2900FC	249.76°
V = 0.877283 × (R – Y) (0.8772832199) Phase inverted @ ½H	V #FF0056	339.76°
W = –0.509370 × (R – Y) – 0.194208 × (B – Y) ⇐ [G – Y] (–0.5093696834) (–0.1942078377)	W #1BFA00	113.52°
I = 0.595901×Red – 0.274557×Green – 0.321344×Blue (0.5959007249) (–0.2745567667) (–0.3213439582)	I #FC6600	24.29°
Q = 0.211537×Red – 0.522736×Green + 0.311200×Blue (0.2115366883) (–0.5227362571) (0.3111995688)	Q #8900FE	272.36°

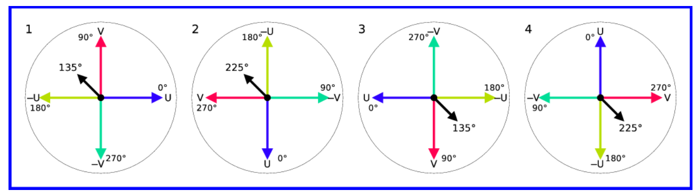
	IRE=1V/140	
Luma (Y) Level:	98	700mV
Sync:	–42	300mV
ColorBurst:	±21	±150mV
Max (Yl & Cy)	130⅔	1.23̅V
Min (Rd & Bl)	–32⅔	66⅔mV

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 **1**ST 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.

Full Wide VGA Standard Definition

PAL-FWVGA 24PsF 480i72 16:9

+46⅔% NTSC/PAL-M & **+3%** PAL-B/G within a **6**MHz Channel Space
70⅖×39⅗cm ⇒ **80⅗**cm/**31¾"** Diag, **825**µm Line Pitch
3.172MHz Chroma

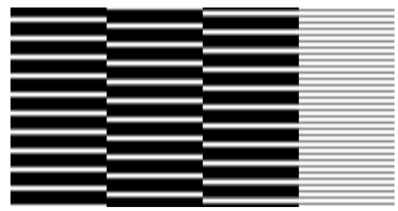
General: Fair Contrast

Aspect Ratio	16:9	119:80 ≈ 1.4874
Total Picture Pixels (Digital)	854×480 ; 409920 Pixels	714×480 ; 342720
Kell Factor (Analog Resolution)	604×340 ; 204960 Pixels	505×340 ; 171360
Maximum Digital Equiv. @−9dB	857×480 ; 411360 Pixels	606×340 ; 205680

Vertical: Pixel Aspect 1:1.196

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: 504⅚ Max@−9dB:606

Lines Per Second	12.624kHz
Period (HP)	79.214µs (502½)
Picture	69.913µs (443½) OverScan
Total Picture Pixels	524⅜≈1⅔×YBW×(HP−HB) ; (504⅚+19½)≈3¾%,2⅗µs
Viewable Picture Pixels/Line	504⅚ ; 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	4½MHz, Full Cut 4⅚MHz
Vestigial Sideband	Vestigial ¾MHz, Corner ½MHz
Chroma:	Sub-Sampling 4⅜:2:2
Sub-Carrier	3.17178MHz ; 8× ⇒ 25.37424MHz
½H Odd Harmonic −¼	502½:**251¼**:167½
U Bandwidth	2⅛MHz (USB +1⅖MHz & LSB −2⅛MHz)
V Bandwidth	2⅛MHz (USB +1⅖MHz & LSB −2⅛MHz)
Color Burst Duration	2.838µs ; 9 cycles 2×(1½+9+4½)=30
Baseband Guard	⅘MHz 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	82.056kHz FM 6½×H
Encoding/Compression	Zenith−**dbx** (THAT Corp.) See **NTSC Specifications**

↓↓ Chroma LoR/Freq: 168¼/1¼MHz, 251½/1⅞MHz

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)

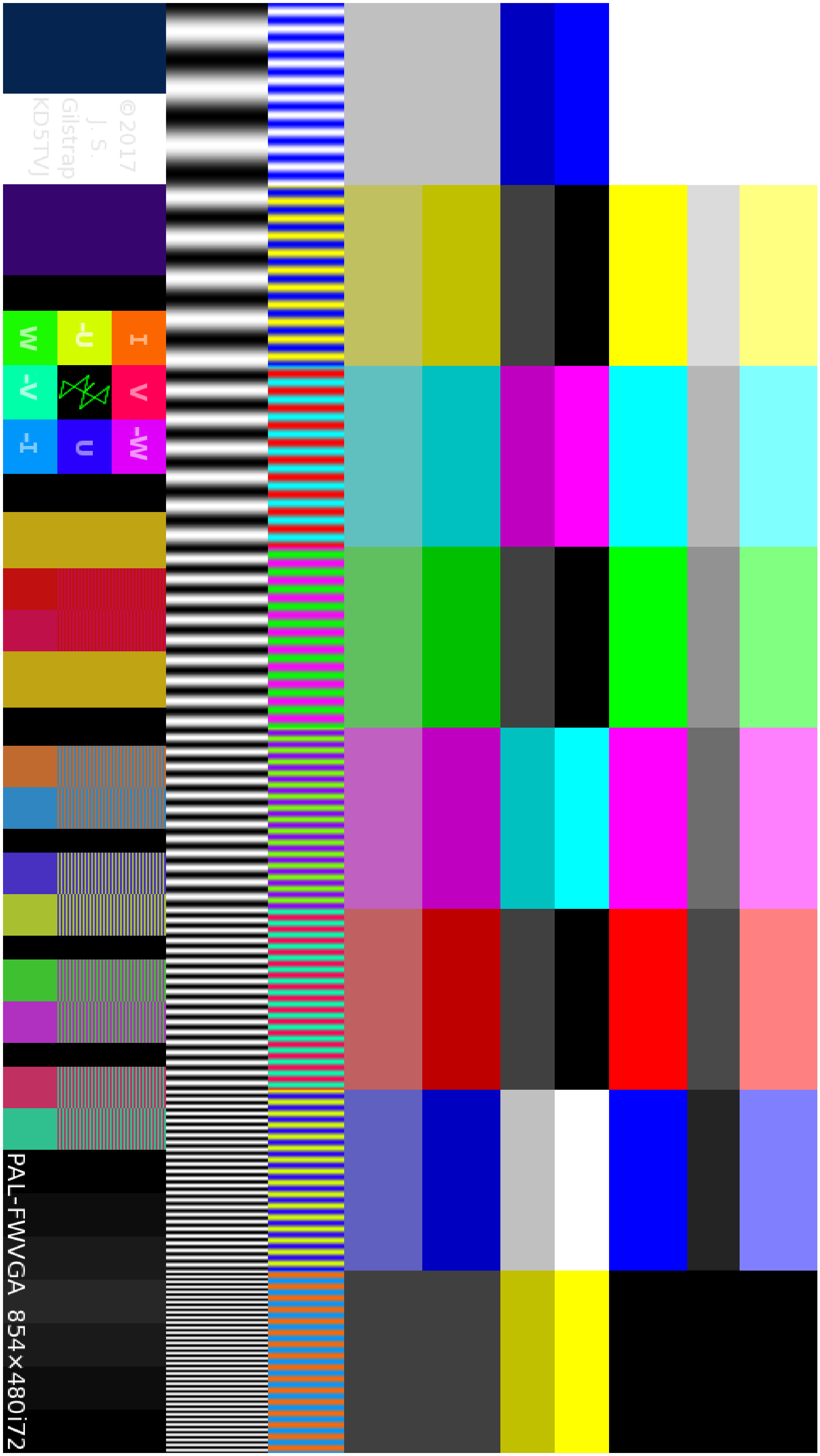
1.060416MHz
84×12624Hz
(142¾ Lines)

1.489632MHz
118×12624Hz
(200½ Lines)

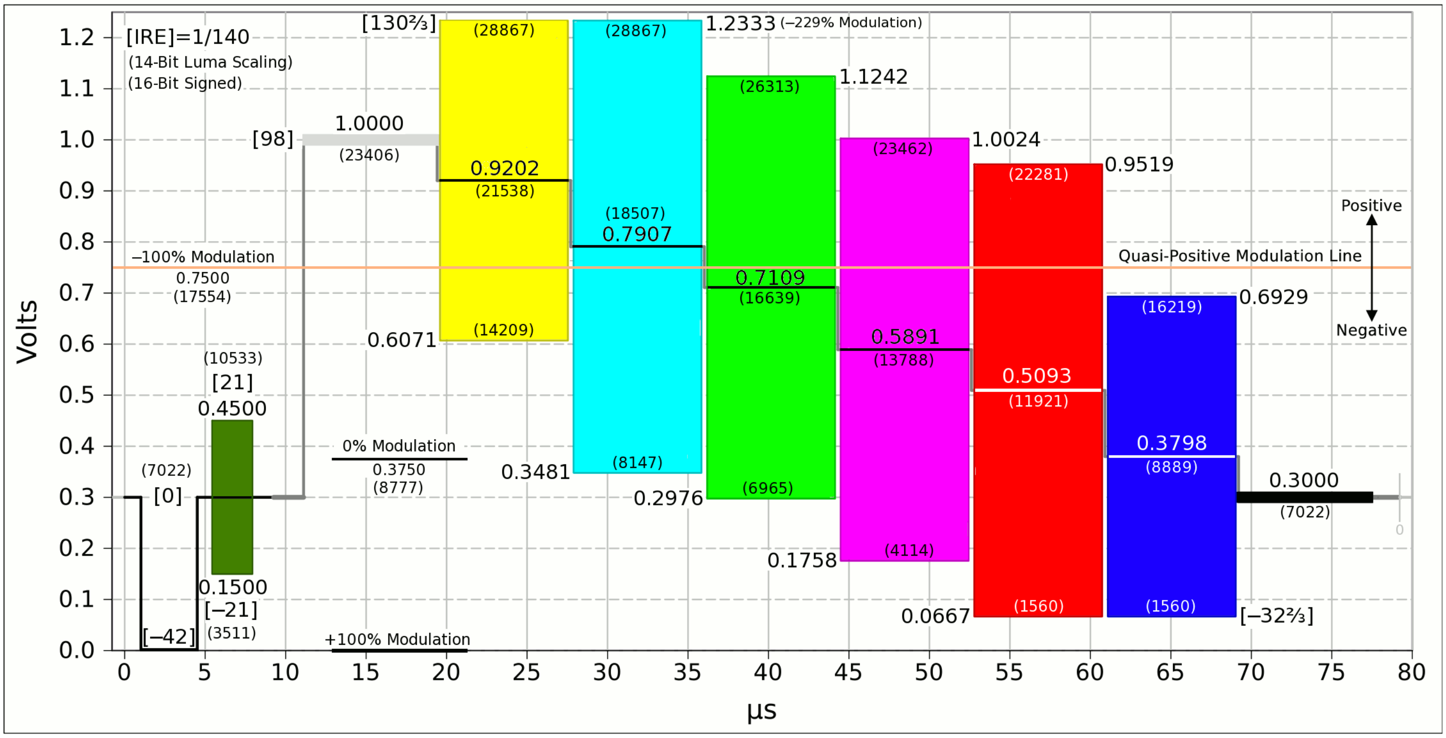
2.120832MHz
168×12624Hz
(285½ Lines)

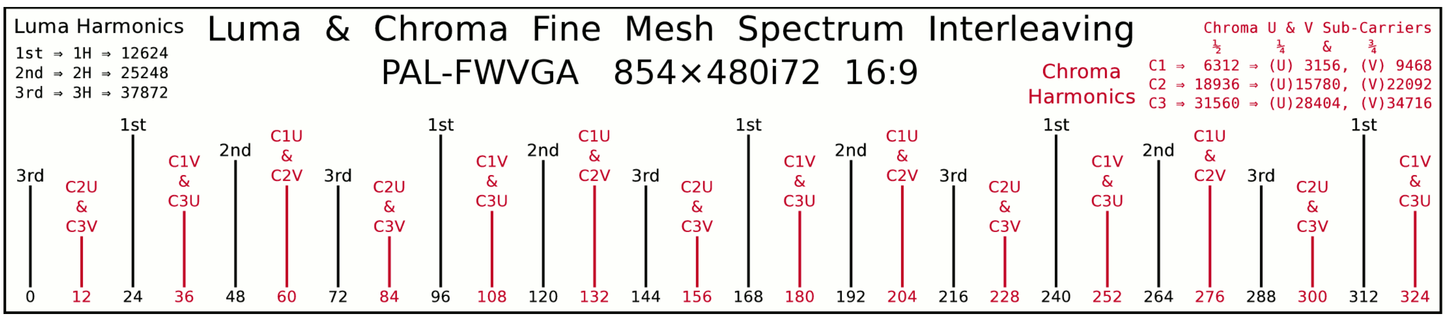
2.991888MHz
237×12624Hz
(402¾ Lines)

4.229040MHz
335×12624Hz
(569⅓ Lines)



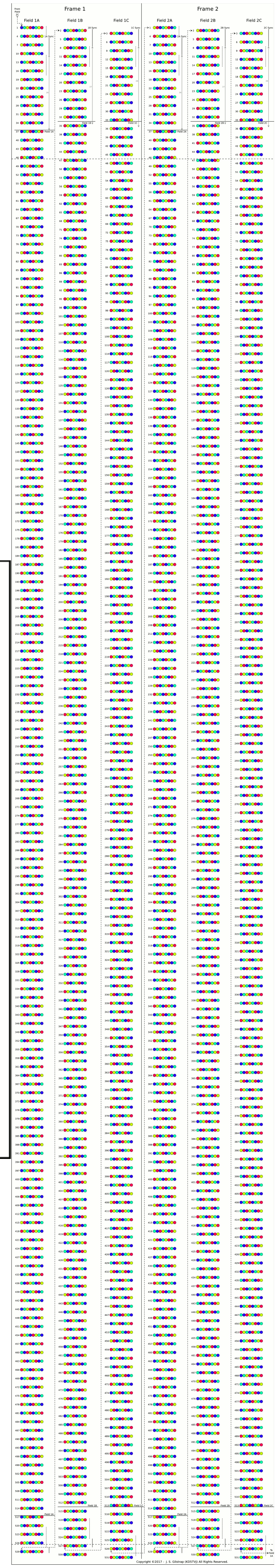
PAL-FWVGA 854×480i72 16:9 Composite Luma Chroma



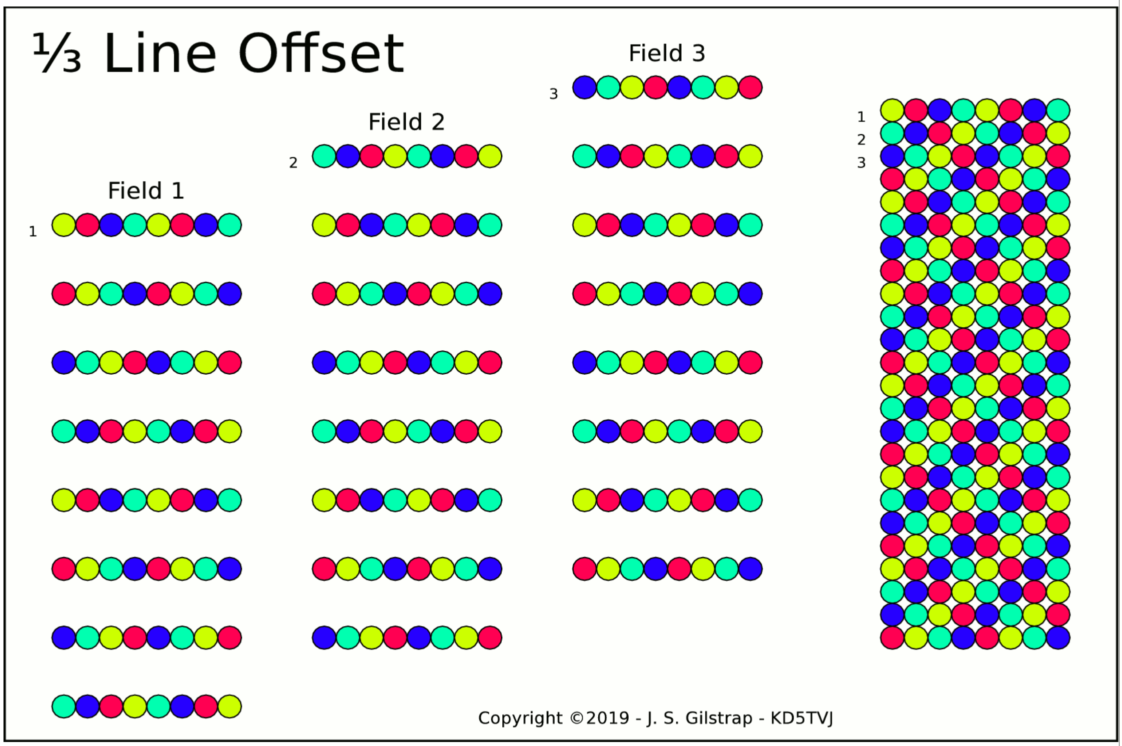


In the image above using a 3:1 interlace the normalized spectrum distribution of Luma with PAL Chroma is shown at the fine mesh level. The 3:1 interlace with a 72Hz field rate ending with ⅓ line causes the Luma and Chroma harmonics to be placed at 24Hz intervals which is also the frame rate. When a 3:1 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.

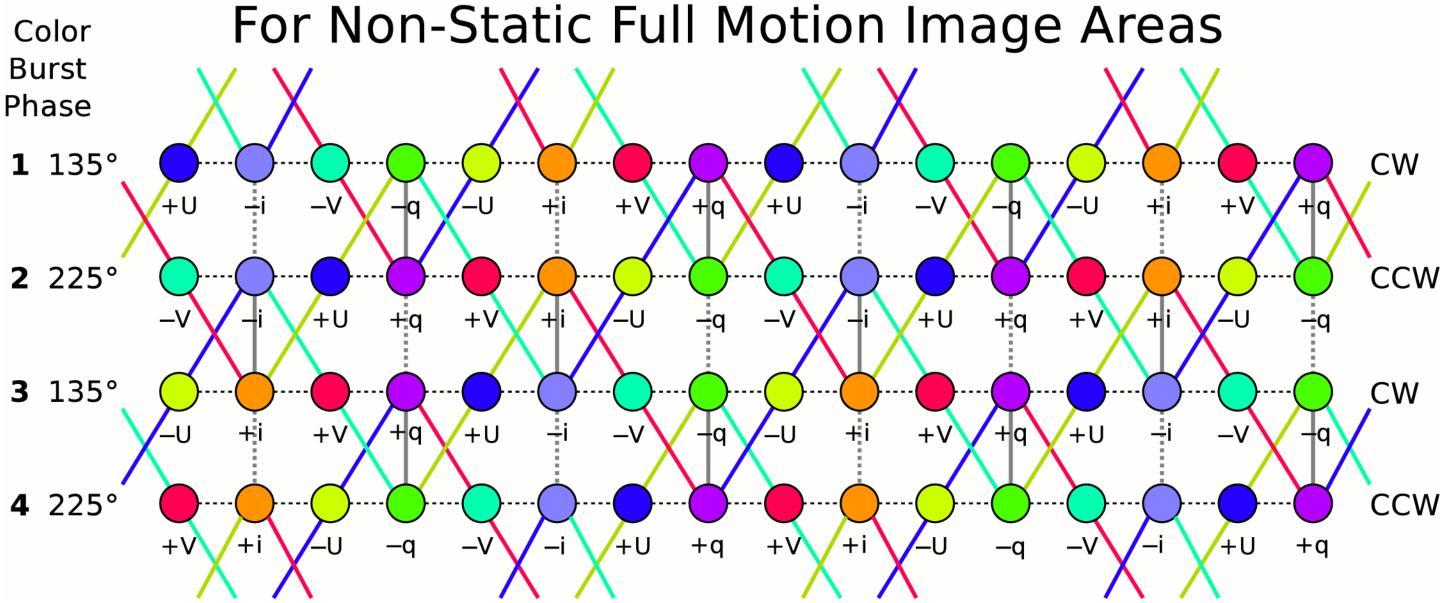


To view the full **526** lines of chroma rotation for **2** frames zoom in on the diagram to the right. You can also highlight the image within the pdf and copy it to the clipboard and then paste it onto an image editor like The GIMP or Photoshop.



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.

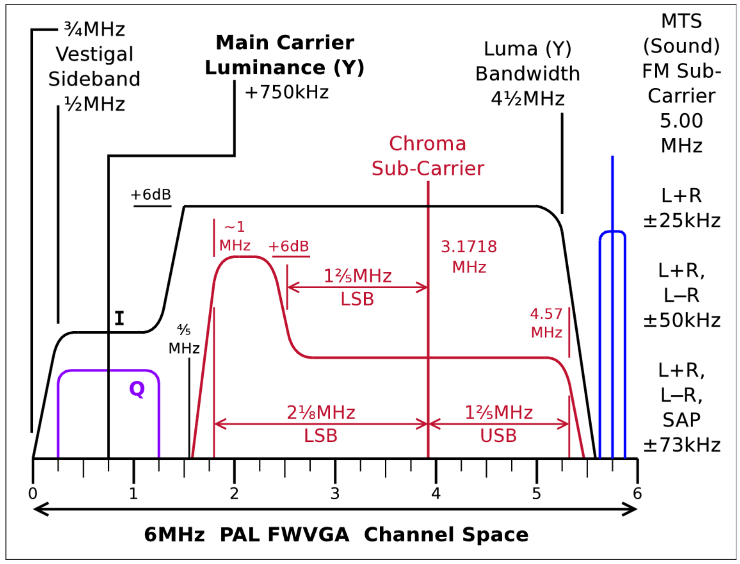
To average out this noise variation between the **i** & **q** and **U** & **V** sample points the recovered **Luma** on a line can be a running average of 3 points in a **¼:½:¼** ratio or 5 points in a **⅘**×(**⅛**:**¼**:**½**:**¼**:**⅛**) ratio. This averaging has minimal effect on sharpness since the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

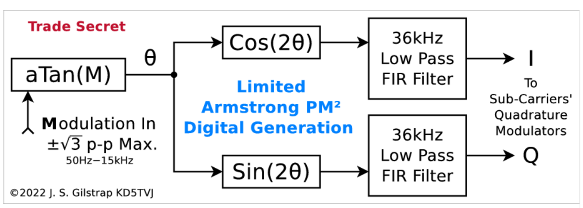
Alternative Narrow Band Sound

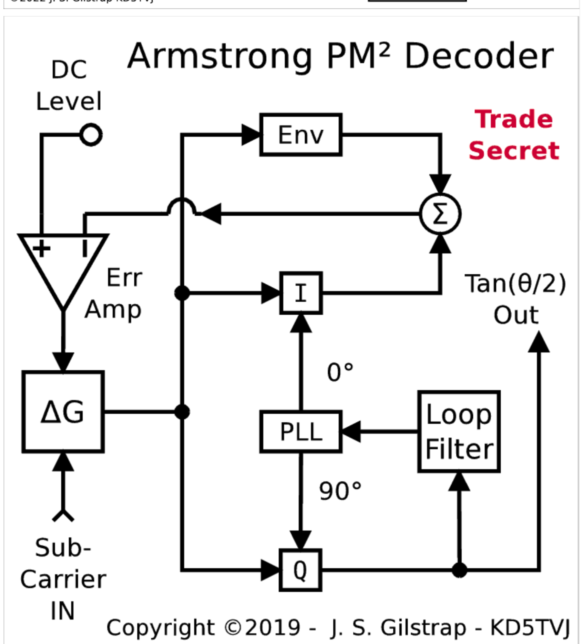
50µs
Pre-Emphasis,
13kHz (12¼µs)
Pole

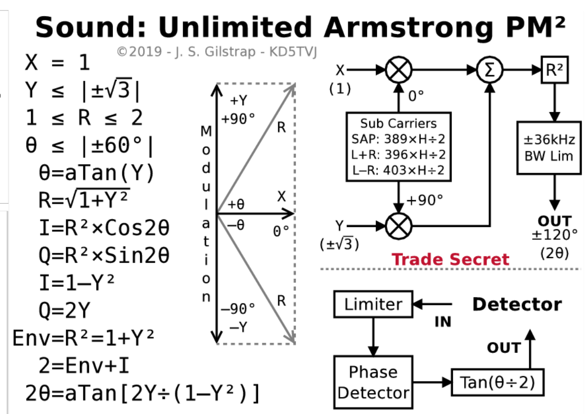
2⅔ms
Pre-Emphasis
180Hz (884µs)
Pole

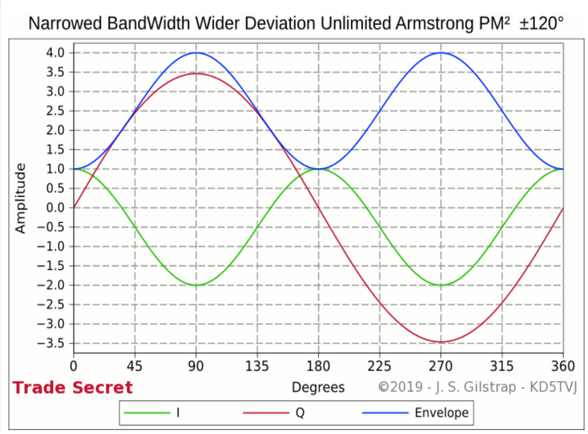
Harmonic Peak
PSNs 2×1ms

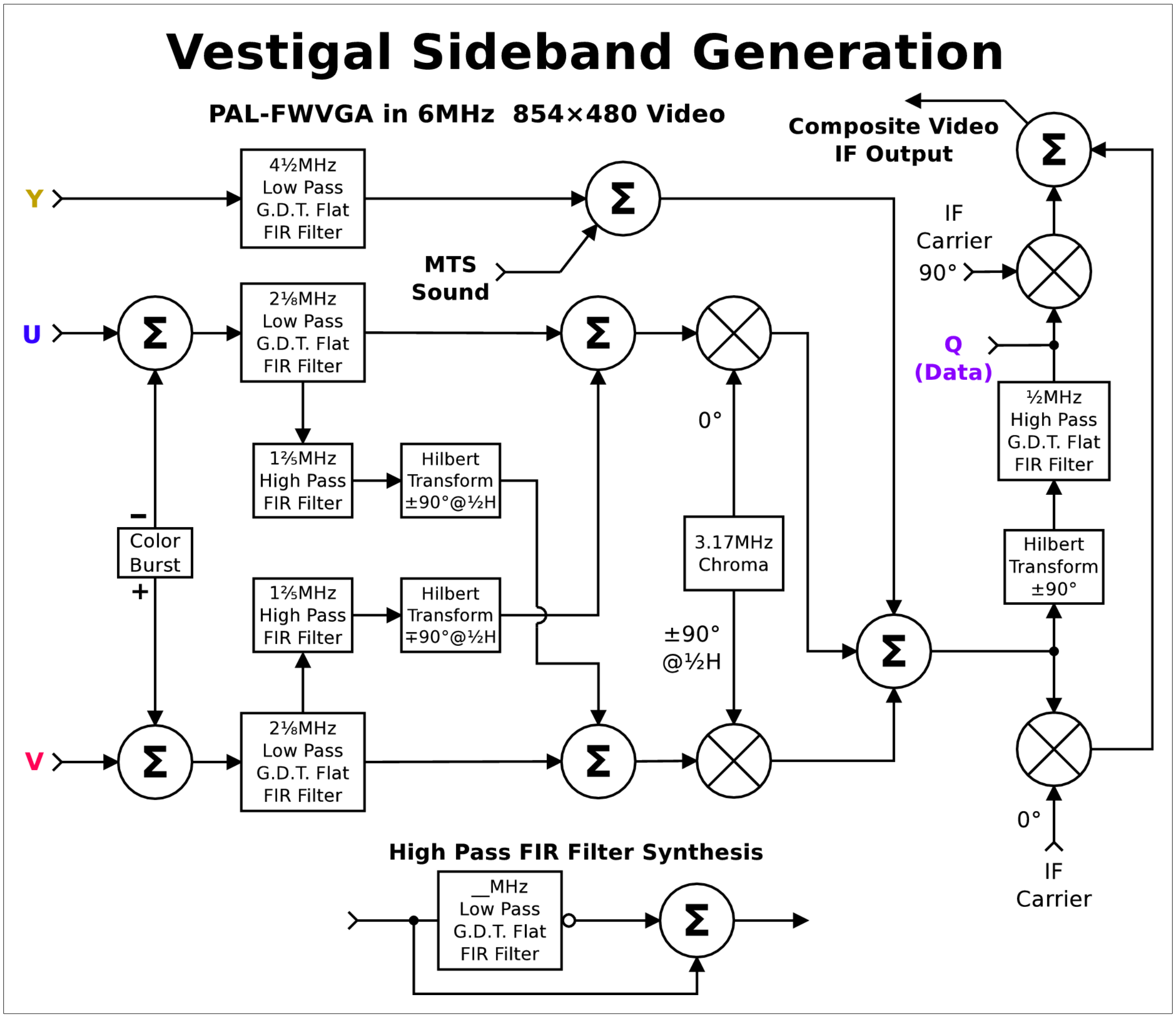
2:1 Linear
Compression,
Attack: 1ms,
Decay: 60ms

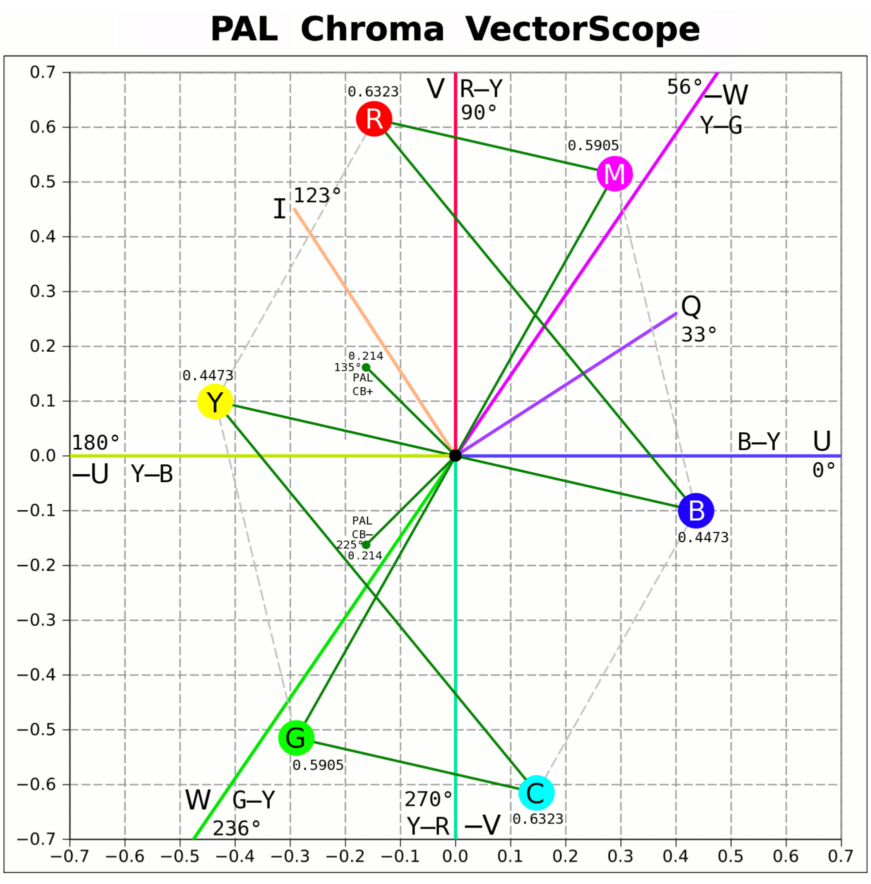









Vestigal Sideband Generation
PAL-FWVGA in 6MHz 854×480 Video
Y
U
V
4½MHz Low Pass G.D.T. Flat FIR Filter
2⅛MHz Low Pass G.D.T. Flat FIR Filter
1⅖MHz High Pass FIR Filter
Hilbert Transform ±90°@½H
Hilbert Transform ∓90°@½H
Color Burst
MTS Sound
0°
3.17MHz Chroma
±90° @½H
Composite Video IF Output
IF Carrier 90°
Q (Data)
½MHz High Pass G.D.T. Flat FIR Filter
Hilbert Transform ±90°
0°
IF Carrier
High Pass FIR Filter Synthesis
__MHz Low Pass G.D.T. Flat FIR Filter


PAL Chroma VectorScope
V R–Y 90°
56° –W Y–G
I 123°
Q 33°
180° –U Y–B
B–Y U 0°
W G–Y 236°
270° Y–R –V
R 0.6323
M 0.5905
Y 0.4473
B 0.4473
G 0.5905
C 0.6323
0.214 135° PAL CB+
PAL CB– 225° 0.214