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

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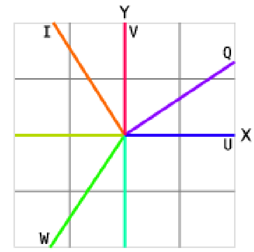
R, G, B, Range: 0–1

$$Y = 0.299 \times Red + 0.587 \times Green + 0.114 \times Blue$$
$$U = 0.492111 \times (B - Y) \quad (0.4921110411)$$
$$V = 0.877283 \times (R - Y) \quad (0.8772832199) \quad \text{Phase inverted @ } \tfrac{1}{2}H$$
$$W = -0.509370 \times (R - Y) - 0.194208 \times (B - Y) \Leftarrow [G - Y]$$
$$(-0.5093696834) \qquad (-0.1942078377)$$
$$I = 0.595901 \times Red - 0.274557 \times Green - 0.321344 \times Blue$$
$$(0.5959007249) \quad (-0.2745567667) \quad (-0.3213439582)$$
$$Q = 0.211537 \times Red - 0.522736 \times Green + 0.311200 \times Blue$$
$$(0.2115366883) \quad (-0.5227362571) \quad (0.3111995688)$$

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

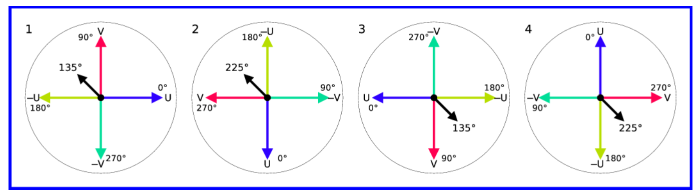
	IRE=1V/140	
Luma (Y) Level:	98	700mV
Sync:	–42	300mV
ColorBurst:	±21	±150mV
Max (Yl & Cy)	130⅔	1.23̅V
Min (Rd & Bl)	–32⅔	66⅔mV

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/Shift & V Switch Phases



Colorburst & Carrier

The **PAL** line phase alternation signal for **V** uses the standard **135°**(+) / **225°**(–) phase toggling of the colorburst. Unsing synchronous detection with a reduced carrier level will increase coverage and signal quality. The sound is placed on the ¼MHz data **Q** channel of the main carrier with additional data possible while the composite video signal modulates the **I** channel.

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**.

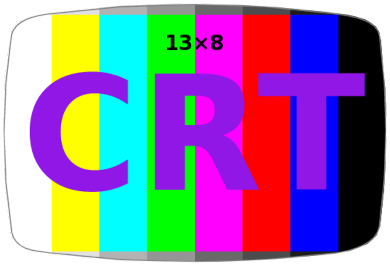
- A **3:1** interlace also creates Hanover lines instead of bars within a completed frame that are stationary and do not scroll unlike a **2:1** interlace; i.e. the hue palette phase rotation reverses on alternate lines of a field and a full frame whereas with a **2:1** interlace the rotation reversal 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 up 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 advanced 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.



Standard Definition

wVGA

PAL-TV **24PsF** **432i72** **13:8**

+17⅖%

+8¾% better than **NTSC/PAL-M** within a **4**MHz Channel Space

54^{1}×33^{3}cm ⇒ **63^{53}**cm Diag, **794**µm Line Pitch **853**µm **29⅘L.P.I.**

21^{94}"×13½" ⇒ **25¾"** Diag **25$^{7}/_{9}$"×14½" ⇒ 29⅗"** **2.293**MHz **Chroma**

655 368 751

General: ½ Contrast

Aspect Ratio **13:8** = 1⅝ ≈ ϕ 147:108 ≈ 1.3613

Total Picture Pixels (Digital) 704×432 ; 304128 Pixels 635 588×432 ; 254016

Kell Factor (Analog Resolution) 498×305 ; 152064 Pixels 449 415×305 ; 127008

Maximum Digital Equiv. @−9dB 761 705×432 ; 309312 Pixels 538 499×305 ; 152280

768×432 137160

Vertical: **16:9** = 1$^{7}/_{9}$ 65½×36⅝=75⅛ **SD Wide** 1.210:1

Frames Per Second 24Hz **Golden** 1.197:1

Total Lines Per Frame 470 Pixel Aspect

Fields Per Second 72Hz

Total Lines Per Field 156⅔

Field Picture Lines 144

Lines Per Blank 12⅔

Blank 1.123ms

Sync 177µs ; 2 Lines

Aspect Ratio [22 / 9] × Super Pixel [32 / 48] = Golden Resolution [704 / 432]

Aspect Ratio [16 / 9] × Super Pixel [48 / 48] = SD Wide Resolution [768 / 432]

Horizontal: Resolution Fair:415⅕ Max@−9dB:499

Lines Per Second 11.280kHz 448¾ 538

Period (HP) 88.652µs (406½) (442½)

Picture 463⅜ 79.275µs (363½) (396½) (448¾+14⅝)≈3⅙%/2½µs

Total Picture Pixels 429⅖ ≈ 1⅔×**Y**BW×(HP−HB) ; (415⅕+12⅕)≈3⅙%/2½µs OverScan

Viewable Picture Pixels/Line 415⅕ ; 76.767µs (352×2 Dot Clock) 76.932 (384×2)

Blank (HB) 448¾ 9.378µs (43) 9.216 (46)

Front Porch 1.090µs (5) 1.002 (5)

Sync 3.489µs (16) 3.506 (17½)

Back Porch 4.798µs (22) 4.708 (23½)

Chroma Rotary Phase™ with TruColor™
2.48724MHz
441:220½:147

Luma & Chroma on **I** Ch. Main Carrier: 3½ (538) 3⅔

Luma (**Y**) Bandwidth @−3dB (506) 3¼MHz FullCut 3½MHz

Vestigial ½MHz ⅓, Corner ⅜MHz ¼

Chroma: Sub-Sampling 2⅙:1:1 4:2:2 19.9656 (8×)

Sub-Carrier 2.29266MHz ; 8× ⇒ 18.34128MHz 2.4957MHz

½H Odd Harmonic 406½:**203¼**:135½ 442½:**221¼**:147½

V Bandwidth (230) 1½MHz (USB +1MHz & LSB −1½MHz) (158) USB +1 MHz

U Bandwidth (230) 1½MHz (USB +1MHz & LSB −1½MHz) (277) LSB −1¾MHz

Color Burst Duration 2.805 3.053µs ; 7 cycles 2×(1¼+7+2¾)=22 (1½+7+3¼)

Baseband Guard ½MHz 491/600ns 1.25/1.14µs

Sound Sub-Carriers on **Q** Ch. of Main Carrier: **Armstrong PM²** ±120° **Stereo: MP3‖Vorbis ‖ Opus 5.1 Surround 4416@256kbps COFDM Carrier within 150kHz Bandwidth**

Sub-Carrier Frequencies: **SAP:** 50.76kHz, **L+R:** 129.72kHz, **L−R:** 208.68kHz

4½×H 11½×H 18½×H

Frequency Response: 50Hz−15kHz @−3dB (Harmonic Peak PSNs 2×1ms)

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

2⅔ms Pre-Emphasis, Pole at 180Hz (884µs)

Alternative Digital: Surround & SAP with analog only **L+R** 60Hz-10kHz (2½×H 28.2kHz)

Processing: Harmonic Peak PSNs 2×1ms

34$^{3}/_{10}$ **L.P.I.** 29⅘

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

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

↓↓ **Chroma** LoR/Freq:86⅗/564kHz, 173⅙/1.128MHz

704×432
Expanded to
1408
2×HorizSample

270.720kHz
(41½)

383.520kHz
(59⅞)

541.440kHz
(83⅛)

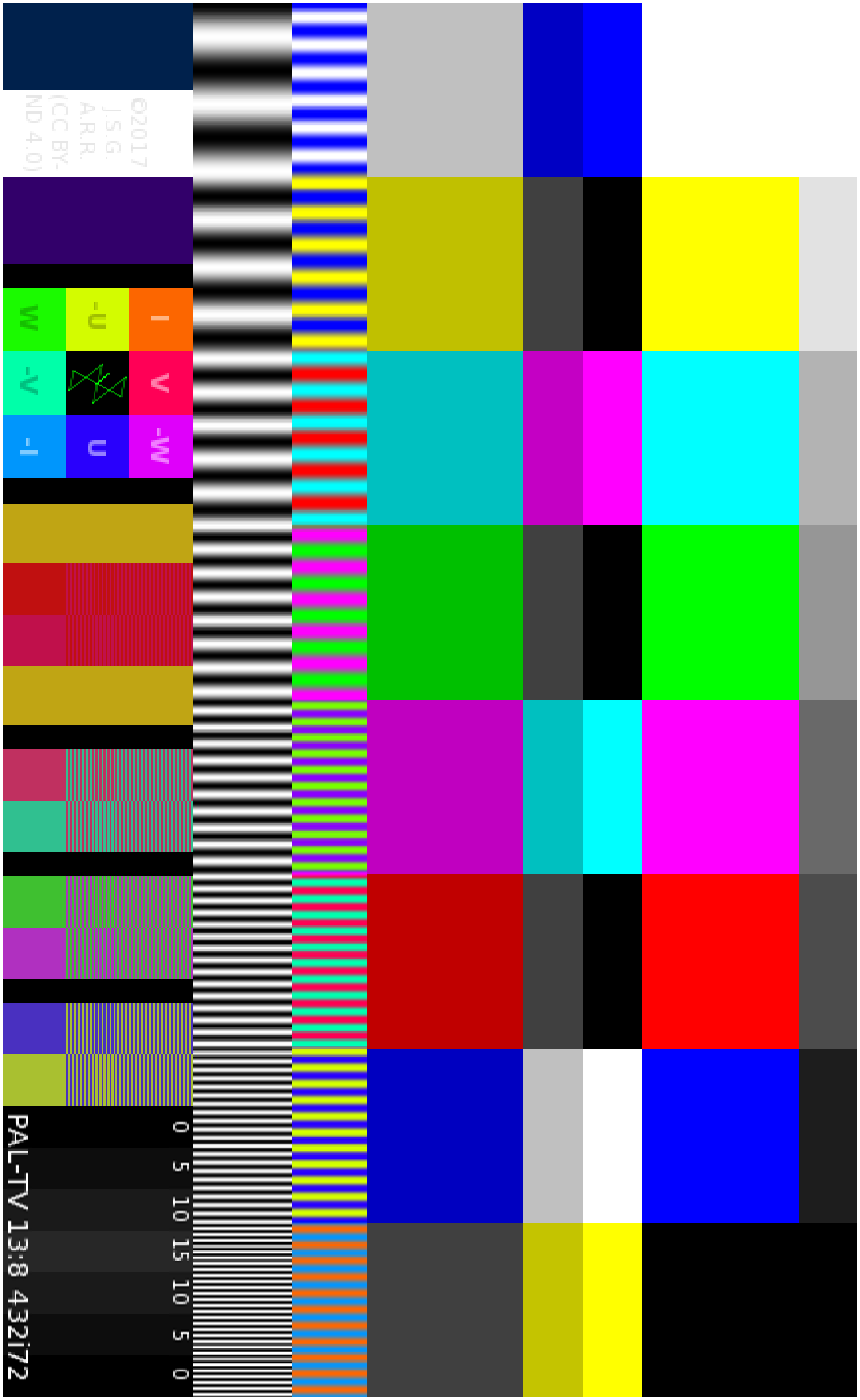
767.040kHz
(117¾)

1.07160MHz
(165¼)

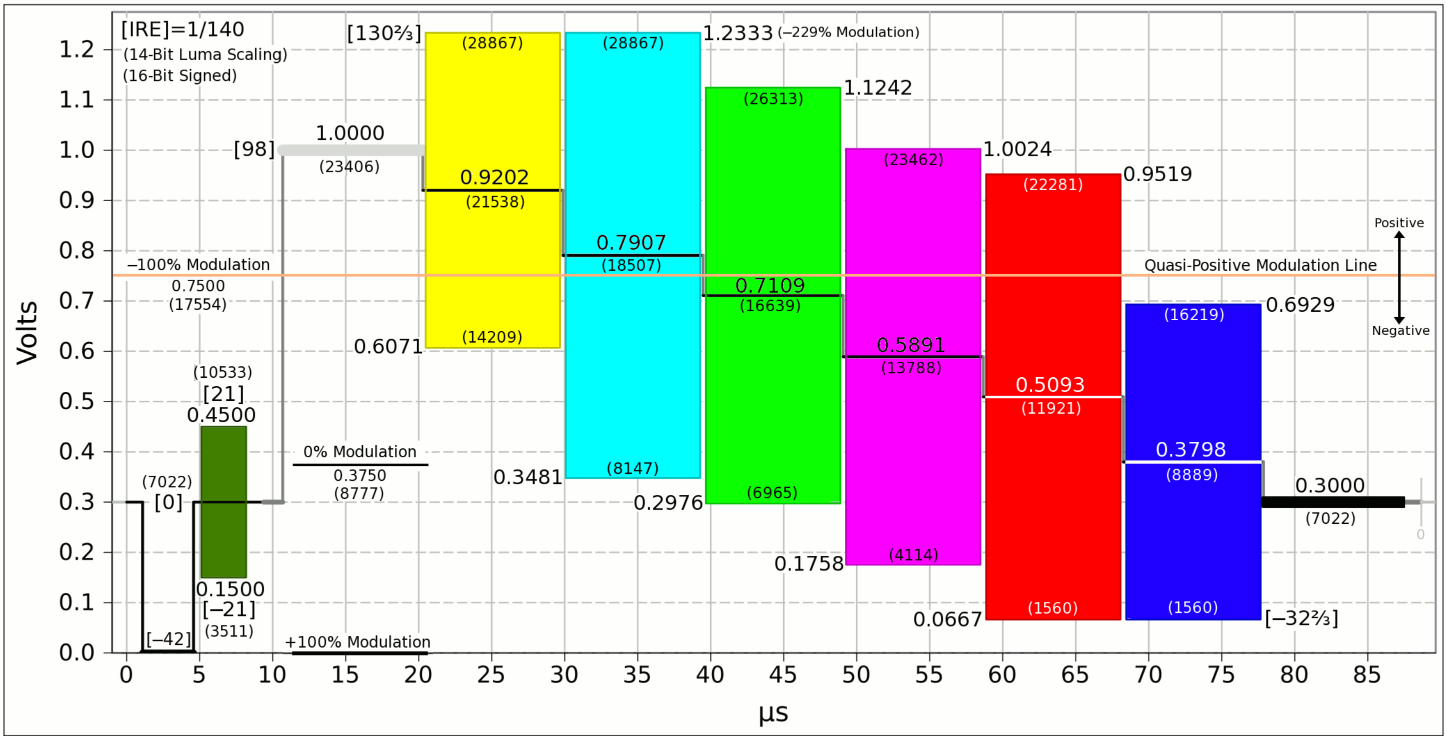
1.52280MHz
(234⅘)

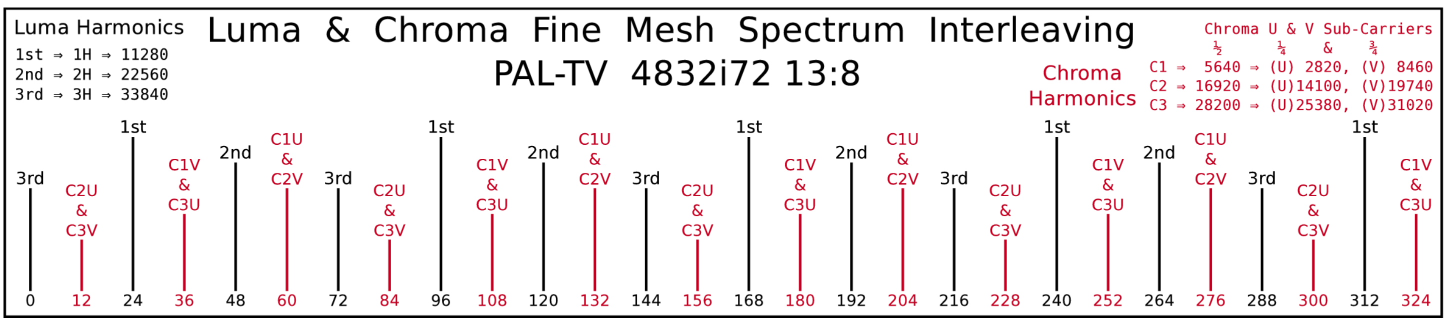
2.15448MHz
(331¾)

3.05690MHz
(469⅓)



PAL-TV 432i72 Composite Luma/Chroma 704×432 Test Pattern

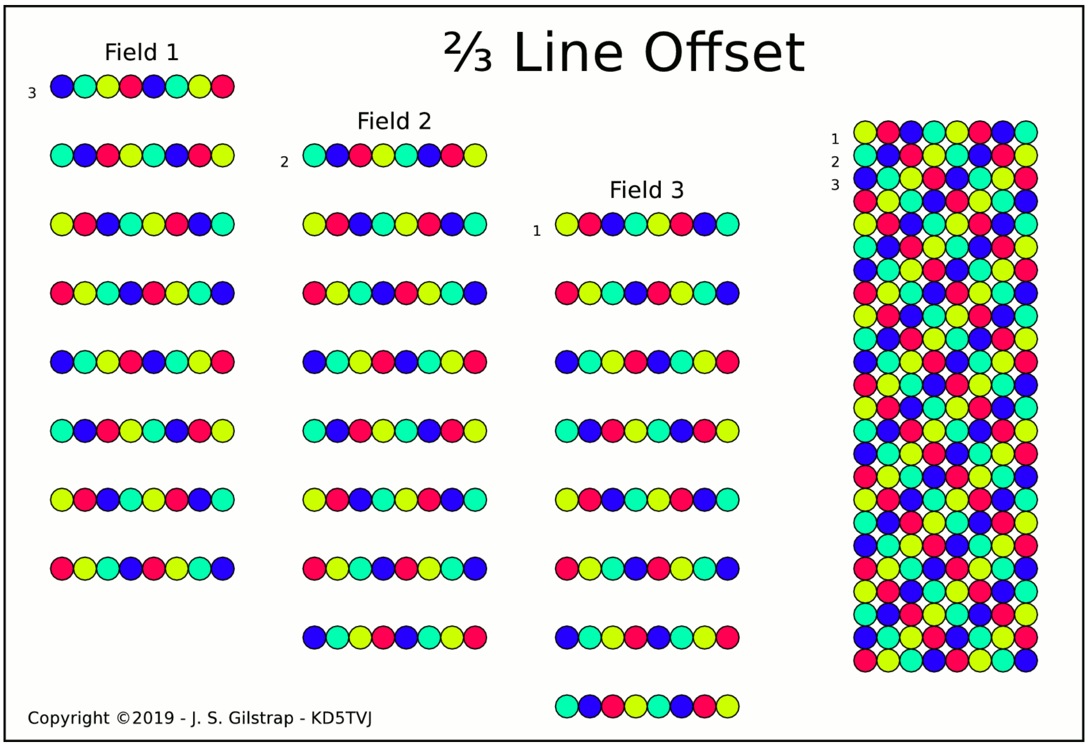




In the image above using a 3:1 interlace the normalized spectrum distribution of Luma with PAL Chroma is shown at the fine mesh level. The 3:1 interlace with a 72Hz field rate ending with ⅓ line causes the Luma and Chroma harmonics to be placed at 24Hz intervals which is also the frame rate. When a 3:1 interlace is used with PAL Chroma the sub-carrier is placed at 3×H×[Integer+½]÷2 (H = Horizontal Sweep) 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 with the Chroma 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 ¼U & ¾V 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 FrameRate/2 for both.

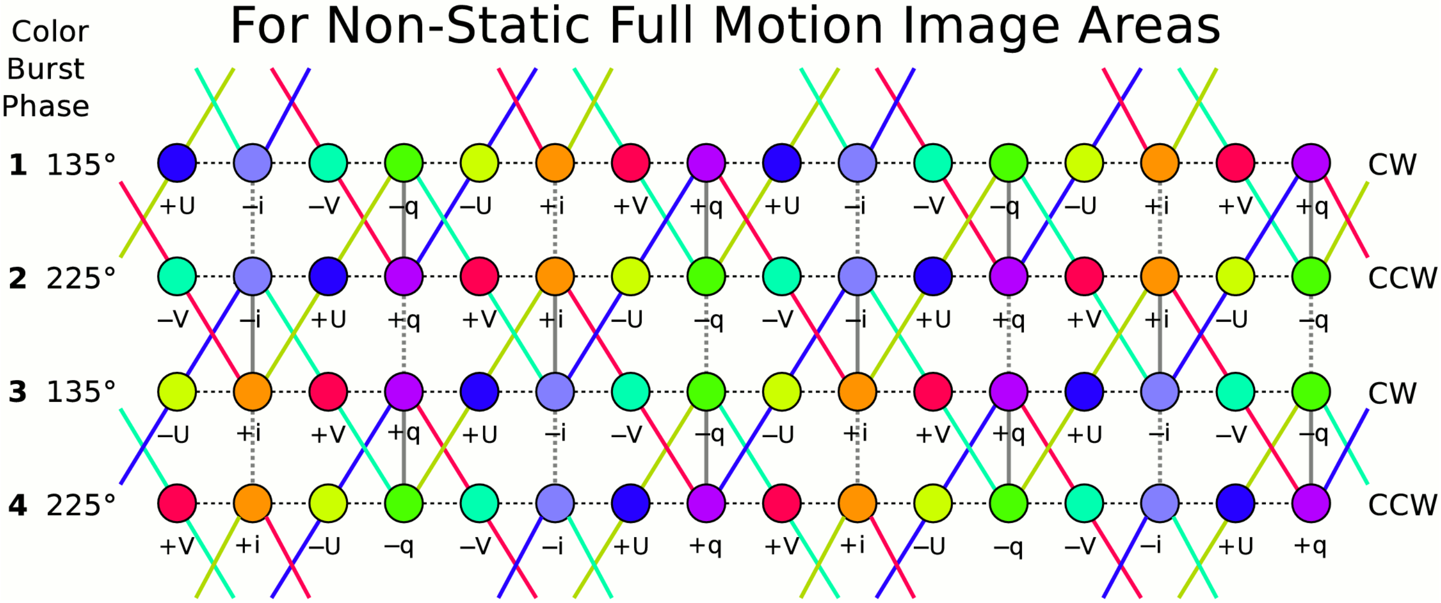
To the right is the chroma dot sequence for a **470** line format using a ⅔ line offset. It shows the **2** frame repeat rate where the chroma dots are inverted on the even frames and the odd frames are non-inverted, or vice-versa, for an on screen per spot basis. The staggered vertical sync pulses cause 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 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 **470** lines of chroma rotation for **2** frames zoom in on the diagram to the right. You can also highlight the image within the pdf and copy it to the clipboard and then paste it onto an image editor like The GIMP or Photoshop.



In the diagram 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.

Sound: Unlimited Armstrong PM²

$X = 1$

$Y \leq |\pm\sqrt{3}|$

$1 \leq R \leq 2$

$\theta \leq |\pm 60°|$

$\theta = \text{aTan}(Y)$

$R = \sqrt{1+Y^2}$

$I = R^2 \times \text{Cos}2\theta$

$Q = R^2 \times \text{Sin}2\theta$

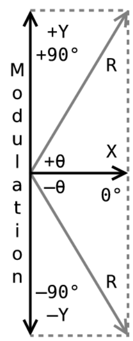
$I = 1 - Y^2$

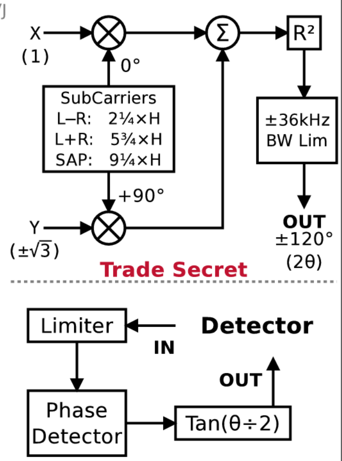
$Q = 2Y$

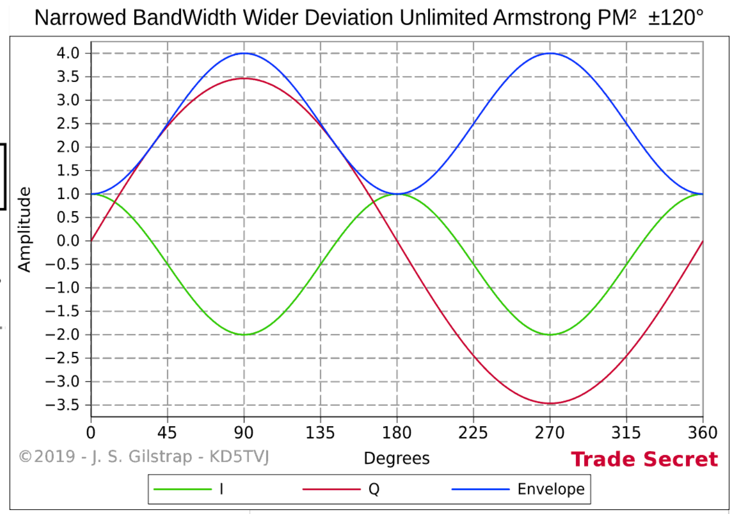
$\text{Env} = R^2 = 1 + Y^2$

$2 = \text{Env} + I$

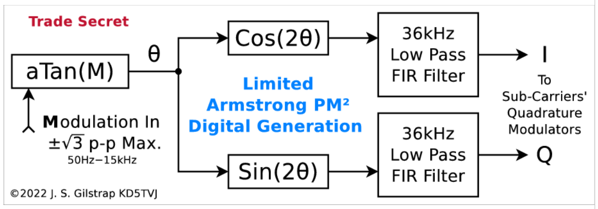
$2\theta = \text{aTan}[2Y \div (1 - Y^2)]$

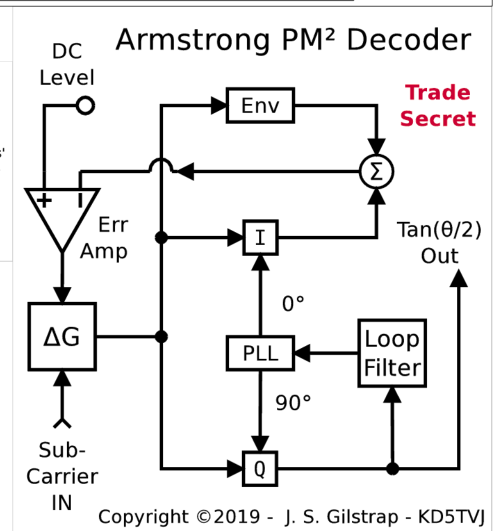




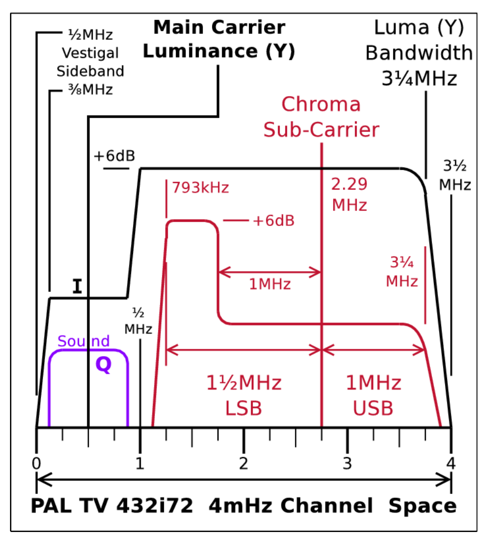


Narrow Band Sound





The sub-carriers which can contain up to 12dB of amplitude modulation can be compressed down to 6dB, possibly following the peak amplitude prior to the squaring of the signal. A full 12dB of compression could be employed but signal quality might be noticeability affected or a 9dB reduction could be a good choice. The over easy compression should have an attack of ~1ms and a decay of ~60ms with the proper amount of compression already achieved prior to the signal modulation, i.e. the compression action should happen ~1ms sooner than the signal modulation. The actual compression modulation should not widen the signal bandwidth any since the attack and decay filtering will only contain low frequency modulation information. This compression will not affect the phase deviation but only lower the S/N ratio by a maximum of 6dB. This will allow twice the headroom and stronger un-modulated carrier levels for all three sound signals on the main **Q** channel. For detection an alternative to hard limiting and Tan(θ/2) wave shaping a similar process used in a C-QUAM® decoder can be employed. The Env and I signals are identical but phase inverted to each other. If the signal doesn't contain any amplitude noise the sum of the two will contain no information, only a DC level. The decoding process will un-modulate any amplitude noise by using the ΔG modulator controlled by the sum of the Env and I signals being compared to a DC reference through a feedback path. This effectively functions as a limiter while also outputting Tan(θ/2) eliminating the need for wave shaping and will also remove any amplitude compression applied.



Cable Band Plan — 4MHz Channel Spacing

Including Broadcast & Amateur Radio Overlapping Spectrum

Cable must carry Broadcast & Ham Channels.

Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable Channels	Broad Cast Channels	Ham Channels
Composite Line Input				00		
	¼	.74570				
112	112½	114.79266	116	01		
116	116½	118.79266	120	02		
120	120½	122.79266	124	03		
124	124½	126.79266	128	04		
128	128½	130.79266	132	05		
132	132½	134.79266	136	06		
136	136½	138.79266	140	07		
140	140½	142.79266	144	08		
144	144½	146.79266	148	09	2M	0
148	148½	150.79266	152	0A		
152	152½	154.79266	156	0B		
156	156½	158.79266	160	0C		
160	160½	162.79266	164	0D		
164	164½	266.79266	168	0E		
168	168½	170.79266	172	0F		
172	172½	174.79266	176	10		
176	176½	178.79266	**180**	11	1	
180	180½	182.79266	184	12	2	
184	184½	186.79266	188	13	3	
188	188½	190.79266	**192**	14	4	
192	192½	194.79266	196	15	5	
196	196½	198.79266	200	16	6	VHF2
200	200½	202.79266	**204**	17	7	
204	204½	206.79266	208	18	8	
208	208½	210.79266	212	19	9	
212	212½	214.79266	**216**	1A	10	
216	216½	218.79266	220	1B		
220	220½	222.79266	224	1C		
224	224½	226.79266	228	1D		
228	228½	230.79266	232	1E		
232	232½	234.79266	236	1F		
236	236½	238.79266	240	20		
240	240½	242.79266	244	21		
244	244½	246.79266	248	22		
248	248½	250.79266	252	23		
252	252½	254.79266	256	24		
256	256½	258.79266	260	25		
260	260½	262.79266	264	26		
264	264½	266.79266	268	27		
268	268½	270.79266	272	28		
272	272½	274.79266	276	29		
276	276½	278.79266	280	2A		
280	280½	282.79266	284	2B		
284	284½	286.79266	288	2C		
288	288½	290.79266	292	2D		
292	292½	294.79266	296	2E		
296	296½	298.79266	300	2F		
300	300½	302.79266	304	30		
304	304½	306.79266	308	31		
308	308½	310.79266	312	32		
312	312½	314.79266	316	33		
316	316½	318.79266	320	34		
320	320½	322.79266	324	35		
324	324½	326.79266	328	36		
328	328½	330.79266	332	37		
332	332½	334.79266	336	38		
336	336½	338.79266	340	39		
340	340½	342.79266	344	3A		
344	344½	346.79266	348	3B		
348	348½	350.79266	352	3C		

Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable Channels	Broad Cast Channels	Ham Channels
620	620½	622.79266	624	80	48	
624	624½	626.79266	628	81	49	
628	628½	630.79266	632	82	50	
632	632½	634.79266	636	83	51	
636	636½	638.79266	640	84	52	
640	640½	642.79266	644	85	53	
644	644½	646.79266	648	86	54	
648	648½	650.79266	652	87	55	
652	652½	654.79266	656	88	56	
656	656½	658.79266	660	89	57	
660	660½	662.79266	664	8A	58	
664	664½	666.79266	668	8B	59	
668	668½	670.79266	672	8C	60	
672	672½	674.79266	676	8D	61	
676	676½	678.79266	680	8E	62	
680	680½	682.79266	684	8F	63	
684	684½	686.79266	688	90	64	
688	688½	690.79266	692	91	65	
692	692½	694.79266	696	92	66	
696	696½	698.79266	700	93	67	
700	700½	702.79266	704	94	68	
704	704½	706.79266	708	95	69	
708	708½	710.79266	712	96	70	
712	712½	714.79266	716	97	71	
716	716½	718.79266	720	98	72	
720	720½	722.79266	724	99	73	
724	724½	726.79266	728	9A	74	
728	728½	730.79266	732	9B	75	
732	732½	734.79266	736	9C	76	UHF
736	736½	738.79266	740	9D	77	Lost
740	740½	742.79266	744	9E	78	to
744	744½	746.79266	748	9F	79	Chan.
748	748½	750.79266	752	A0	80	Repak
752	752½	754.79266	756	A1	81	
756	756½	758.79266	760	A2	82	
760	760½	762.79266	764	A3	83	
764	764½	766.79266	768	A4	84	
768	768½	770.79266	772	A5	85	
772	772½	774.79266	776	A6	86	
776	776½	778.79266	780	A7	87	
780	780½	782.79266	784	A8	88	
784	784½	786.79266	788	A9	89	
788	788½	790.79266	792	AA	90	
792	792½	794.79266	796	AB	91	
796	796½	798.79266	800	AC	92	
800	800½	802.79266	804	AD	93	
804	804½	806.79266	808	AE	94	
808	808½	810.79266	812	AF	95	
812	812½	814.79266	816	B0	96	
816	816½	818.79266	820	B1	97	
820	820½	822.79266	824	B2	98	
824	824½	826.79266	828	B3	99	
828	828½	830.79266	832	B4	100	
832	832½	834.79266	836	B5	101	
836	836½	838.79266	840	B6	102	
840	840½	842.79266	844	B7	103	
844	844½	846.79266	848	B8	104	
848	848½	850.79266	852	B9	105	
852	852½	854.79266	856	BA	106	
856	856½	858.79266	860	BB	107	
860	860½	862.79266	864	BC	108	

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

Lower MHz	Carrier MHz	Chroma MHz	Upper MHz	Cable	Broad Cast	Ham
352	352½	354.79266	356	3D		
356	356½	358.79266	360	3E		
360	360½	362.79266	364	3F		
364	364½	366.79266	368	40		
368	368½	370.79266	372	41		
372	372½	374.79266	376	42		
376	376½	378.79266	380	43		
380	380½	382.79266	384	44		
384	384½	386.79266	388	45		
388	388½	390.79266	392	46		
392	392½	394.79266	396	47		
396	396½	398.79266	400	48		
400	400½	402.79266	404	49		
404	404½	406.79266	408	4A		
408	408½	410.79266	412	4B		
412	412½	414.79266	416	4C		
416	416½	418.79266	420	4D		
420	420½	422.79266	424	4E		1
424	424½	426.79266	428	4F		2
428	428½	430.79266	432	50		3
432	432½	434.79266	436	51	70CM	4
436	436½	438.79266	440	52		5
440	440½	442.79266	444	53		6
444	444½	446.79266	448	54		7
448	448½	450.79266	452	55		
452	452½	454.79266	456	56		
456	456½	458.79266	460	57		
460	460½	462.79266	464	58		
464	464½	466.79266	468	59		
468	468½	470.79266	472	5A		
472	472½	474.79266	**476**	5B	11	
476	476½	478.79266	480	5C	12	
480	480½	482.79266	484	5D	13	
484	484½	486.79266	**488**	5E	14	
488	488½	490.79266	492	5F	15	
492	492½	494.79266	496	60	16	
496	496½	498.79266	**500**	61	17	
500	500½	502.79266	504	62	18	
504	504½	506.79266	508	63	19	
508	508½	510.79266	**512**	64	20	
512	512½	514.79266	516	65	21	
516	516½	518.79266	520	66	22	
520	520½	522.79266	**524**	67	23	
524	524½	526.79266	528	68	24	
528	528½	530.79266	532	69	25	
532	532½	534.79266	**536**	6A	26	UHF
536	536½	538.79266	540	6B	27	
540	540½	542.79266	544	6C	28	
544	544½	546.79266	**548**	6D	29	
548	548½	550.79266	552	6E	30	
552	552½	554.79266	556	6F	31	
556	556½	558.79266	**560**	70	32	
560	560½	562.79266	564	71	33	
564	564½	566.79266	568	72	34	
568	568½	570.79266	**572**	73	35	
572	572½	574.79266	576	74	36	
576	576½	578.79266	580	75	37	
580	580½	582.79266	**584**	76	38	
584	584½	586.79266	588	77	39	
588	588½	590.79266	592	78	40	
592	592½	594.79266	**596**	79	41	
596	596½	598.79266	600	7A	42	
600	600½	602.79266	604	7B	43	
604	604½	606.79266	**608**	7C	44	
608	608½	610.79266	**612**	7D	45	
612	612½	614.79266	616	7E	46	
616	616½	618.79266	620	7F	47	
864	864½	866.79266	868	BD	109	
868	868½	870.79266	872	BE	110	
872	872½	874.79266	876	BF	111	
876	876½	878.79266	880	C0	112	
880	880½	882.79266	884	C1	113	
884	884½	886.79266	888	C2	114	
888	888½	890.79266	892	C3		
892	892½	894.79266	896	C4		
896	896½	898.79266	900	C5		
900	900½	902.79266	904	C6		
904	904½	906.79266	908	C7		8
908	908½	910.79266	912	C8		9
912	912½	914.79266	916	C9		10
916	916½	918.79266	920	CA	33CM	11
920	920½	922.79266	924	CB		12
924	924½	926.79266	928	CC		13
928	928½	930.79266	932	CD		
932	932½	934.79266	936	CE		
936	936½	938.79266	940	CF		
940	940½	942.79266	944	D0		
944	944½	946.79266	948	D1		
948	948½	950.79266	952	D2		
952	952½	954.79266	956	D3		
956	956½	958.79266	960	D4		
960	960½	962.79266	964	D5		
964	964½	966.79266	968	D6		
968	968½	970.79266	972	D7		
972	972½	974.79266	976	D8		
976	976½	978.79266	980	D9		
980	980½	982.79266	984	DA		
984	984½	986.79266	988	DB		
988	988½	990.79266	992	DC		
992	992½	994.79266	996	DD		
996	996½	998.79266	1000	DE		
1000	1000½	1002.79266	1004	DF		
1004	1004½	1006.79266	1008	E0		
1008	1008½	1010.79266	1012	E1		
1012	1012½	1014.79266	1016	E2		
1016	1016½	1018.79266	1020	E3		
1020	1020½	1022.79266	1024	E4		
1024	1024½	1026.79266	1028	E5		
1028	1028½	1030.79266	1032	E6		
1032	1032½	1034.79266	1036	E7		
1036	1036½	1038.79266	1040	E8		
1040	1040½	1042.79266	1044	E9		
1044	1044½	1046.79266	1048	EA		
1048	1048½	1050.79266	1052	EB		
1052	1052½	1054.79266	1056	EC		
1056	1056½	1058.79266	1060	ED		
1060	1060½	1062.79266	1064	EE		
1064	1064½	1066.79266	1068	EF		
1068	1068½	1070.79266	1072	F0		
1072	1072½	1074.79266	1076	F1		
1076	1076½	1078.79266	1080	F2		
1080	1080½	1082.79266	1084	F3		
1084	1084½	1086.79266	1088	F4		
1088	1088½	1090.79266	1092	F5		
1092	1092½	1094.79266	1096	F6		
1096	1096½	1098.79266	1100	F7		
1100	1100½	1102.79266	1104	F8		
1104	1104½	1106.79266	1108	F9		
1108	1108½	1110.79266	1112	FA		
1112	1112½	1114.79266	1116	FB		
1116	1116½	1118.79266	1120	FC		
1120	1120½	1122.79266	1124	FD		
1124	1124½	1126.79266	1128	FE		
1128	1128½	1130.79266	1132	FF		

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

768×432
Expanded to
1536
2×HorizSample

293.280kHz
(45⅖)

417.360kHz
(64⅔)

586.560kHz
(90⅞)

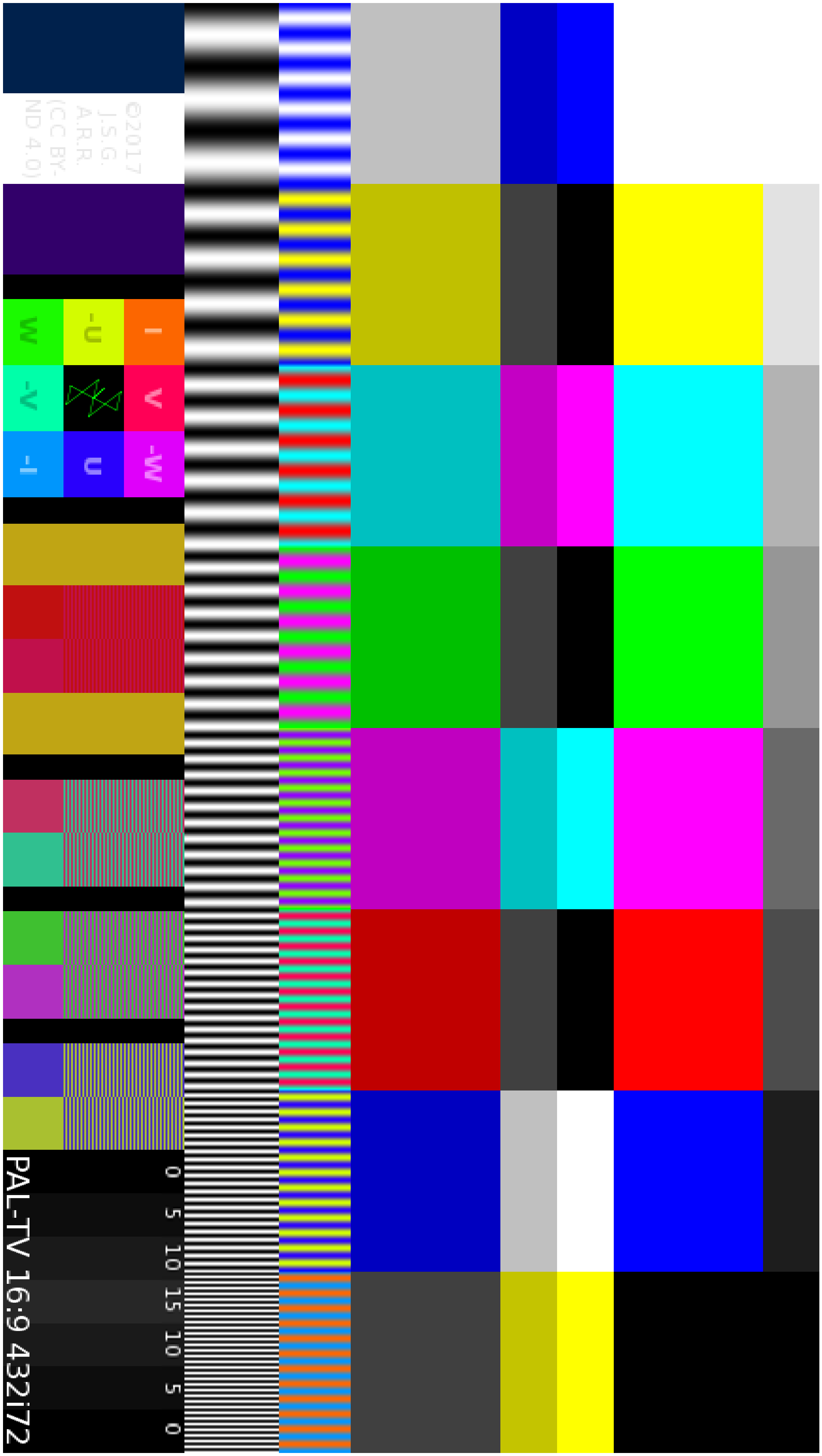
823.440kHz
(127½)

1.173120MHz
(181¾)

1.164880MHz
(255⅛)

2.334960MHz
(361¾)

3.305040MHz
(512)



CRT

Standard Definition

PAL-½Ch

24PsF | **432i72** | VGA **4:3**

+21% better than **VHS** & **88%** of **NTSC** within a **3**MHz Channel Space

18"×13½" ⇒ **22½"** Diag, **794**µm Line Pitch

45¾×34⅕cm ⇒ **57⅛** Diag

Average SD Broadcast Quality

1.87MHz **Chroma**

General: — Fair Contrast

Aspect Ratio	4:3 = 1⅓	119:108 ≈ 1.1031
Total Picture Pixels (Digital)	576×432 ; 311040 Pixels	476×432 ; 205632
Kell Factor (Analog Resolution)	407×305 ; 155520 Pixels	337×305 ; 102816
Maximum Digital Equiv.	572×432 ; 247104 Pixels	404×305 ; 123552

Vertical: — Pixel Aspect 1.208:1

Frames Per Second	24Hz
Total Lines Per Frame	470
Fields Per Second	72Hz
Total Lines Per Field	156⅔
Field Picture Lines	144
Lines Per Blank	12⅔
Blank	1.123ms
Sync	177µs ; 2 Lines

Aspect Ratio × Super Pixel = Pixel Resolution

$$\begin{bmatrix}12\\9\end{bmatrix} \times \begin{bmatrix}48\\48\end{bmatrix} = \begin{bmatrix}576\\432\end{bmatrix}$$

Horizontal: — Resolution Fair:337 Max@−9dB:404

Lines Per Second	11.280kHz
Period (HP)	88.652µs (331½)
Picture	79.426µs (297)
Total Picture Pixels	353 ≈ 1⅔×YBW×(HP−HB) (342⅓+10⅔)≈3%/2⅖µs OverScan
Viewable Picture Pixels/Line	342⅓ ; 77.019µs (288×2 Dot Clock)
Blank (HB)	9.226µs (34½)
Front Porch	0.935µs (3½)
Sync	3.476µs (13½)
Back Porch	4.638µs (17½)

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

Luma (**Y**) Bandwidth @−3dB	**(404)** 2⅝MHz FullCut 2¾MHz
	Vestigial ¼MHz Corner ⅕MHz
Chroma:	Sub-Sampling 2:1:1
Sub-Carrier	1.86966MHz ; 8× ⇒ 14.95728MHz
½H Odd Harmonic	331½:**165¾**:110½
V Bandwidth	**(202)** 1⅓MHz (USB +¾MHz & LSB −1⅓MHz)
U Bandwidth	**(202)** 1⅓MHz (USB +¾MHz & LSB −1⅓MHz)
Color Burst Duration	2.674µs ; 5 cycles 2×(1+5+2¾)=17½
Baseband Guard	⅜MHz

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

Sub-Carrier Frequency: **Mono**: 8½×H 95.88kHz **SAP** **L+R** **L−R**

Armstrong PM² Stereo: 3½×H, 8½×H, 13½×H, ±120°, pg8

Equalization: 50Hz−15kHz @−3dB **39.48** **95.88** **152.28**

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

2⅔ms Pre-Emphasis, Pole at 180Hz (884µs)

Harmonic Peak PSNs 2×1ms

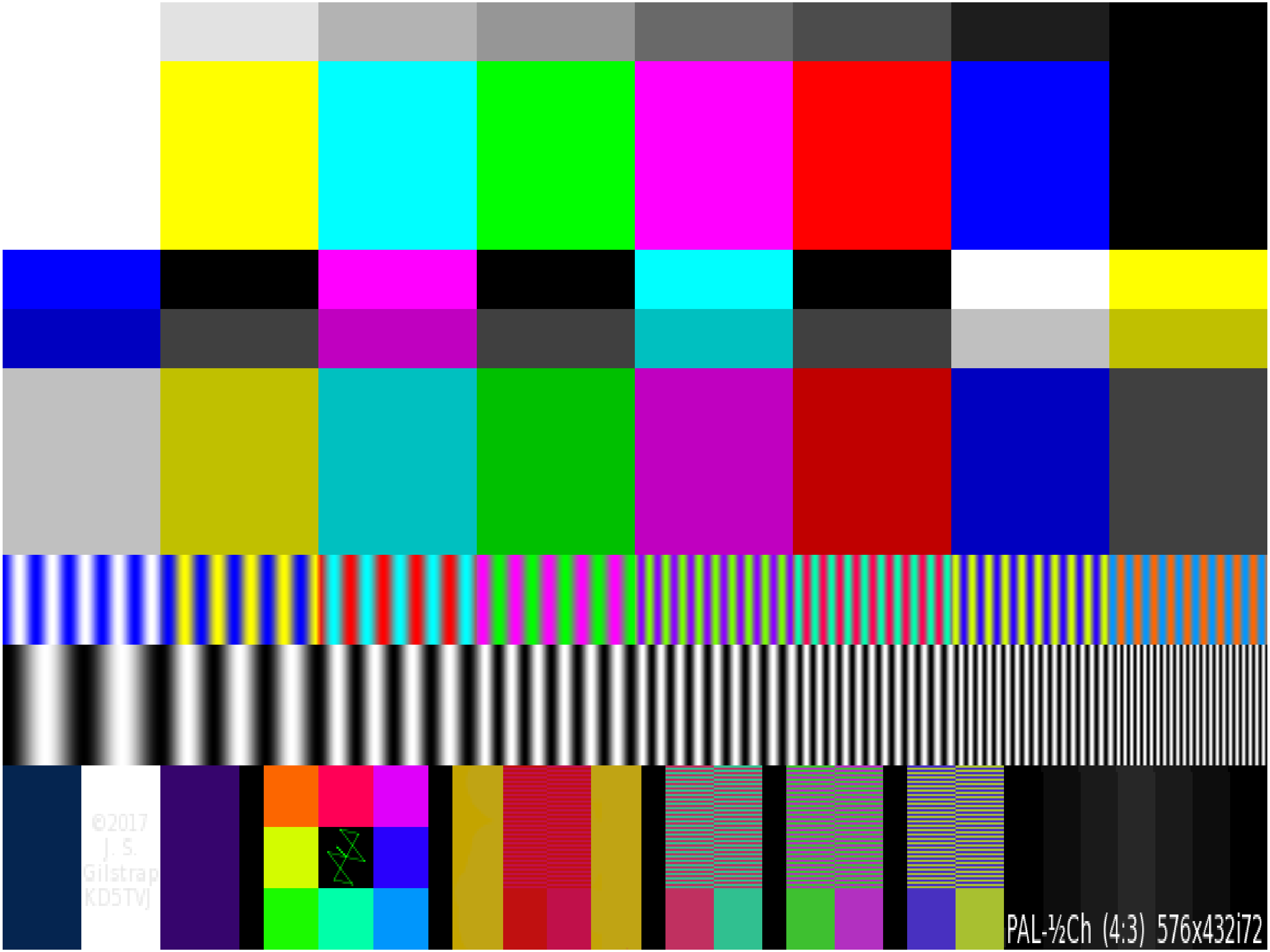
2:1 Linear Compression, Attack: 1ms, Decay: 60ms

576×432

Expnaded to 1152 2×HorizSample

Freq.	LoR	
214.32kHz	33	
315.84kHz	48⅔	
439.92kHz	67¾	L
620.40kHz	95½	u
879.84kHz	135½	m
1.25208MHz	192⅞	a
1.75968MHz	271	
2.49288MHz	384	

↓↓ **Chroma** LoR/Freq: 76½/496kHz, 153/993kHz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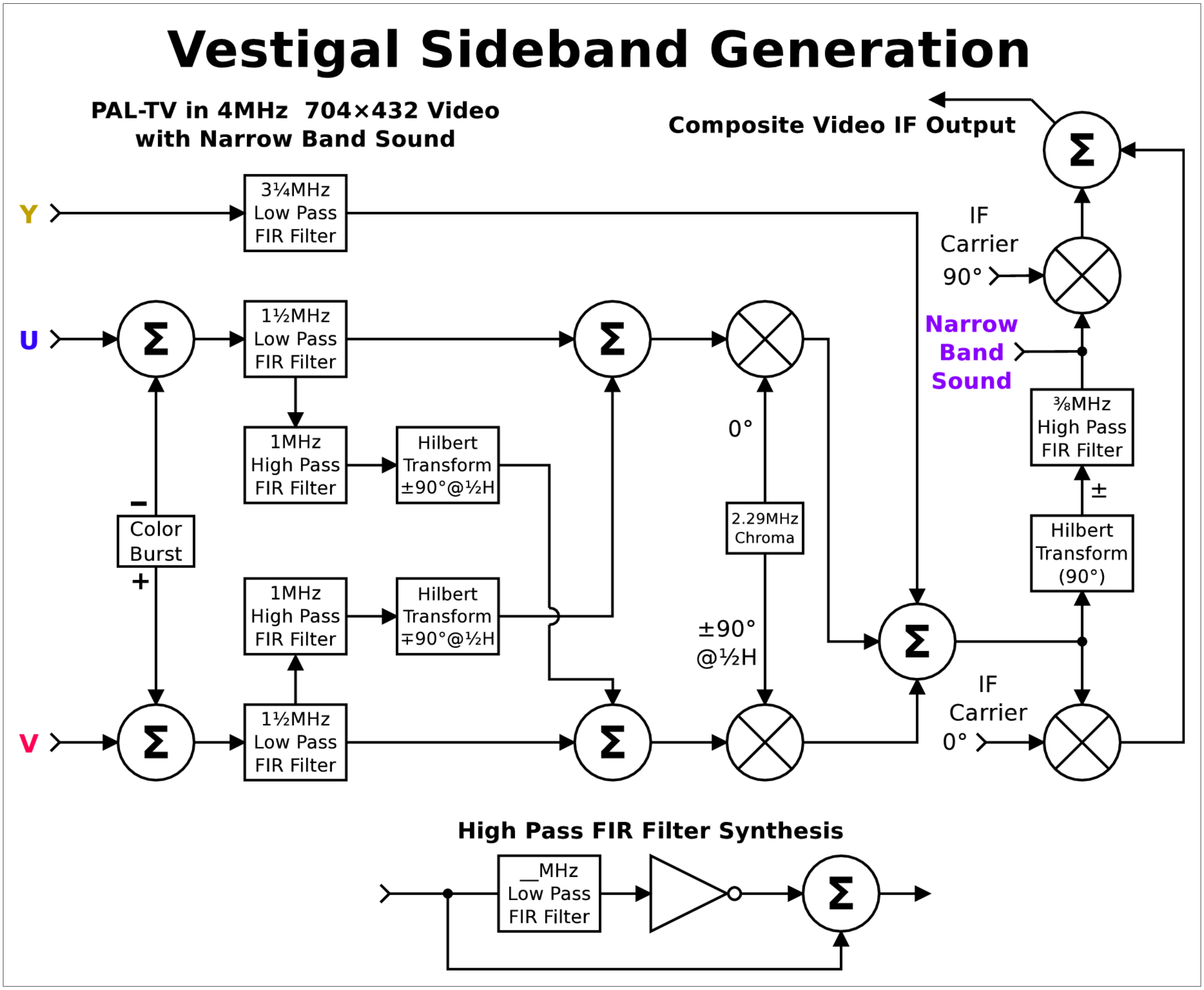
J. S.
Gilstrap
KD5TVJ
PAL-½Ch (4:3) 576x432i72



PAL-NB in 2MHz 24PsF 288i72 16:9

Has been moved/updated into PAL-Film and may eventually have its own document.