The first analog Color TV system realized which is backward compatible with the existing B & W signal. To combine a Chroma signal with the existing Luma(Y) signal a quadrature sub-carrier Chroma signal is used. On the Cartesian grid the x & y axes are defined with B−Y & R−Y respectively. When transmitted along with the Luma(Y) G−Y signal can be recovered from the B−Y & R−Y signals.

Matrixing

Let:

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

\[
\begin{align*}
Y &= \text{Matrixed B & W Luma sub-channel.} \\
U &= \text{Matrixed Blue Chroma sub-channel.} \\
V &= \text{Matrixed Red Chroma sub-channel.} \\
W &= \text{Matrixed Green Chroma sub-channel.}
\end{align*}
\]

\[
\begin{align*}
U &= \#2900FC \quad \text{Hue} = 249.76^\circ \\
V &= \#FF0056 \quad \text{Hue} = 339.76^\circ \\
W &= \#1BFA00 \quad \text{Hue} = 113.52^\circ \\
I &= \#FC6600 \quad \text{Hue} = 24.29^\circ \\
Q &= \#8900FE \quad \text{Hue} = 272.36^\circ \\
\end{align*}
\]

Enhanced channels:

I = Matrixed Skin Chroma sub-channel.
Q = Matrixed Purple Chroma sub-channel.

We have:

\[
\begin{align*}
Y &= 0.299 \times R + 0.587 \times G + 0.114 \times B \\
B - Y &= -0.299 \times R - 0.587 \times G + 0.886 \times B \\
R - Y &= 0.701 \times R - 0.587 \times G - 0.114 \times B \\
\end{align*}
\]

\[
\begin{align*}
G - Y &= -0.299 \times R + 0.413 \times G - 0.114 \times B \\
&= -0.194208 \times (B - Y) - 0.509370 \times (R - Y)
\end{align*}
\]

Encode:

If:  \[
\begin{align*}
U(x) &= 0.492111 \times (B - Y) \times 0^\circ \quad \text{Quadrature} \\
V(y) &= 0.877283 \times (R - Y) \times 90^\circ \quad \text{Sub-Carrier}
\end{align*}
\]

Then:  \[
W = 1.424414 \times (G - Y) @ 235.797^\circ
\]

Chroma Vector  \[ \sqrt{U^2 + V^2} \]

Chroma Hue  \[ \theta = \text{aTan2}(V,U) \] [Radians]

If \( \theta < 0 \) then add \( 2\pi \).[360°]

Decode:  \[ \text{SyncDet} \]

\[
\begin{align*}
U: B - Y &= \text{---} @ 0.000^\circ \div 0.492111 \\
V: R - Y &= \text{---} @ 0.877283 \\
W: G - Y &= \text{---} @ 235.797^\circ \div 1.424414 \\
\end{align*}
\]

or \[
G - Y = -0.394642 \times (B - Y) - 0.580622 \times (R - Y)
\]

These scaling factors are for the quadrature Chroma signal before the 0.492111 & 0.877283 unscaling factors are applied to the B−Y & R−Y axes respectively.
The **Chroma** scaling for the colors with full saturation produces a minimum peak level of 0.4473 for the **Yellow–Blue** axis and a maximum peak level of 0.6323 for the **Cyan–Red** axis while the **Green–Magenta** axis is in the middle with 0.5904. When modulated the p-p levels are 0.8947, 1.2647, & 1.1809 respectively. When combined with **Luma** the Luma + Chroma peak for **Yellow & Cyan** is at +133½% and **Red & Blue** is at -33½%.
After scaling the degree of separation between the RGB color axes and their amplitudes is made even more unequal as shown in the vector image below.

When the B−Y axis portion is added to the Luma the Yellow positive peak produced peak levels exceeding maximum signal levels and the negative peak levels for Blue exceeded sync levels thus interfering with syncing so this axis has been reduced by a factor of 0.492111. This greater level of reduction compared to R−Y is needed due to a value of only 0.114 of the Blue signal used to create the Luma signal. This has a double impact in that the Blue percentage only subtracts 0.114 from the Luma level of 1 placing the Luma level at 0.886 for the Yellow portion of the Chroma sub-carrier to be biased with and for the Blue portion only adds 0.114 to the black level to be biased with. Also when B−Y is generated the low percentage of Blue within the Luma does not reduce Y by much for Yellow & Blue peak modulations thus making it larger in amplitude compared to R−Y.

The same holds true for the Cyan−Red axis but to a lesser extent. For Cyan 0.299 is subtracted from the Luma and for Red 0.701 is subtracted leaving Luma signal levels for Cyan & Red at 0.701 & 0.299 respectively for biasing requiring only a 0.877283 reduction for R−Y. This puts the Cyan−Red axis peak levels roughly at the same peak levels as the Yellow−Blue axis in the composite signal as seen in the composite image.

After the B−Y & R−Y axes scaling the Green−Magenta axis levels produced within the quadrature Chroma sub-carrier are somewhere in between the Yellow−Blue and Cyan−Red axes levels. The Luma levels for Green & Magenta are centered around 50% of the Luma at 0.587 & 0.413 respectively for biasing and does not produce any peak levels exceeding maximum signal level modulations so no adjustment is needed.

Since NTSC is required to be compatible with the existing B & W receivers and fit within the 6 MHz channel allocation this did not leave much bandwidth available for the Chroma signal so maximizing signal quality is greatly needed. It was discovered that vision of the eye is less sensitive to color changes than it is to brightness changes thus allowing a lower fidelity color signal transmitted in relation to the B & W signal without being noticed. The B & W portion would have a maximum bandwidth of 4.2 MHz while the highest color fidelity would be 35% of that at 1.5 MHz. The eye is also more sensitive to the flesh tones than to the other colors so the I & Q method, In phase and Quadrature alignment, was devised where the I channel would carry the oranges where the flesh tones are and would have a higher bandwidth for the lower sideband at 1.5 MHz and the upper sideband would be vestigial with a 500 kHz bandwidth. The Q channel where the purples are would have both its upper and lower sidebands limited to a 500 kHz bandwidth. The total bandwidth of the Chroma signal is 2 MHz. The I & Q channels are usually matrixed directly from the Red, Green & Blue signals for transmission and band limited to 1½ MHz & 500 kHz respectively before being sent to the quadrature modulators. A ColorBurst signal is added that is 57° away from the I channel at 180°. I & Q can also be obtained from the U & V signals which represent the B−Y & R−Y signals respectively with the following formulas:

\[
\begin{align*}
&\text{Skin (I)} & & 123^\circ & & (U \times \cos(123^\circ)) & & V \times \sin(123^\circ) \\
&\text{Purple (Q)} & & 33^\circ & & (U \times \cos(33^\circ)) & & V \times \sin(33^\circ)
\end{align*}
\]

To derive I & Q directly from Red, Green, Blue, and since \(Y=0.299 \times R + 0.587 \times G + 0.114 \times B\), substituting Y with the scaled Red, Green, Blue, values into \(0.492111 \times (B-Y)\) & \(0.877283 \times (R-Y)\) and substituting these into the equations above and solving for Red, Green, Blue, will give the scaling factors for each color.

\[
\begin{align*}
U &= 0.492111 \times (B-Y) 'x' \\
&= 0.492111 \times [-0.299 -0.587 +0.886] \\
V &= 0.877283 \times (R-Y) 'y' \\
&= 0.877283 \times [+0.701 -0.587 -0.114] \\
I &= 0.492111 \times \cos(123^\circ) \times (B-Y) +0.877283 \times \sin(123^\circ) \times (R-Y) \\
&= 0.492111 \times \cos(33^\circ) \times (B-Y) +0.877283 \times \sin(33^\circ) \times (R-Y) \\
I &= -0.268023 \times [-0.299 -0.587 +0.886] 'Ux' +0.735751 \times [+0.701 -0.587 -0.114] 'Vy' \\
&= 0.412719 \times [-0.299 -0.587 +0.886] 'Ux' +0.477803 \times [+0.701 -0.587 -0.114] 'Vy' \\
I &= 0.595901 \times Rd -0.274557 \times Grn -0.321344 \times Bl \\
Q &= 0.211537 \times Rd -0.522736 \times Grn +0.311200 \times Bl
\end{align*}
\]
In the vector image below it can be seen that the B-Y axis is compressed in amplitude and expanded in Hue layout compared to the R-Y axis which is compressed in Hue layout and expanded in amplitude because B-Y axis has been reduced to 56.1% of the R-Y axis level creating a tall hexagon using the MRYSCB points that has been squashed on each side. This means the Yellow-Blue axis is affected more by noise in regards to saturation level and less to Hue changes but the opposite is true for the Cyan-Red axis and to a lesser extent the Green-Magenta axis since it is about half the distance away from the R-Y axis as it is from the B-Y axis. For transmission and reception this does not have a big detrimental effect and may be a benefit since the eye is less sensitive to amplitude and phase variations to the colors centered around the Yellow-Blue axis very near to the B-Y axis compared to the colors centered around the Cyan-Red & Green-Magenta axes which are closer to the R-Y axis.
NOTE: In the vector image above it also shows the ColorBurst for PAL, the German adaptation of NTSC where the $R-Y$ axis is phase inverted on every other line but the scaling for $R-Y$ & $B-Y$ is the same. In Europe channel spacing is 8 mHz, the field refresh rate is 50 Hz vs. 60 Hz for NTSC allowing higher resolution and the Chroma sub-carrier is at 4.43 mHz instead of 3.58 mHz for NTSC. There are several variations of PAL and PAL-M used in Brasil is basically U.S. NTSC with 6 mHz channel spacing but $R-Y$ is phase inverted every other line. They would have used NTSC since they were already on the U.S. B & W standard but Philips and Telefunken persuaded them to Pay Another License.

Any vector noise added to the Chroma signal for colors centered around the $B-Y$ axis will have more of an effect on amplitude than phase since peak levels are lower and the Hue layout is expanded. For colors near the $R-Y$ axis the opposite is true but the signal is stronger for peak levels and noise does not change saturation much nor does it affect the Hue much either.

However it is a different story for VCR recordings where phase jitter can be a problem with the Chroma signal regardless of the amplitude. The colors where the Hue layout is compressed around the $R-Y$ axis the detrimental effects are greater and can be objectionable but the colors near the $B-Y$ axis where the Hue layout is expanded phase jitter has less of an effect and the eye is less sensitive to Hue and amplitude changes for these colors. VHS and probably other formats use the color under method where the Chroma signal is heterodyned down to around a 650 kHz carrier since phase jitter is less of an issue in the lower frequencies of the recording medium. The unequal shape of the Chroma hexagon also does not optimize peak tape saturation levels for colors near the $B-Y$ axis.

For a 1Vp-p B & W video signal with sync 0.6607 composite scaling is used with Chroma levels of 0.5911Vp-p minimum peak and 0.8356Vp-p maximum peak depending on the color. Blanking level is exactly 2/7 V [-40]. Color Burst is $\pm 1/7$ V $[\pm 20]$, centered on blanking level, 1/7 V $[-20]$ to 3/7 V $[+20]$. 

In order to interlace the 2 fields into 1 frame there needs to be a 1/2 line offset of the vertical sync pulse between the fields of odd and even lines. By adding equalization pulses before and after the vertical sync pulse at a rate of 2H this will allow the vertical sync pulse to start in the middle of a horizontal line for one of the fields. This shifts the lines of one field vertically by one half line in order to fit between the lines of the other field. It is also necessary for each field to start or end with a half of a horizontal line and a full frame will have an odd number of lines. For NTSC-M there are 525 lines per frame, divide by 2 and each field will have 262.5 lines. Since the horizontal sync oscillator is synced to the regular horizontal sync pulses it ignores the extra equalization pulses while it is in the middle of a sweep.
Specifications for a 6mHz Channel Space

To the right is the spectrum layout within the 6 mHz channel space. The bandwidth of a double sideband signal would waste spectrum so a vestigial sideband signal is used. As long as the lower frequencies of the signal are represented by both sidebands the higher frequencies can be represented by only one sideband without any detrimental effects. This is also used for the I channel of the Chroma signal. Since quadrature modulation requires both sidebands to carry 2 channels the Q channel bandwidth is limited to ±500 kHz modulation but the I channel has an extra +1 mHz added to the LSB to extend the 500 kHz within the quadrature sub-carrier for a 1½ mHz bandwidth which is the channel that handles flesh tones. The sound is on a 4.5 mHz sub-carrier that can handle 3 separate channels of audio, L+R, L−R, and SAP.

General:
- **Aspect Ratio** 4:3 = 1 1/3
- **Total Picture Pixels (Digital)** 640x480; 387200 Pixels
- **Analog Resolution (Kell Factor)** 452x340; 153600 Pixels (Studio)
- **Broadcast** 330x340; 112006 Avg. 408x340; 138480 Max.

Vertical:
- **Frames Per Second** 29.97 Hz
- **Frame Period** 33.3667 ms
- **Total Lines Per Frame** 525
- **Picture Lines Per Frame** 480
- **Field Sweep** 59.94 Hz
- **Field Period** 16.68335 ms
- **Total Lines Per Field** 262 1/2
- **Picture Lines Per Field** 240
- **Lines Per Blank** 22 1/2
- **Blank** 1.43 ms
- **Sync** 190.6 µs; 3 Lines

Horizontal:
- **Resolution ; Pixel Aspect** Avg: 330 ; 1.37 Max: 408 ; 1.109 (@-7dB)
- **Line Sweep** 15.734264 kHz
- **Line (Havg) ; Picture Period** 63.55556 µs (455); 52.66032 µs (377)
- **Picture BW Pixels** \( 354 = \phi \times Y_{BW} \times (H+H_b) \); \( (330+24) = 6\frac{2}{3} \% \) OverScan
- **Blank (Hb)** 10.895 µs (78)
- **Front Porch** 1.502 µs (10 1/4)
- **Sync** 4.679 µs (33 1/2)
- **Back Porch** 4.714 µs (33 1/4)

Luma & Chroma:
- **Luma (Y) Bandwidth** 4 1/8 mHz
- **Chroma:**
  - **Sub-Carrier** 3.57954506 mHz
  - **H/2 Odd Harmonic** 455
  - **I Bandwidth** 1 1/2 mHz
  - **Q Bandwidth** 1 1/2 mHz
  - **Color Burst** 2.51 µs ; 9 Cycles ; \( 2 \times (4+9+3\frac{1}{8}) = 33 \frac{1}{4} \)
  - **Baseband Guard** 2mHz

MTS Sound:
- **Carrier** 4.4999995 mHz FM ±25kHz, ±50kHz, ±73kHz
- **H Harmonic** 286 \((L+R) \ add(L-R) \ add(SAP)\)
- **L+R Equalization** 75 µs Pre-Emphasis
- **L−R Sub-Carrier** 2xH 31.468528 kHz AM DSB Suppressed Carrier
  - **Processing/Compression** dbx
PAL (Der SystemBruch)

PAL is a modified form of NTSC. It addresses the drifting **Hue** issues that are present in NTSC giving inaccurate colors when the phase tracking of the **Chroma** decoder is in error. This is accomplished by inverting the phase of the R−Y channel on every other horizontal line hence the name **Phase Alternation Line**. Any decoding phase errors will cancel out visually on the screen in the PAL Simple decoding mode. PAL Simple mode also has the effect of creating what is called Hanover Bars where under severe phase decoding errors two scan lines of a full frame will have its **Hue** shifted in one direction and the next two will have its **Hue** shifted in an equal but opposite direction. The visual addition of the two sets will produce the near perfect **Hue** as the eye's color resolution is less than what it is for the B & W **Luma** portion of the image. Depending on how severe the phase error is and the viewing distance from the screen they may or may not be noticeable. The greater the error the greater the viewing distance is needed to have the eye blend them together and not be noticed. A more advanced decoder uses a delay line of 1H or 1/6Hz to electronically blend two lines together before being put on screen eliminating Hannover Bars. The enhanced version of this controls the delay time by a chrominance lock of so many cycles for the perfect and most accurate delay. Both methods reduce color saturation levels when phase decoding errors occur and the greater the error the greater the saturation reduction. This is more acceptable to the viewer than the wrong **Hue**.

In NTSC each horizontal line ends with 1/2 **Chroma** cycle which causes the clusters of **Chroma** energy to fall in between the clusters of **Luma** energy. In PAL the phase inversion of every other line of R−Y by H/2 effectively modulates it with a square wave smearing its spectrum and creating sidebands of ±H/2 causing R−Y energy clusters to fall directly on top of the **Luma** clusters causing interference. The solution to this is to adjust the **Chroma** sub-carrier frequency so that each horizontal line ends with either 1/4 or 3/4 of a cycle of the **Chroma**. Having the sub-carrier frequency end with 1/4 or 3/4 of a cycle and not 1/2 of a cycle does not cause interference with the **Luma** even on the fine mesh level for B−Y. When R−Y is phase inverted at the H/2 rate its modulated sidebands are fall on the 3/4 cycle marks when the line ends with 1/4 cycle of the **Chroma** sub-carrier and when the sub-carrier ends with 1/4 of a cycle the R−Y modulated sidebands fall on the 3/4 cycle marks.

The downside to not ending the line with 1/2 cycle of the carrier fractures the dot pattern system of NTSC when the **Chroma** signal is super-imposed onto the **Luma** which is designed to average out the **Luma** brightness for each spot on screen both vertically and temporally. The vertical inversion breaks up the vertical stripes which is realized by the lines ending in 1/2 cycle and the temporal inversion is created by having an odd number of lines per frame. Ending the lines with 1/4 or 3/4 of a **Chroma** cycle creates a very noticeable dot pattern motion. In NTSC this pattern repeats over two frames inverting on every frame and is unnoticeable to the eye when viewed at a distance. In PAL this pattern repeats over 8 fields or 4 frames and produces a visible slanted vertical line pattern that can move either to the left or right. To counteract this visible dot pattern motion the number of fame cycles per second is added to the **Chroma** frequency to cause the **Chroma** phase to invert 180° at the beginning of every field from its normal repeat pattern to simulate a similar effect as NTSC. This maintains a 4 frame repeat pattern and a motion that is not visible. Adding the frame rate to the **Chroma** frequency creates phase creep; 4 × the Number of Frame Scan Lines is the number of unique **Luma/Chroma** scan line combinations, a digital coding nightmare where NTSC has only, Two. For (PAL[-N]) this 180° inversion can also be realized by using 621 scan lines without creating phase creep producing only Four line combinations. The R−Y switching has a 4 line repeat pattern and adding the frame rate to the **Chroma** frequency aligns with the repeat rate of 8 fields or 4 frames, 41.3% the speed of NTSC. Therefore NTSC with its higher frame and dot repeat rate handles fast motion better and allows a picture 5 times as bright before flicker is noticed.

NTSC-M variant PAL-M used in Brasil is one example. In Brasil before Color TV was introduced they were on the U.S. 525 lines 30 frames per second M' B & W system using a 6mHz channel spacing. Facing the same compatibility issues as the U.S. and being a large country with many B & W sets in service it was only logical that
they use NTSC-M or a variant thereof and thus PAL-M was spawned. The two systems are so alike that it is very easy to convert from one format to the other. PAL-M uses a slightly lower Chroma sub-carrier frequency of \(3.5756115\) mHz so a horizontal line will end with \(\frac{1}{4}\) of a cycle where NTSC-M uses \(3.57954506\) mHz for the chroma and \(15.734264\) kHz horizontal scan which is \(\frac{1}{227.5}\) of the Chroma. For PAL-M the frequencies are: \(15.734264\) kHz \(\times 227.5 = 3.5756115\) mHz. The horizontal, vertical, and sound frequencies are identical and only the Chroma sub-carrier frequency was reduced enough to create the \(\frac{1}{4}\) cycle per line offset but does not need the frame rate cycle increase. Both systems are B&W and stereo sound compatible with each other.

The next image shows what is happening on screen where NTSC uses \(\frac{1}{2}\) cycle offset and PAL uses \(\frac{1}{4}\) or \(\frac{3}{4}\) cycle offset.

---

Why Brasil chose PAL over NTSC in the early 1970's when solid state Chroma decoders were coming on the scene having much greater phase accuracy, greatly reduced the Hue issues that NTSC posed during the vacuum tube days leaves one pondering. When IC decoders arrived in the mid 1970's in Japanese sets it was rare to require any Hue adjustment once it was set. By the late 1970's and early 1980's all U.S. brands were using IC decoders also. In the end NTSC with its simpler dot pattern and \(\frac{1}{2}\) cycle/frame ending Chroma 3-Line and 3-D Comb Filters provided an almost complete Chroma/Luma separation whereas PAL Chroma with its \(\frac{1}{4}\) cycle and frame cycle offset and the spectrum smearing \(\frac{1}{2}\) switching make separation a much more complicated an incomplete process. Here is a GIF animation of **PAL On Screen Vector Rotation and V Switch** (CC BY-ND 4.0).
Repairing the Brokenness of PAL
Reparieren der Zerbrochenheit von PAL

The big mistake in PAL's design is adding the frame rate to the chroma frequency to re-arrange the on screen chroma dots into a non-objectionable pattern. Unfortunately this creates an unlocked relationship between the horizontal and Chroma frequencies, as they are locked in NTSC. This unlocked condition makes digital coding impossible to do efficiently. This pattern varies in relation to the number of scan lines and the 4 phase states of PAL color. It just so happens that 625 lines cause the 2 fields within a frame to pair lines with the same chroma dot position on screen. The next pair of lines within a frame will be shifted to the left or right 90°. The results produced are diagonal lines moving to the left or right in a 4 frame step repeat pattern. The pattern is not fast enough to blur the motion so it must be altered. When adding the frame rate the 1st line in the next field will be inverted 180° from its original phase. This same inverted order on a scan line in a field is 2 lines away (4 lines in a frame). Adding or subtracting 4 frame lines from the total number of lines in a frame will also break up this pattern. It then becomes unnecessary to add the frame rate to the chroma frequency thus keeping the horizontal and Chroma frequencies locked. Conventional PAL[-N] sets should be able to handle the 4 line adjustment as this is a <1% change in the lines per frame. Here are some new specs. for 625 line PAL formats.

**PAL-EU**

<table>
<thead>
<tr>
<th>Lines/Frame</th>
<th>Lines/Field</th>
<th>Vertical</th>
<th>Horizontal</th>
<th>Luma</th>
<th>Chroma</th>
<th>4 x Chroma</th>
<th>LSB</th>
<th>USB</th>
<th>Sound</th>
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</thead>
<tbody>
<tr>
<td>621</td>
<td>310½</td>
<td>50Hz</td>
<td>15.525kHz</td>
<td>6MHz</td>
<td>4.4362875MHz</td>
<td>17.745075kHz</td>
<td>6.504975MHz</td>
<td>621</td>
<td>310½</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.33ms V. Blank</td>
<td>15.51526</td>
<td>4.43361875</td>
<td>3.57463125MHz</td>
<td>14.298525MHz</td>
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**PAL-N**

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<th>Lines/Frame</th>
<th>Lines/Field</th>
<th>Vertical</th>
<th>Horizontal</th>
<th>Luma</th>
<th>Chroma</th>
<th>4 x Chroma</th>
<th>LSB</th>
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<td>230½ Factor</td>
<td>923 Factor</td>
<td>4.5018258</td>
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<td></td>
</tr>
</tbody>
</table>

**Determining the Need for Frame Rate Increase of Chroma Frequency**

Depending on the number of scan lines in combination with the 4 phase states of PAL Color the Chroma dot arrangement may create an on screen objectionable pattern.

There must be an odd number of scan lines in a frame for a 2:1 interlace. Divide the total number of scan lines by 4. If the quotient is even with a ½ remainder or if the quotient is odd with a ¾ remainder then add the frame rate to the Chroma frequency. If the quotient is odd with a ½ remainder or if the quotient is even with a ¾ remainder then it is not necessary to modify the Chroma frequency. This is the ideal situation as there will be only 4 unique Luma/Chroma line combinations making it easy to digitally process.
B&W 'M' Standard

PAL-M

| 525 Lines/Frame | NTSC-M & PAL-M Vert. |
| 262 ½ Lines/Field | 59.94Hz -0.1% |
| 60Hz Vertical | 15.75kHz Horizontal |
| 1.43ms V. Blank | 15,734.264±0.044Hz |
| 4 ⅝mHz Luma | NTSC Frequencies |
| 3.5791875mHz Chroma | 3.575611494mHz |
| 227⅔ Factor | PAL-M Adjusted Chroma |
| 14.31675mHz 4 x Chroma | 14.3024598mHz |
| 909 Factor | NTSC-M & PAL-M Sound |
| ⅓mHz LSB (2⅓) | 4.5mHz Sound (286) 4.49999504mHz |

An Alternate NTSC-M & PAL-M Frequency Arrangement

Looking at the commonality of the frequencies between NTSC-M & PAL-M an alternative to keeping the Horizontal line Vertical refresh frequencies the same and changing the Chroma frequency is to use the same Chroma frequency and slightly alter the Horizontal and Vertical frequencies. For PAL-M it turns out that this keeps the Horizontal and Vertical frequencies the same as they are for a Type-M B & W signal, making TV sets that are dual NTSC-M & PAL-M simple to manufacture. A set would automatically switch between the two systems depending on whether the colorburst has a static phase for NTSC-M or a swinging gate for PAL-M, controlling the R-Y V Switch phase. This would apply to VCRs as well. The color under system would have to properly preserve the Horizontal, Vertical and Chroma frequency relationships since 1 scan stripe of the tape is one field and this would differ slightly between the two systems. The only side effect would be if a show was in NTSC-M the frame rate would be 0.11% slower than a PAL-M show or faster vice-versa. The RC timing circuits for the Horizontal and Vertical sections will operate well within these tolerances whereas the Chroma crystal oscillator would stay exactly the same.

| PAL-M | NTSC |
| 525 Lines/Frame | 59.934Hz -0.11% |
| 262 ½ Lines/Field | 15.732692kHz |
| 60Hz Vertical | 3.5791875mHz |
| 1.43ms V. Blank | 227⅔ |
| 15.75kHz Horizontal | 14.31675mHz |
| 4 ⅝mHz Luma | 909 |
| 3.5791875mHz Chroma | 910 |
| 227⅔ Factor | ⅔mHz LSB (2⅔) |
| 14.31675mHz 4 x Chroma | ⅔mHz USB (⅔) |
| 909 Factor | 4.5045mHz Sound (286) 4.49999504mHz |
Was OSKM really NTSC-D/K?  8/4.43/15625/625/50/25

Early in 1960, before adopting SÉCAM 7 years later, the USSR experimented with a 625 line 50Hz system on an 8mHz channel space for about 3 years. The Chroma system was basically NTSC with a full DSB-SC ±1½mHz BW at 4.43mHz. “Simultaneous System with Quadrature Modulation” (Одновременная Система с Квадратурной Модуляцией). Since the quadrature modulation did not have a vestigial sideband it was not necessary to use the dual bandwidth I & Q system but used the European B−Y & R−Y / U & V matrixing that PAL and SÉCAM adopted later. The use of an NTSC style Chroma (an adaptation of NTSC for the current European scan and field/frame rate at the time) and given the rules in selecting frequencies, syncs, and bandwidths for analog TV systems, this is maybe a fair description of the specification. The potential resolution is not bad at all. If they would have stayed with this system with the hue drifting issues becoming a minor issue with the advent of transistor/IC Chroma decoders, the benefits of a simpler on screen Chroma dot pattern with the use of 3 line and digital 3D comb filters would have provided superior Luma/Chroma separation and image enhancement that NTSC greatly benefited from. SÉCAM (Système Extrêmement Contraire à la Américaine Méthode) or PAL (Bild Immer Schön) never achieved this level of separation. It would have had the best picture out of all the systems in use.

General:

<table>
<thead>
<tr>
<th>Aspect Ratio</th>
<th>4:3 = 1⅓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Picture Pixels (Digital)</td>
<td>768×576 ; 442368 Pixels</td>
</tr>
<tr>
<td>Analog Resolution (Kell Factor)</td>
<td>543×407 ; 221184 Pixels (Studio)</td>
</tr>
<tr>
<td>Broadcast</td>
<td>483×407 ; 196581 Avg. 597×407 ; 242572 Max.</td>
</tr>
</tbody>
</table>

Vertical:

<table>
<thead>
<tr>
<th>Frames Per Second</th>
<th>25 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame Period</td>
<td>40 ms</td>
</tr>
<tr>
<td>Total Lines Per Frame</td>
<td>625</td>
</tr>
<tr>
<td>Picture Lines Per Frame</td>
<td>576</td>
</tr>
<tr>
<td>Field Sweep</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Field Period</td>
<td>20 ms</td>
</tr>
<tr>
<td>Total Lines Per Field</td>
<td>312½</td>
</tr>
<tr>
<td>Picture Lines Per Field</td>
<td>288</td>
</tr>
<tr>
<td>Lines Per Blank</td>
<td>24½</td>
</tr>
<tr>
<td>Blank</td>
<td>1.568 ms</td>
</tr>
<tr>
<td>Sync</td>
<td>192 μs ; 3 Lines</td>
</tr>
</tbody>
</table>

Horizontal:

<table>
<thead>
<tr>
<th>Resolution ; Pixel Aspect</th>
<th>Avg: 483 ; 1.124 Max: 597 ; 0.91 (@−8dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Sweep</td>
<td>15.625 kHz</td>
</tr>
<tr>
<td>Line (H rowData) ; Picture Period</td>
<td>64 μs (567) ; 53.277 μs (472)</td>
</tr>
<tr>
<td>Picture BW Pixels</td>
<td>517=ф×YBW×(H rowData−H blank) ; (483+34)=6⅔% OverScan</td>
</tr>
<tr>
<td>Blank (H rowData)</td>
<td>10.723 μs (95)</td>
</tr>
<tr>
<td>Front Porch</td>
<td>1.467 μs (13)</td>
</tr>
<tr>
<td>Sync</td>
<td>4.515 μs (40)</td>
</tr>
<tr>
<td>Back Porch</td>
<td>4.741 μs (42)</td>
</tr>
</tbody>
</table>

Luma & Chroma:

<table>
<thead>
<tr>
<th>Luma (Y) Bandwidth</th>
<th>6 mHz ; Vestigial 1⅓ mHz, Corner 3⅔ mHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chroma:</td>
<td></td>
</tr>
<tr>
<td>Sub-Carrier</td>
<td>4.4296875 mHz</td>
</tr>
<tr>
<td>H/2 Odd Harmonic</td>
<td>567</td>
</tr>
<tr>
<td>U Bandwidth</td>
<td>1⅓ mHz</td>
</tr>
<tr>
<td>V Bandwidth</td>
<td>1½ mHz</td>
</tr>
<tr>
<td>Color Burst</td>
<td>2.48 μs ; 11 Cycles ; 2×(5+11+5)=42</td>
</tr>
<tr>
<td>Baseband Guard</td>
<td>2⅔mHz</td>
</tr>
</tbody>
</table>

Sound:

<table>
<thead>
<tr>
<th>Carrier</th>
<th>6.5 mHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>H Harmonic</td>
<td>416</td>
</tr>
</tbody>
</table>