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Software only: GNU General Public License 2.0 (GPL)
Hardware (w/ || w/o software): Tucson Arizona Packet Radio TAPR PDF ODT TXT

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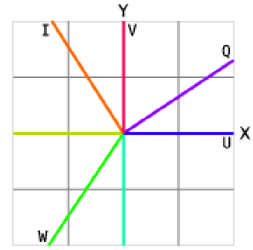
R, G, B, Range: 0–1

| | | 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° |

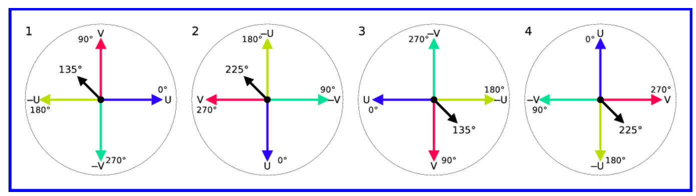
| | IRE=1V/140 | |
|---|---|---|
| Luma (Y) Level: | 98 | 700mV |
| Sync: | −42 | 300mV |
| ColorBurst: | ±21 | ±150mV |
| Max (Yl & Cy) | 130⅔ | 1.23̅V |
| Min (Rd & Bl) | −32⅔ | 66⅔mV |

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/Shift & V Switch Phases




## Colorburst & Carrier

The **PAL** line phase alternation signal for **V** uses the standard **135°**(+) / **225°**(–) phase toggling of the colorburst. Using synchronous detection with a greatly reduced carrier level will increase coverage and signal quality. The sound is placed on the ⅕MHz **Q** channel on the main carrier 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**.

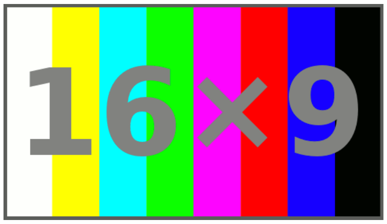
• A **3:1** interlace also creates Hanover lines instead of bars within a completed frame that are stationary and do not scroll unlike a **2:1** interlace; i.e. the hue palette phase rotation reverses on alternate lines of a field and a full frame whereas with a **2:1** interlace the rotation reversal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




**½ Std.Def. ⅓ Ch. (⅓ PAL-B/G Def. ²/₇ Ch.)** **wide**

# PAL-NB 24PsF 288i72 16:9

**52½%** resolution of **NTSC/PAL-M** within a **2**MHz Channel Space
**$40^{\underline{64}}\times 22^{\underline{86}}$** ⇒ **46⅝**cm Diag, **794**µm Line Pitch **1.179**MHz **Chroma**
**16"×9"**⇒ **$18^{\underline{36}}$**" Diag ¾ VHS Quality

Ideal for 6″ Smart Phone Displays, ~250µm Line Pitch

General: Fair Contrast

| | | |
|---|---|---|
| Aspect Ratio | 16:9 = $1\frac{7}{9}$ | 213:144 ≈ 1.4803 |
| Total Picture Pixels (Digital) | 512×288 ; 147456 Pixels | 426×288 ; 122688 |
| Kell Factor (Analog Resolution) | 362×204 ; 73728 Pixels | 301×204 ; 61344 |
| Maximum Digital Equiv. @−9dB | 512×288 ; 147456 Pixels | 362×204 ; 73728 |

Vertical: Pixel Aspect 1.201:1

| | |
|---|---|
| Frames Per Second | 24Hz |
| Total Lines Per Frame | 326 |
| Fields Per Second | 72Hz |
| Total Lines Per Field | 108⅔ |
| Field Picture Lines | 96 |
| Lines Per Blank | 12⅔ |
| Blank | 1.619ms |
| Sync | 256µs ; 2 Lines |

Aspect Ratio × Super Pixel = ½ SD Wide Resolution

$$\begin{bmatrix}16\\9\end{bmatrix}\times\begin{bmatrix}32\\32\end{bmatrix}=\begin{bmatrix}512\\288\end{bmatrix}$$

SD Wide

$$1\tfrac{2}{3}\times\begin{bmatrix}512\\288\end{bmatrix}=\begin{bmatrix}853\\480\end{bmatrix}$$

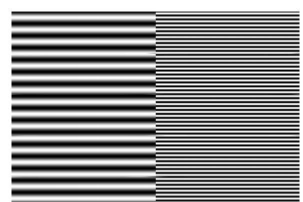
HD Wide

$$2\tfrac{1}{2}\times\begin{bmatrix}512\\288\end{bmatrix}=\begin{bmatrix}1280\\720\end{bmatrix}$$

Horizontal: Resolution Fair:301½ Max @ −9dB:362

| | |
|---|---|
| Lines Per Second | 7.824kHz |
| Period (Hᴘ) | 127.812µs (301½) |
| Picture | 111.915µs (264) |
| Total Picture Pixels | 310⅞ ≈ 1⅔×Yʙᴡ×(Hᴘ−Hʙ) ; (301½+9⅜)≈3%/3⅖µs OverScan |
| Viewable Picture Pixels/Line | 301½ ; 108.524µs (256×2 Dot Clock) |
| Blank (Hʙ) | 15.896 (37½) |
| Front Porch | 1.696 (4) |
| Sync | 5.935 (14) |
| Back Porch | 8.266 (19½) |

**32** **98**



Lines / Inch

Luma & Chroma: Vestigial ¼MHz Corner ⅕MHz

| | |
|---|---|
| **Luma** (**Y**) Bandwidth @−3dB | 1⅔MHz Full Cut 1¾MHz |
| Chroma: | Sub-Sampling 2:1:1 |
| Sub-Carrier | 1.179468MHz ; 8× ⇒ 9.435744MHz |
| ½H Odd Harmonic +¼ | 301½:**150¾**:100½ |
| **V** Bandwidth | ⅚MHz (USB +⅖MHz & LSB −⅚MHz) |
| **U** Bandwidth | ⅚MHz (USB +⅖MHz & LSB −⅚MHz) |
| Color Burst Duration | 5.087µs, 6 cycles |
| Baseband Guard | ¼MHz ; 2×(1¼+6+2½)=19½ |

Sound: Sub-Carrier on '**Q**' Channel of Main Carrier.

| | |
|---|---|
| Frequency Response | 50Hz−12½kHz @ −3dB |
| **Mono PM**: | 11½×H = 89.976kHz, Deviation: ±⅞π ±2¾R ±157½° |
| **Armstrong PM² Stereo:** | Deviation ±120° |
| Sub-Carrier Frequencies: | **L−R**: 58.68kHz **L+R**: 152.568kHz |
| | 7½×H 19½×H |
| **Analog Processing:** | 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 |
| **Digital:** | COFDM Sub-Carrier, 175kHz Bandwidth |
| Stereo: | Vorbis ‖ MP3 4416@192kbps |

**512×288**
Expanded to
1024
2×HorizSampl

140.832kHz
(30½)

195.600kHz
(42½)

281.664kHz
(61⅛)

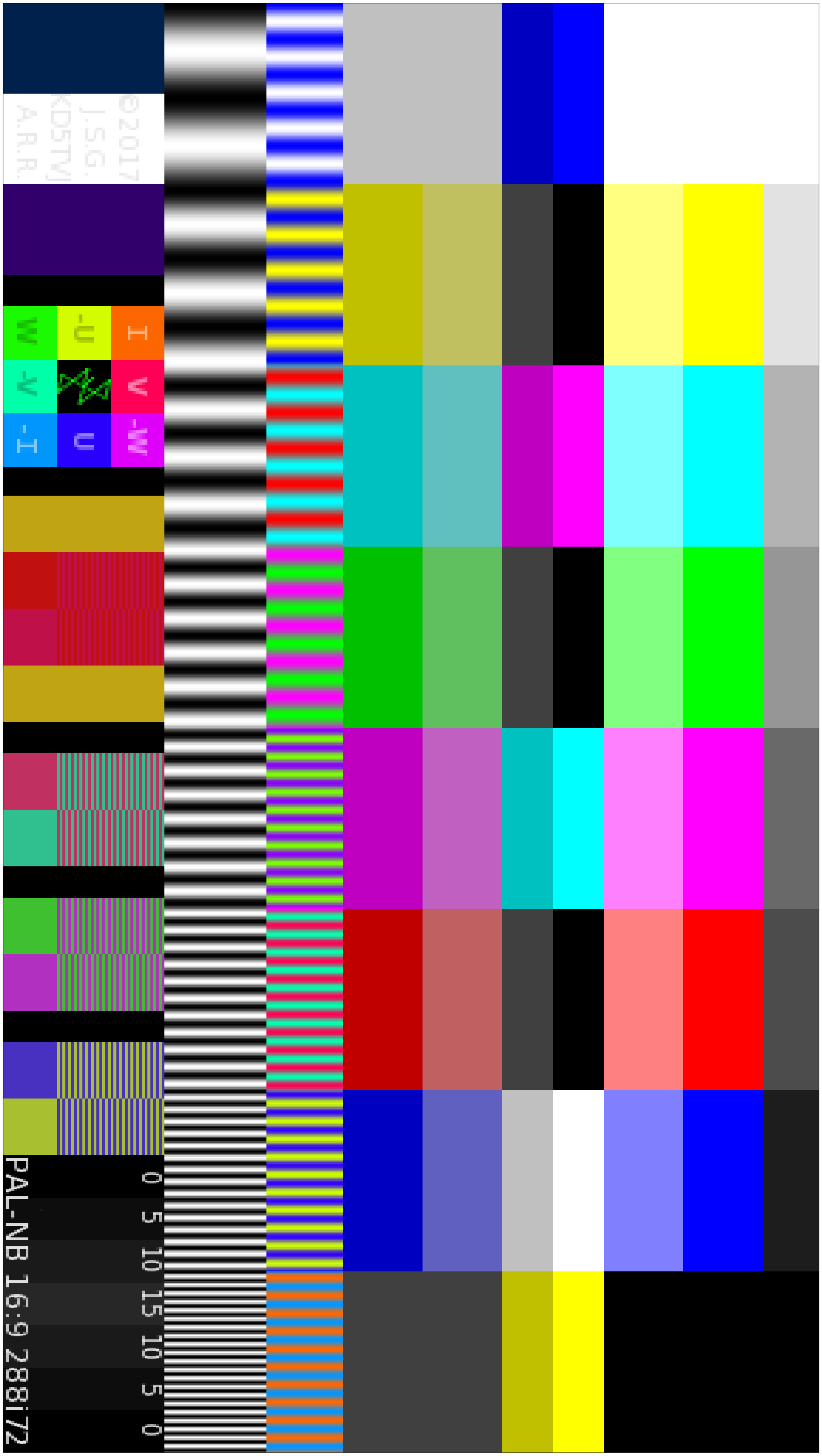
391.200kHz
(84⅞)

555.504kHz
(120½)

782.400kHz
(169⅘)

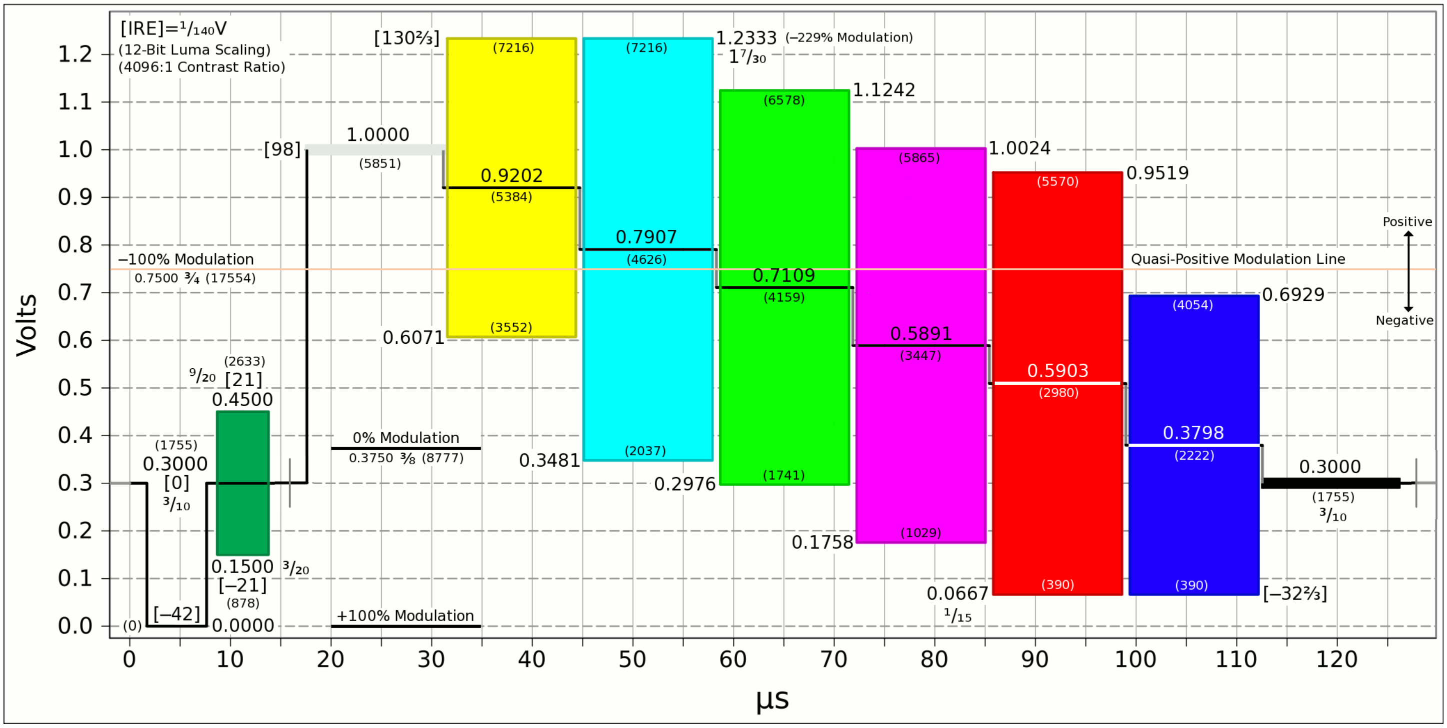
1.111008MHz
(241⅛)

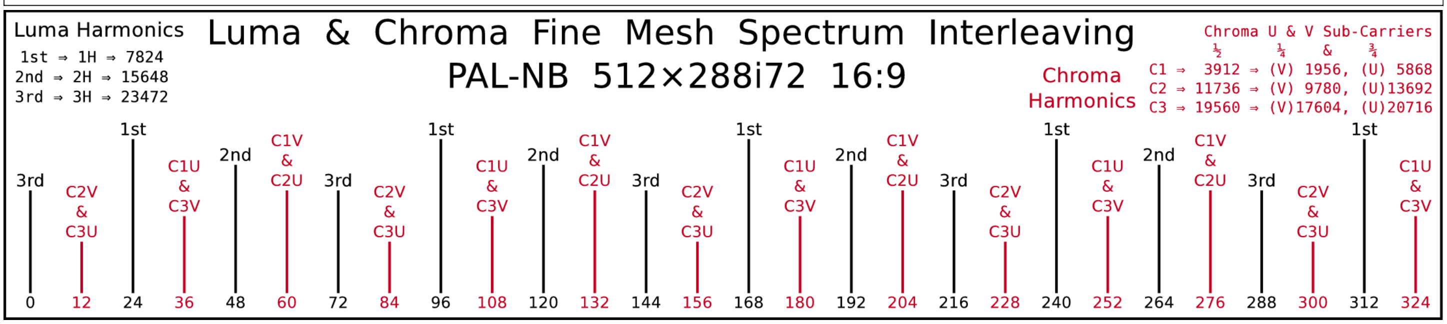
1.572624MHz
(341⅓)



↑↑ Chroma LoR/Freq: 81½/⅜MHz, 163/¾MHz

## PAL-NB 512×288i72 Composite Luma/Chroma 16:9 Test Pattern

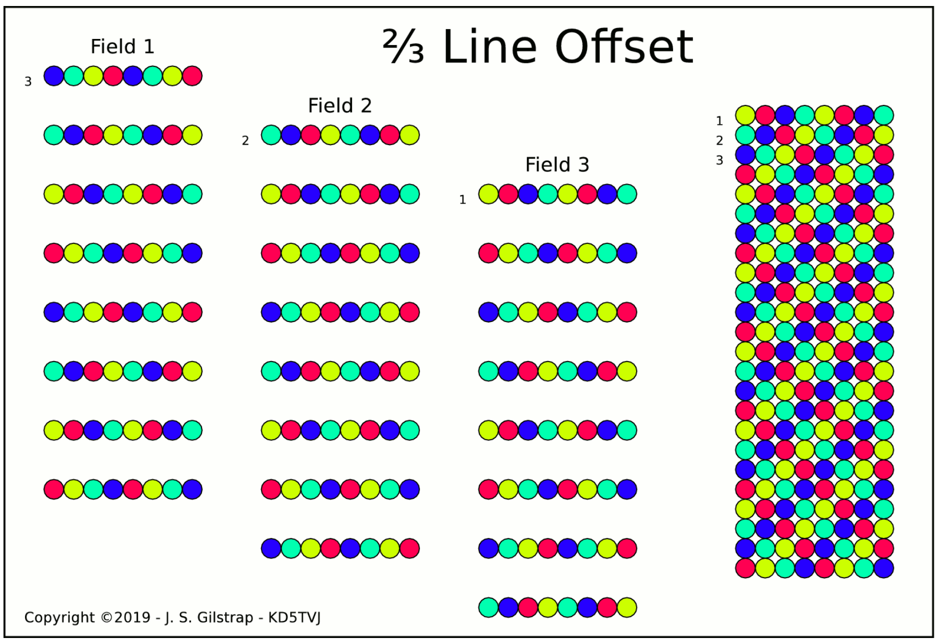



In the image above using a 3:1 interlace the normalized spectrum distribution of Luma with PAL Chroma is shown at the fine mesh level. The 3:1 interlace with a 72Hz field rate ending with ⅓ line causes the Luma and Chroma harmonics to be placed at 24Hz intervals which is also the frame rate. When a 3:1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

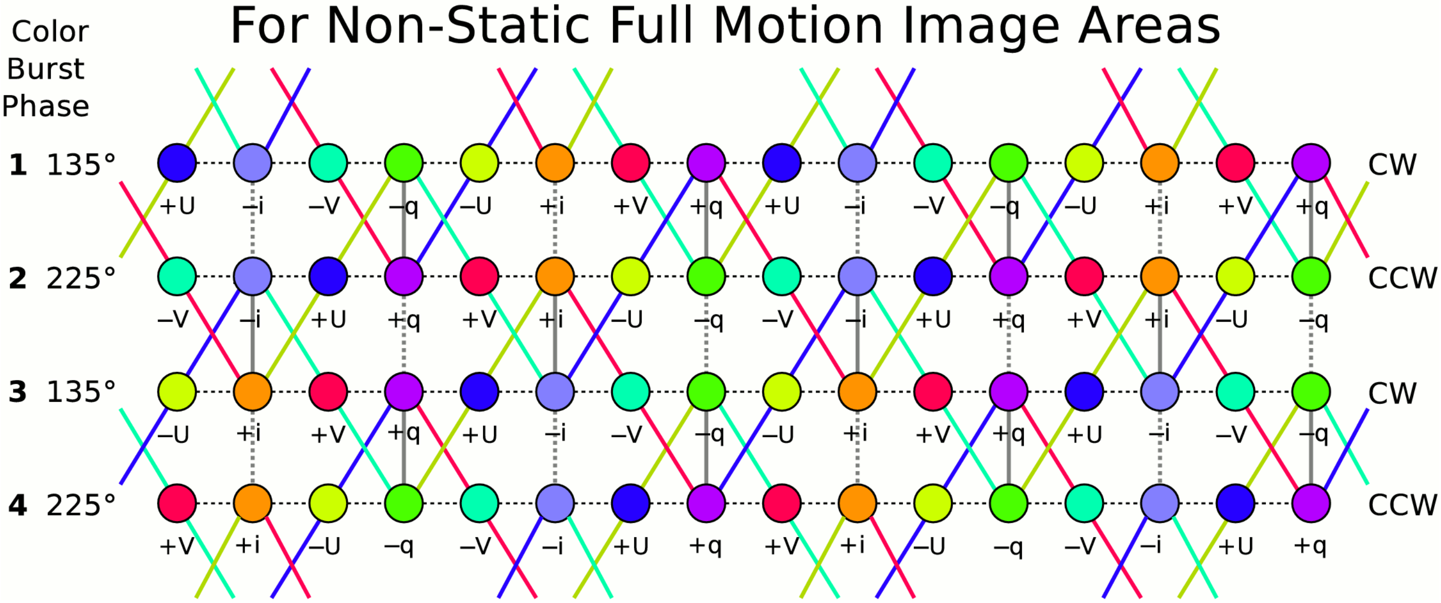
To the right is the chroma dot sequence for a **326** line format using a ⅔ line offset. It shows the **2** frame repeat rate where the chroma dots are inverted on the even frames and the odd frames are non-inverted, or vice-versa, for an on screen per spot basis. The staggered vertical sync pulses cause 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 shift on screen **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. For the **398** line version add **72** lines to the picture area.

To view the full **326** 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 complimentary color lines connected to an **U** or **V** sample and the associated **i** & **q** samples. The ratio is $(\sqrt{2}:2:\sqrt{2})/(1+\sqrt{2})/2$ .

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

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

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

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

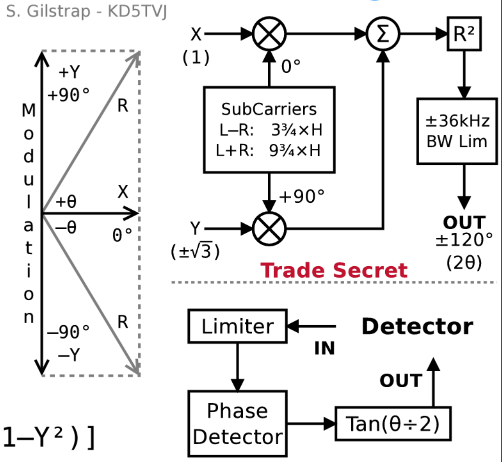
Subtracting one line, above or below from the current line will eliminate the Luma and either the **i** or **q** **Chroma** channel. This method will correct for hue phase errors and produce much better S/N ratio but the **Chroma** lines of resolution will be cut in half. Which **Chroma** channel that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

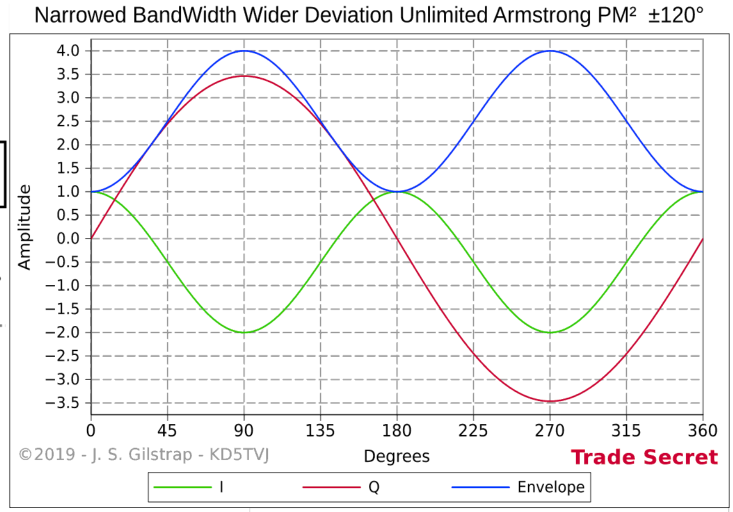
Since the **Chroma** sub-carrier is inverted 180° from frame to frame to average out **Luma** brightness two frames can be added or subtracted to obtain the **Luma** or **Chroma** respectively so motion free static image areas will produce full **Luma**/**Chroma** separation without any artifacts. This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

# Sound: Unlimited Armstrong PM²

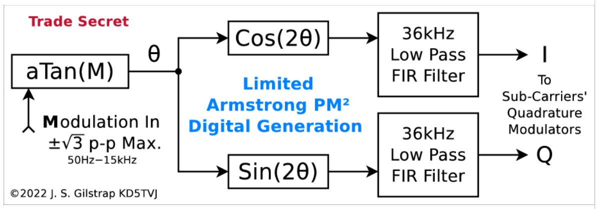


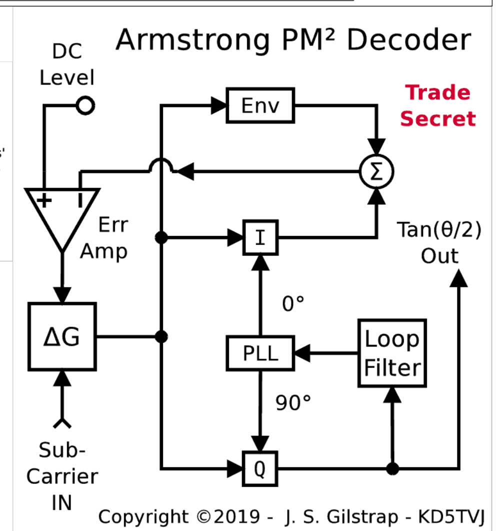
$X = 1$
$Y \le |\pm\sqrt{3}|$
$1 \le R \le 2$
$\theta \le |\pm 60°|$
$\theta = \mathrm{aTan}(Y)$
$R = \sqrt{1+Y^2}$
$I = R^2 \times \mathrm{Cos}2\theta$
$Q = R^2 \times \mathrm{Sin}2\theta$
$I = 1 - Y^2$
$Q = 2Y$
$Env = R^2 = 1+Y^2$
$2 = Env + I$
$2\theta = \mathrm{aTan}[2Y \div (1-Y^2)]$



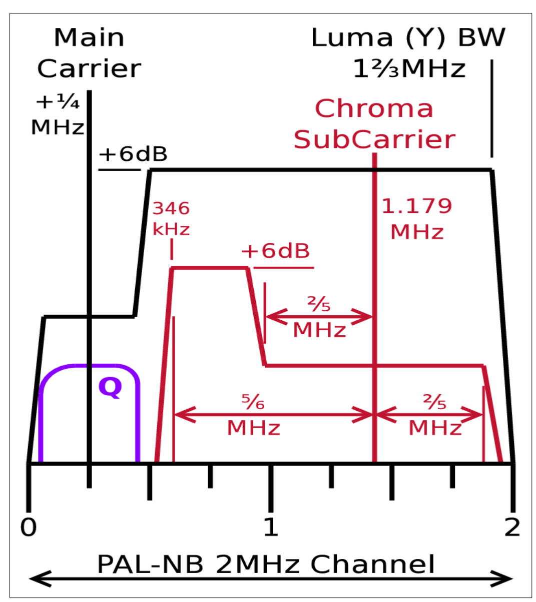




## Narrow Band Sound

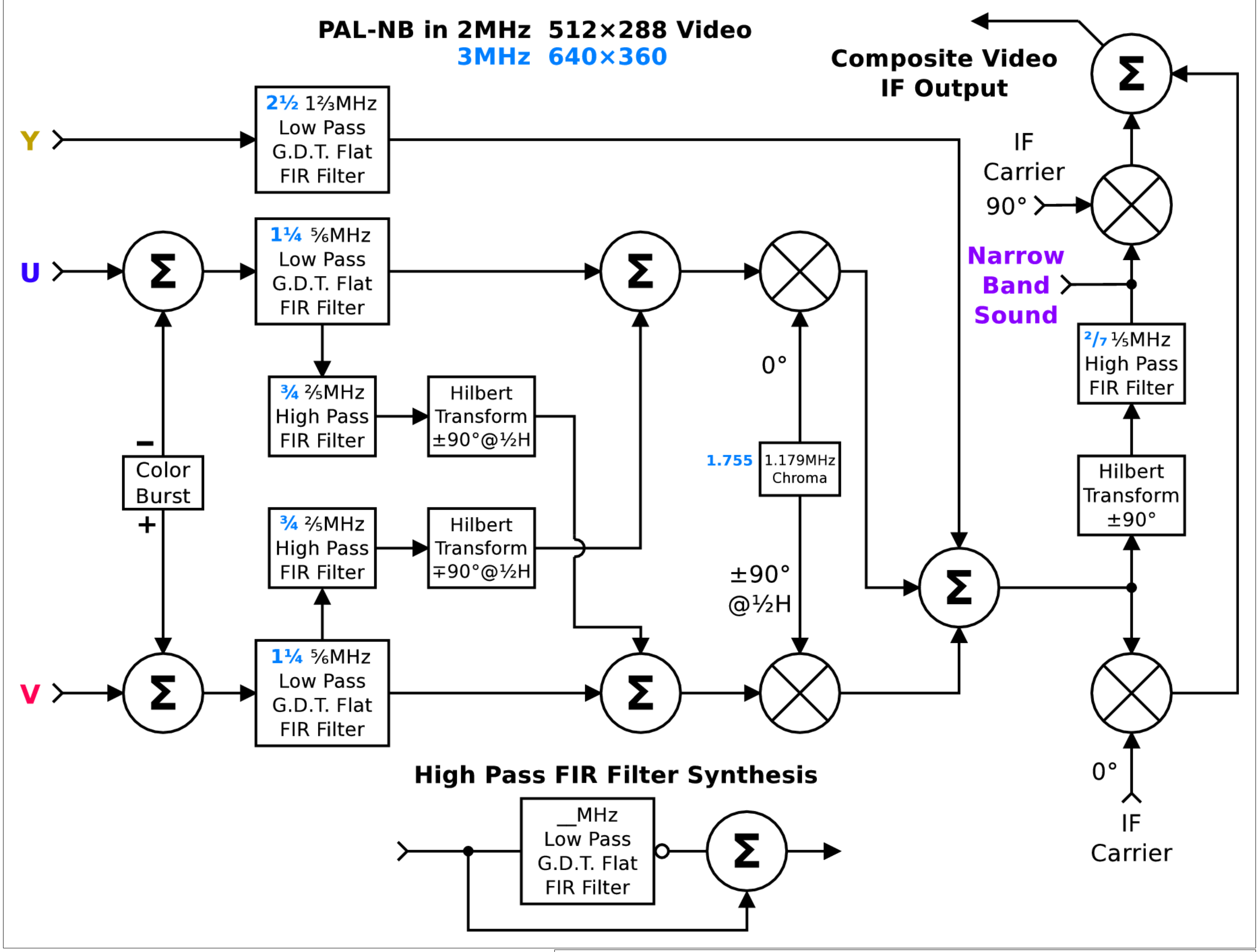


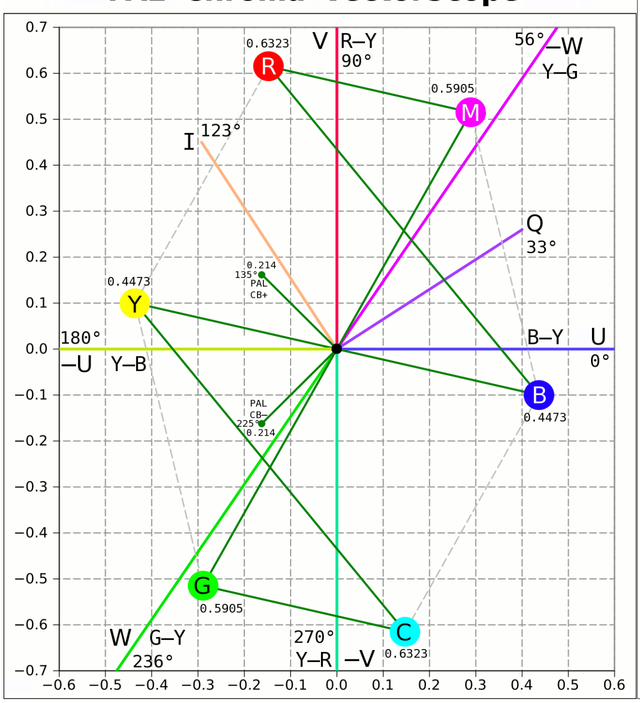

The sub-carriers which can contain up to 12dB of amplitude modulation can be compressed down to 6dB, possibly following the peak amplitude prior to the squaring of the signal. A full 12dB of compression could be employed but signal quality might be noticeability affected or a 9dB reduction could be a 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.

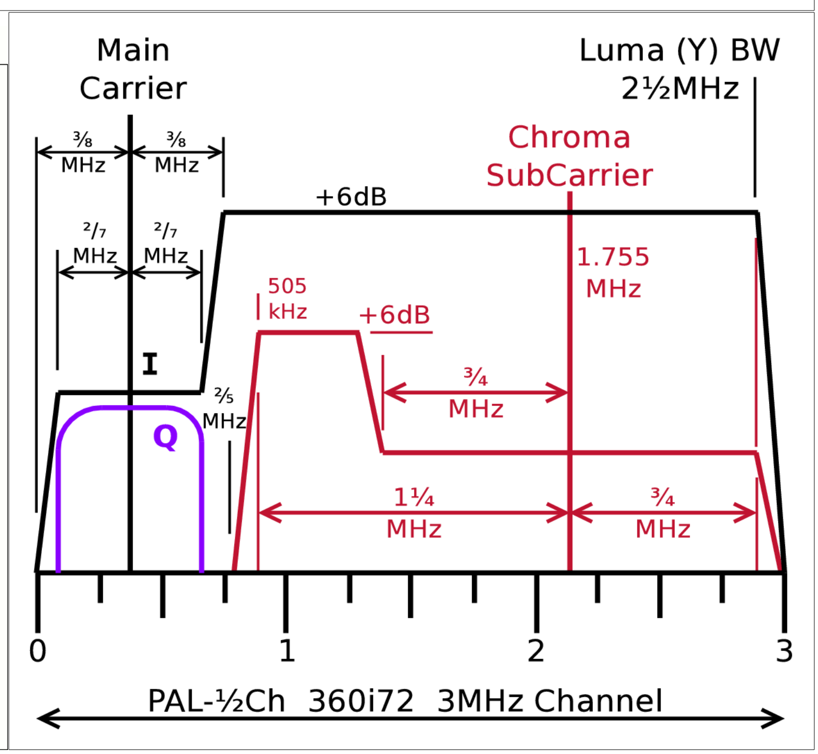


# Vestigal Sideband Generation




## PAL Chroma VectorScope



**1280×720 Micromirror Array**


**2×[640×360]@40” Diag, 692µm LP**

**Half Channel**

# PAL-½Ch | 24PsF | 360i72 | 16:9

wvga

**+11⅖%** better than **VHS** & **81⅓%** of **NTSC** within a **3**MHz Channel

**53⅛×29⅞** ⇒ **61**cm Diag, **830**µm **L**ine **P**itch

**20⅞"×11¾"** ⇒ **24**in. Diag

**1.755**MHz **Chroma**

Ideal for 15” (16:10) Laptop, Letter Boxed, ~500µm **L**ine **P**itch

**General:** **(16:9 Letter Boxed onto NTSC w/89% DVD quality)** Fair Contrast

| | | |
|---|---|---|
| Aspect Ratio | 16:9 = $1\frac{7}{9}$ | 179:120 ≈ 1.4921 |
| Total Picture Pixels (Digital) | 640×360 ; 230400 Pixels | 537×360 ; 193320 |
| Kell Factor (Analog Resolution) | 453×255 ; 115200 Pixels | 380×255 ; 96660 |
| Maximum Digital Equiv. @−9dB | 645×360 ; 232200 Pixels | 456×255 ; 116100 |

**Vertical:** Pixel Aspect 1.191:1

| | |
|---|---|
| Frames Per Second | 24Hz |
| Total Lines Per Frame | 398 |
| Fields Per Second | 72Hz |
| Total Lines Per Field | 132⅔ |
| Field Picture Lines | 120 |
| Lines Per Blank | 12⅔ |
| Blank | 1.326ms |
| Sync | 209⅖µs ; 2 Lines |

Aspect Ratio × Super Pixel = ½ FWVGA Resolution

$$\begin{bmatrix}20\\15\end{bmatrix}\times\begin{bmatrix}32\\24\end{bmatrix}=\begin{bmatrix}640\\360\end{bmatrix}$$

FWVGA

$$1\tfrac{1}{3}\times\begin{bmatrix}640\\360\end{bmatrix}=\begin{bmatrix}853\\480\end{bmatrix}$$

$$2\times\begin{bmatrix}640\\360\end{bmatrix}=\begin{bmatrix}1280\\720\end{bmatrix}$$

HD Wide

$$3\times\begin{bmatrix}640\\360\end{bmatrix}=\begin{bmatrix}1920\\1080\end{bmatrix}$$

**Horizontal:** Resolution Fair: 379⅚

| | |
|---|---|
| Lines Per Second | 9.552kHz Max @−9dB: 455⅘ |
| Period ($H_P$) | 104.690µs (367½) |
| Picture | 93.295µs (327½) |
| Total Picture Pixels | 388¾ ≈ 1⅔×$Y_{BW}$×($H_P$−$H_B$) ; (379⅚+892)≈229%/214µs OverScan |
| Viewable Picture Pixels/Line | 379⅚ ; 91.159µs (320×2 Dot Clock) |
| Blank ($H_B$) | 11.395µs (40) |
| Front Porch | 1.282µs (4½) |
| Sync | 3.988µs (14) |
| Back Porch | 6.125µs (21½) |

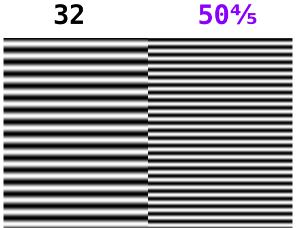
**Luma & Chroma:**

| | |
|---|---|
| **Luma** (**Y**) Bandwidth @−3dB | 2½MHz FullCut 2⅝MHz ; Vestigial ⅜MHz Corner $\frac{2}{7}$MHz |
| **Chroma:** | Sub-Sampling 2:1:1 |
| Sub-Carrier | 1.75518MHz ; 8× ⇒ 14.04144MHz |
| ½H Odd Harmonic +¼ | 367½:**183¾**:122½ |
| **V** Bandwidth | 1¼MHz (USB +¾MHz & LSB −1¼MHz) |
| **U** Bandwidth | 1¼MHz (USB +¾MHz & LSB −1¼MHz) |
| Color Burst Duration | 3.418µs ; 6 cycles 2×(1½+6+3¼)=21½ |
| Baseband Guard | ⅖MHz |

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

| | |
|---|---|
| Sub-Carrier Frequency: | **Mono**: 14½×H 138.504kHz **(pg8)** |
| | **Armstrong PM² Stereo:** **SAP** 5½×H, **L−R** 15½×H, **L+R** 25½×H |
| Frequency Response: | 50Hz–15kHz@−3dB. 52.536kHz 148.056kHz 243.576kHz |
| Equalization: | 50µs Pre-Emphasis, Pole at 13kHz (12¼µs) |
| | 2⅔ms Pre-Emphasis, Pole at 180Hz (884µs) |
| Processing: | Harmonic Peak PSNs 2×1ms |
| | 2:1 Linear Compression, Attack: 1ms, Decay: 60ms |

**32** **50⅘**



Scan Lines /Inch

| | |
|---|---|
| **Digital:** | COFDM Sub-Carrier, 200kHz Bandwidth |
| Stereo: | Vorbis ‖ MP3 4816@256kbps |
| Surround: | Opus 5.1 4416@384kbps |
| Mono Analog: | **Armstrong PM²** 25½×H, 243.576kHz, 50Hz–15kHz@−3dB |
| Fall Back | |

↓↓ **Chroma** LoR/Freq: 101/554kHz, 202/1.11MHz

**640×360**
Expanded to
1280
2×HorizSample

210.144kHz
(38⅓)

296.112kHz
(54)

410.736kHz
(78⅞)

582.672kHz
(106¼)

831.024kHz
(151½)

1.174896MHz
(214⅕)

1.652496MHz
(301¼)

2.340240MHz
(426⅔)