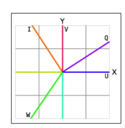
NTSC-DVD

OTA Broadcast with Studio/LaserDisc/DVD Quality

NTSC-M is 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

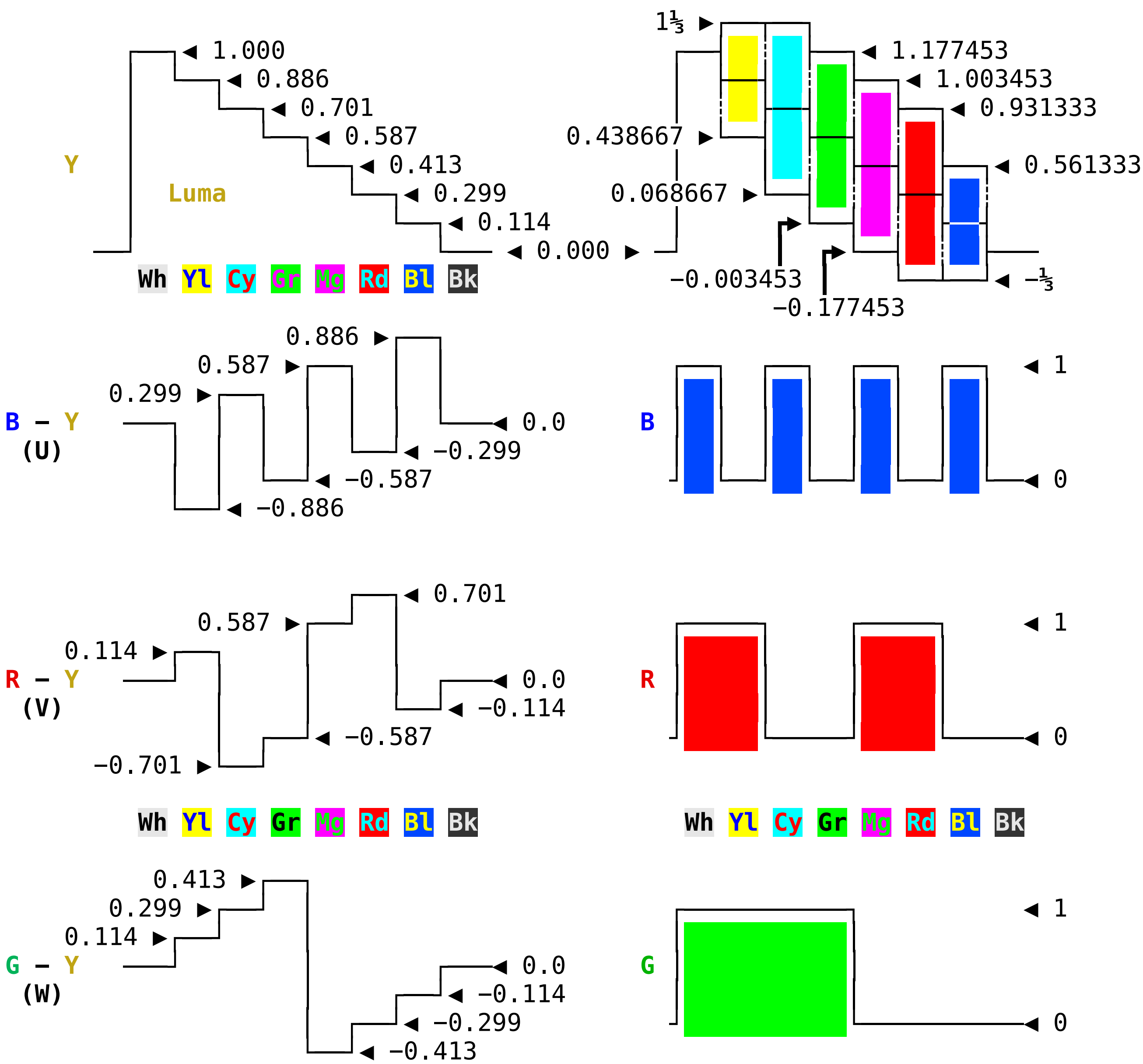
```
Let:

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

Y = Matrixed B & W     Luma sub-channel.
U = Matrixed Blue    Chroma sub-channel.   U #2900FC 249.76°   -U #D3FC00  69.76°
V = Matrixed Red     Chroma sub-channel.   V #FF0056 339.76°   -V #00FFA9 159.76°
W = Matrixed Green   Chroma sub-channel.   W #1BFA00 113.52°   -W #DF00FA 293.52°
                                                      HSV                    HSV
Enhanced channels:                                    Hue                    Hue
I = Matrixed  Skin   Chroma sub-channel.   I #FC6600  24.29°   -I #0096FC 204.29°
Q = Matrixed Purple  Chroma sub-channel.   Q #8900FE 272.36°   -Q #75FE00  92.36°

We have:
    Y =  0.299 × R + 0.587 × G + 0.114 × B
B − Y = −0.299 × R − 0.587 × G + 0.886 × B
R − Y =  0.701 × R − 0.587 × G − 0.114 × B

G − Y = −0.299 × R + 0.413 × G − 0.114 × B
      = −0.194208 × (B − Y) −0.509370 × (R − Y)          (−0.1942078377, −0.5093696834)
Encode:
If:   U[x] = 0.492111 × ( B − Y ) ×   0° ┐ Quadrature    (0.4921110411)
      V[y] = 0.877283 × ( R − Y ) ×  90° ┘ Sub-Carrier   (0.8772832199)
Then: W    = 1.424415 × ( G − Y ) @ 235.796°
Chroma Vector   = √ U² + V²
Chroma Hue    θ = aTan2(V,U) [Radians]
           If θ < 0 then add 2π.[360°]
Decode:                 SyncDet
U: B − Y = -┼- @    0.000° ÷ 0.492111
V: R − Y = -┼- @   90.000° ÷ 0.877283
W: G − Y = -┼- @  235.796° ÷ 1.424415                   (1.4244145537, 235.79647610°)
 or
   G − Y = −0.394642 × (B − Y) − 0.580622 × (R − Y)     (−0.3946423068, −0.5806217020)
```



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.

100% Color Bars

Composite Luma & Chroma
0.492111×(B−Y) & 0.877283×(R−Y)



Color Bar	Luma Level	Chroma 0.492111×U	Levels 0.877283×V	Chroma Hue θ	Chroma Peak Level
White	100.0%	N/A	N/A	N/A	N/A
Yellow	88.6%	−0.436010	+0.100010	167.08°	0.447333
Cyan	70.1%	+0.147141	−0.614976	283.46°	0.632333
Green	58.7%	−0.288869	−0.514965	240.71°	0.590453
Magenta	41.3%	+0.288869	+0.514965	60.71°	0.590453
Red	29.9%	−0.147141	+0.614976	103.46°	0.632333
Blue	11.4%	+0.436010	−0.100010	347.08°	0.447333
Black	0.0%	N/A	N/A	N/A	N/A

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 **0.5905**. 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 **+133⅓%** and Red & Blue is at **-33⅓%**.

After scaling the degree of separation between the MRYGCB color axes and their amplitudes is made even more unequal as shown in the vector image on page 4.

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 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 modulation 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 **4⅕** MHz while the highest color fidelity would be **35$^{5}/_{7}$%** of that at **1½** 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 **1½** MHz and the upper sideband would be vestigial with **⅗** MHz bandwidth. The **Q** channel where the purples are would have both its upper and lower sidebands limited to **⅗** MHz bandwidth. The total bandwidth of the **Chroma** signal is **2^{1}** MHz. The **I** **&** **Q** channels are usually matrixed directly from the **Red, Green & Blue** signals for transmission and band limited to **1½** MHz & **⅗** MHz 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:

Skin	(I)	123°	(U × Cos(123°) + V × Sin(123°))
Purple	(Q)	33°	(U × Cos(33°) + V × Sin(33°))

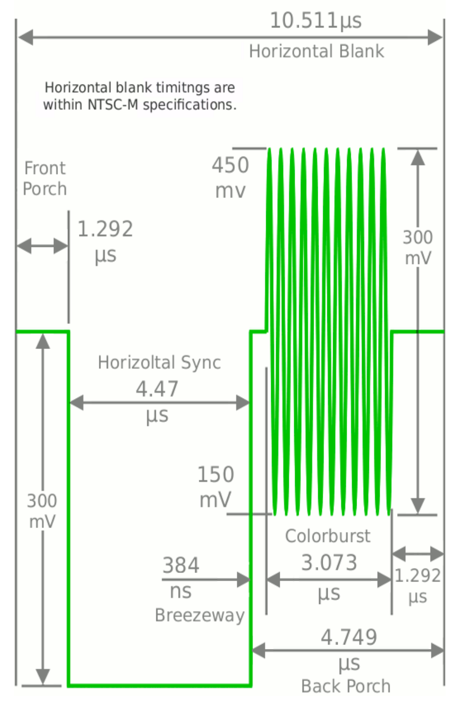
To derive **I** **&** **Q** directly from **Red, Green, Blue,** and since **Y = 0.299×R + 0.587×G + 0.114×B**, substituting **Y** with the scaled **Red, Green, Blue,** values into **0.492111×(B−Y) & 0.877283×(R−Y)** and substituting these into the equations above and solving for **Red, Green, Blue,**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

```
U =  0.492111 × (B − Y) 'x'
  =  0.492111 × [−0.299 −0.587 +0.886]

I =  0.492111 × Cos(123°) × (B − Y)
    +0.877283 × Sin(123°) × (R − Y)

I = −0.268023 × [−0.299 −0.587 +0.886] 'U_x'
    +0.735751 × [+0.701 −0.587 −0.114] 'V_y'

    (0.5959007249   −0.2745567667    −0.3213439582)
I = 0.595901×Rd −0.274557×Gr −0.321344×Bl
```

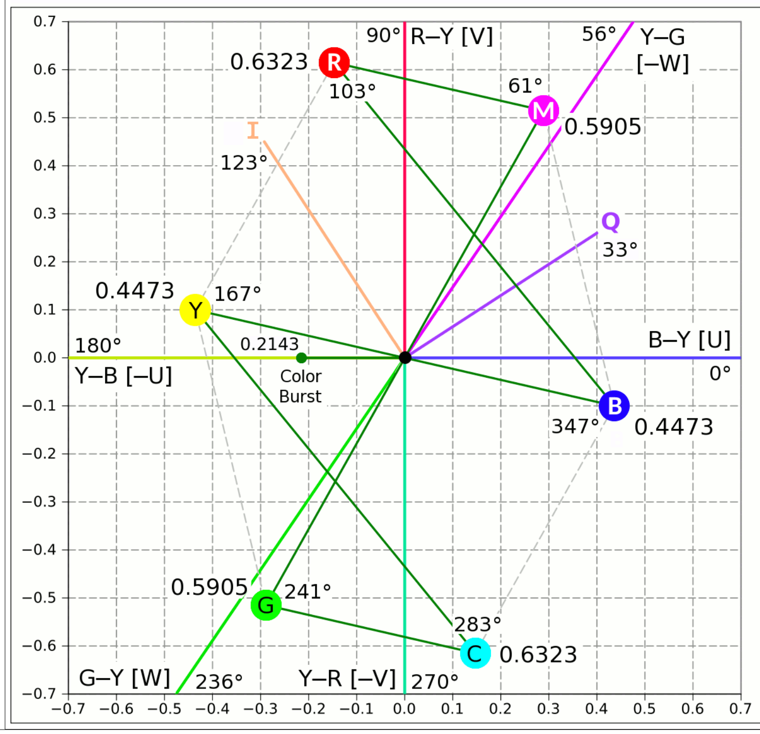
```
V =  0.877283 × (R − Y) 'y'
  =  0.877283 × [+0.701 −0.587 −0.114]

Q =  0.492111 × Cos(33°) × (B − Y)
    +0.877283 × Sin(33°) × (R − Y)

Q =  0.412719 × [−0.299 −0.587 +0.886] 'U_x'
    +0.477803 × [+0.701 −0.587 −0.114] 'V_y'

    (0.2115366883   −0.5227362571     0.3111995688)
Q = 0.211537×Rd −0.522736×Gr +0.311200×Bl
```

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 the **R–Y** axis level creating a tall hexagon using the MRYGCB 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: Voltage values in vector graph below are for a Luma with value of 0–1V. Multiply by 0.7 for values reflecting levels related in the composite graph below.

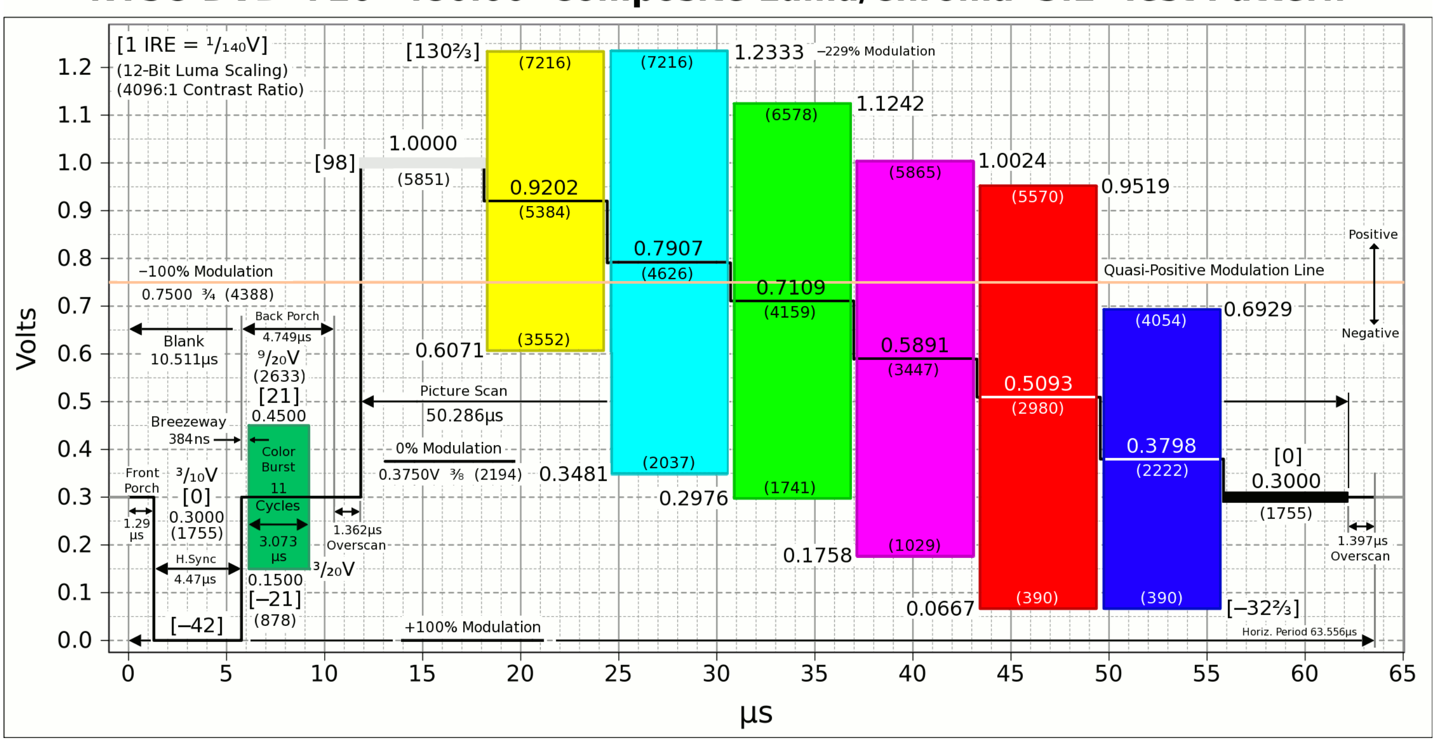
NTSC-DVD Horizontal Blank



NTSC-DVD Chroma VectorScope

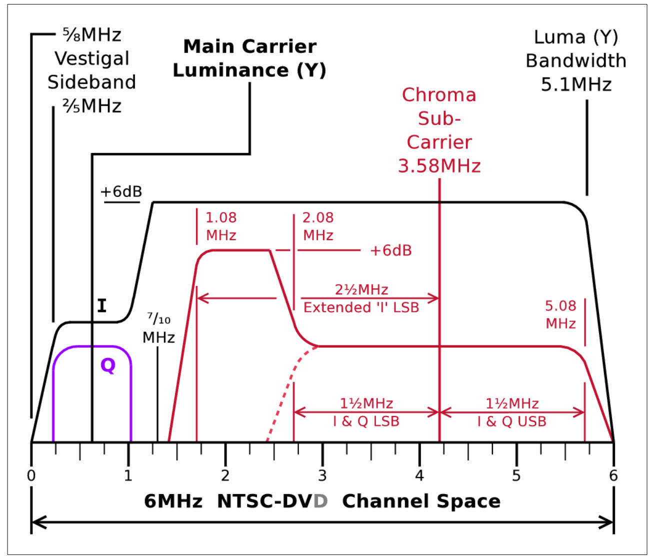


NTSC-DVD 720×480i60 Composite Luma/Chroma 3:2 Test Pattern



NTSC-DVD 6MHz Channel Specifications

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 with a **2½**MHz bandwidth. The sound is on the **Q** channel of the main carrier that can handle **3** separate channels of audio, **L+R**, **L−R**, and **SAP**.



$57^{\underline{15}}$×$38^{\underline{1}}$ ⇒ $68^{\underline{69}}$cm Diag. **793¾**µm Line Pitch
22½″×15″ ⇒ 27″ Diag. **32** L.P.I.

General:

Aspect Ratio	3:2	= 1½	151:120 ≈ 1.2593
Total Picture Pixels (Digital)	720×480	; 345600 Pixels	604×480 ; 289920
Analog Resolution (Kell Factor)	509×340	; 172800 Pixels	427×340 ; 144960
Maximum Digital Equivalent @-9dB	725×480	; 348000 Pixels	513×340 ; 174000

Vertical: Pixel Aspect 1.191:1

Frames Per Second	29.97Hz (**PsF**)
Frame Period	33.3667ms
Total Lines Per Frame	525
Picture Lines Per Frame	480
Field Sweep	59.94Hz
Field Period	16.68335ms
Total Lines Per Field	262½
Picture Lines Per Field	240
Lines Per Blank	22½
Blank	1.43ms
Sync	190.6̄µs ; 3 Lines

Levels		[1 IRE]	¹/₁₄₀V
Setup:	0 V	[0/140]	
Video:	700mV	[98/140]	⁷/₁₀V
Sync:	300mV	[42/140]	³/₁₀V
Burst:	±150mV	[±21/140]	±³/₂₀V
→ Peak:	450mV	[63/140]	⁹/₂₀V
→ Bias:	300mV	[42/140]	³/₁₀V
→ Trough:	150mV	[21/140]	³/₂₀V

Horizontal: Resolution Fair: 427⅖ Max@-9dB:513

Lines Per Second	15.734264kHz
Picture Period (Hᴘ)	63.556µs (455)
Picture	53.044µs (379¾)
Total Picture Pixels	450⅞≈1⅔×Yʙᴡ×(Hᴘ−Hʙ) ; (427⅖+23½) OverScan≈2¾µs/5⅕%
Viewable Picture Pixels	427⅖ ; 50.286µs (360×2 Dot Clock)
Overscan Lead Out	1.397µs (10)
Blank (Hʙ)	10.511µs (75¼)
Front Porch	1.292µs (9¼)
Back Porch	4.749µs (34) ├ **Chroma**
Breezeway	384ns (2¾) ├ **½Cycles**
Sync	4.470µs (32)
Overscan Lead In	1.362µs (9¾)

These Horizontal blank timings are within NTSC-M specifications.

32
Scan
Lines
/Inch
793¾µm
Line Pitch

Luma & Chroma:

Luma (**Y**) **B**and**W**idth — **513** 5$^{\underline{1}}$MHz ; Full Cut: 5⅜MHz ; Vestigial ⅝MHz Corner ⅖MHz

Chroma: Sub-Sampling **4**:**2**:**1⅕** 3⅖:1:1 — **PAL-M**

- Sub-Carrier — 3.57954506MHz ; 8× ⇒ 28.63636048 — 3.575611494MHz
- ½ Odd Harmonic — 455:**227½** — **454½:227¼:151½**
- **I** Bandwidth — 1½ 2½MHz **251**
- **Q** Bandwidth — 1½MHz **151**
- Color Burst — 3.073µs ; 11 Cycles ; 2×{1⅜+11+4⅝}=(34) (**Chroma Cycles**: **Brzwy+Brst+Brst2BlnkEnd**)
- Baseband Guard — ⁷/₁₀MHz

Sound:

- FM Sub-Carrier on **Q** Channel — 275.34962kHz 17½×H, Bandwidth ±100kHz.
- MTS Zenith-**dbx** — See **NTSC Specifications** pg18.

25-150kHz
125kHz COFDM
Data Channel

Other sound options include 3 channel narrow band PM for **L+R**, **L−R** & **SAP**. For digital COFDM sub-carrier: MP3 320kbps, Vorbis 256kbps or Opus 5.1 Surround 512kbps, with mono narrow band PM channel included for fallback.

720×480

424.825kHz
27×15734Hz
(42¾)

597.902kHz
38×15734Hz
(60⅛)

849.650kHz
54×15734Hz
(85½)

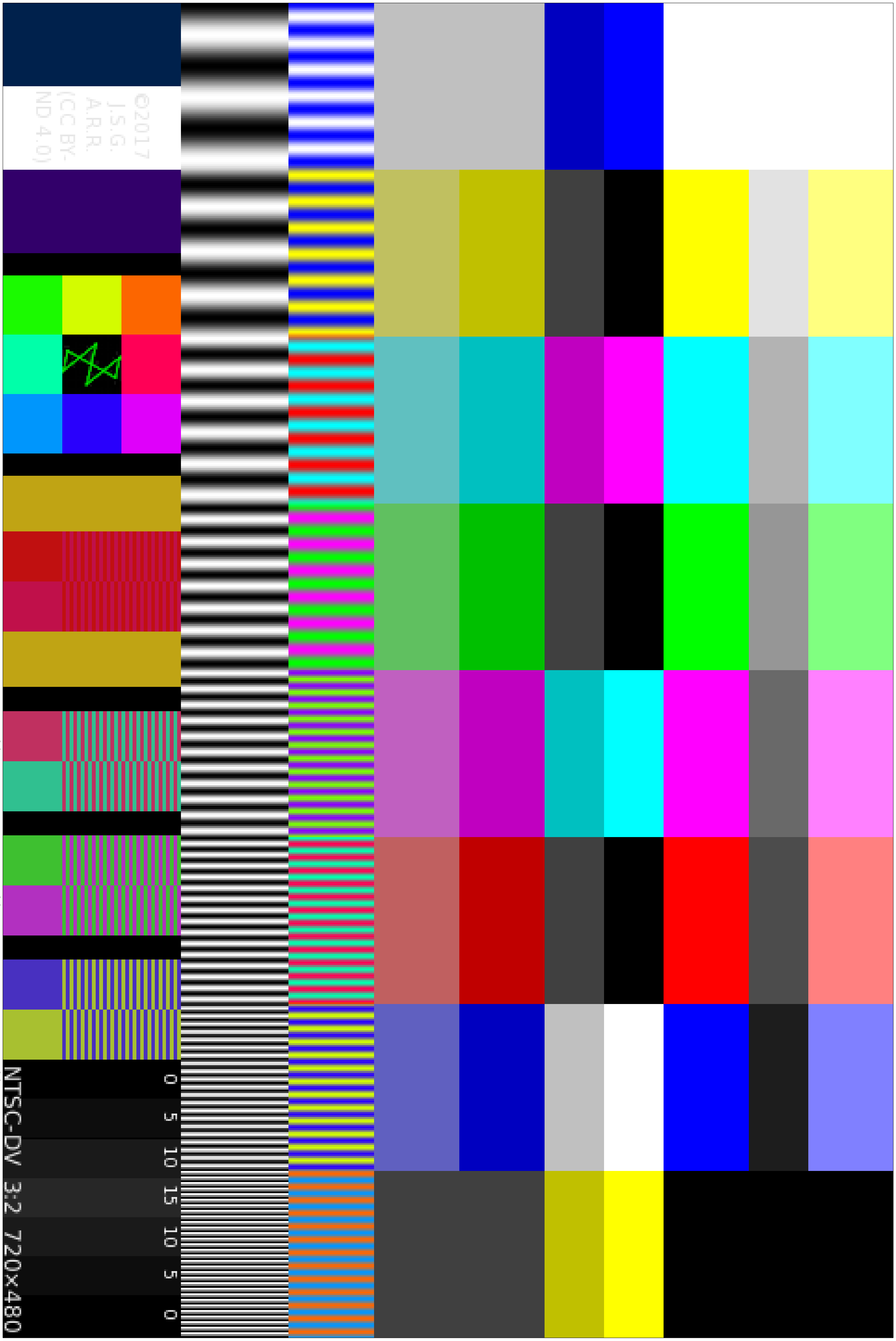
1.195804MHz
76×15734Hz
(120¼)

1.683566MHz
107×15734Hz
(169⅓)

2.391608MHz
152×15734Hz
(240½)

3.367132MHz
214×15734Hz
(338⅝)

4.772727MHz
303⅓×
15734Hz
(480)



↑↑ Chroma LoR/Freq: 101¼/1MHz, 202½/2MHz

Copy test pattern image to clipboard and paste into image editor, rotate CCW and save.

Notes:

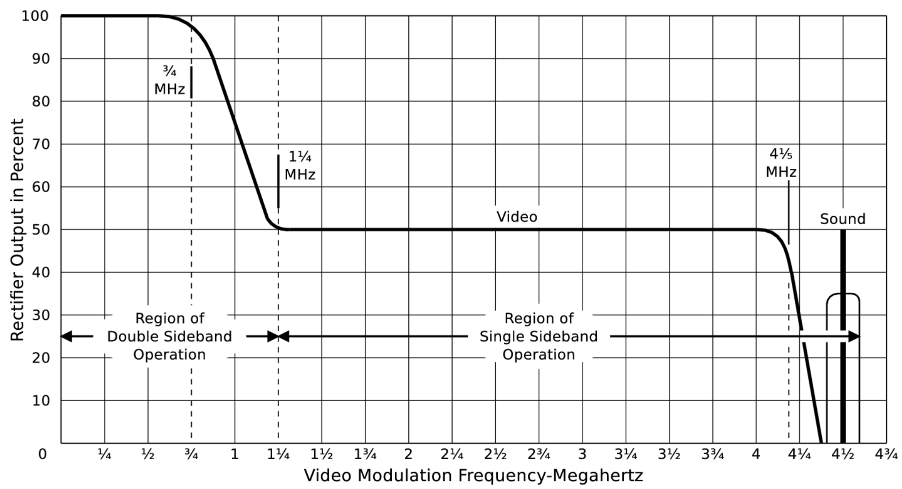
To regain the some of the overscan lost from increasing the active picture area from 49.168µs to 50.284µs to accommodate 720 chroma locked pixels the horizontal blank timings have been reduced to within minimum specifications. The front porch, sync and back porch are each within specs and so is sync to blank, although the 11 colorburst cycles exceeds the max by 22ns. This still keeps the picture area mostly centered from the start of sync in relation to the 704 pixel position. The overscan is now at 5⅕%, the original being 6⅔%. This is facilitated by reducing the blank by 384ns to 10.511µs. Since there is no setup this should be of little consequence.

For NTSC–J, without setup, luma being 100 IRE, leaves only 47.6mV foot room for the peak red and blue chroma modulation levels whereas PAL–B/G with a sync of 43 IRE and luma of 100 IRE provides 69mV of foot room. Here, using a 42 IRE sync and 98 IRE luma, still keeps the sync+luma at 1V with 66⅔mV foot room, a 19mV increase over NTSC–J, and peak modulation with chroma is still within NTSC limits of 125% (1¼V). The Sync:Luma ratio is within ⅓% of PAL-B/G and if using the back porch for AGC control the sync ratios of 40:42 IRE will effectively reduce the luma 98 IRE level to a 93⅓ IRE in the receiver, <1% difference from the original 92½ IRE. With a luma+sync of 1V this provides a 5.9% luma increase, +½dB, vs +⅔dB for NTSC–J. With an increased sync level working on the receivers AGC there should be no noticeable contrast increase but a minor brightness adjustment may be necessary. A 98 IRE is only 14.3mV less than the 100 IRE of NTSC–J/PAL–B/G.

To increase the luma bandwidth to 5.1MHz the sound has been moved to the **Q** channel on the main carrier and the 1¼MHz vestigial sideband has been cut in half to ⅝MHz. This should provide full DVD/LaserDisc quality for a 6MHz broadcast producing almost square analog (Kell factor) pixels at the absolute maximum resolution. To obtain this FIR filters with a nice elliptical style amplitude response must be used for both generation/transmission and reception/decode. On the **Q** channel a bandwidth of ⅖MHz is available for the NTSC style FM sub-carrier with MTS and a data channel e.g. digital 5.1 surround sound or picture processing data.

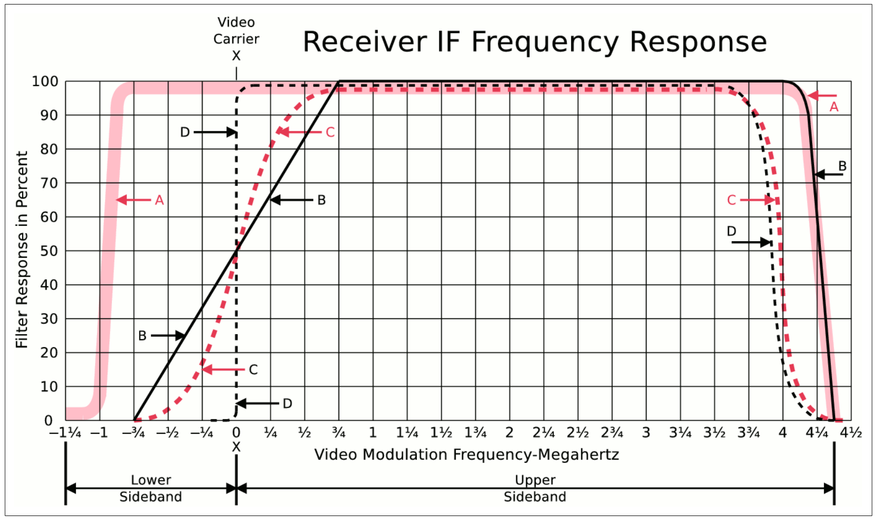
Use of synchronous detection is necessary when using quadrature modulation, luma on the **I** channel and sound on the **Q** channel. Using an envelope detector on the main carrier would not separate the two signals and would also produce distortion. This also allows the use of greatly reduced carrier levels providing more power for the signal in the sideband. This also reduces transmitter load, allowing cooler running. On page 4 the composite signal shows where negative modulation ends and positive modulation begins at the **–100%** line. This level is probably where most scenes would produce minimum carrier levels although another level should be chosen that would better fit this criteria. A floating carrier level could be used that would maximize carrier suppression, one that would allow the receiver's clamping circuit to track.

In the channel spectrum image on page 5 it shows that there is a +6dB boost to the signal above the vestigial sidebands' cutoffs for both luma and chroma. This is necessary to equalize signal levels above and below the cutoff point. In a double sideband signal both sidebands contribute to the modulation level but when one of the sidebands is partially removed the modulation level below the cutoff point is twice as strong as that which is above the cutoff point, as shown in the image to the right, Fig. 186/13-2. This will also produce image distortion, mainly softer edges and reduced high frequency S/N since the phase/amplitude



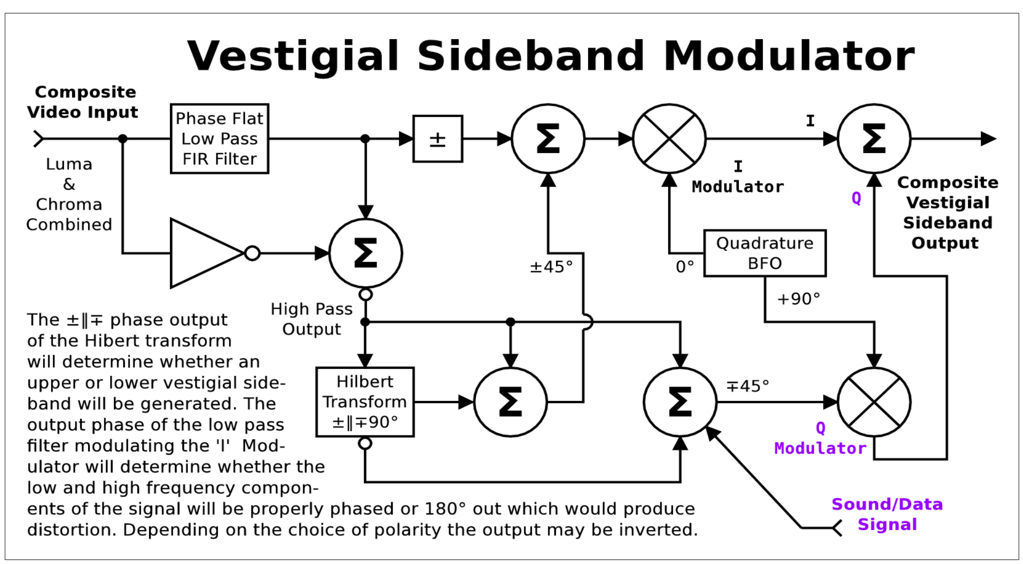
Vestigial Sideband Frequency Response

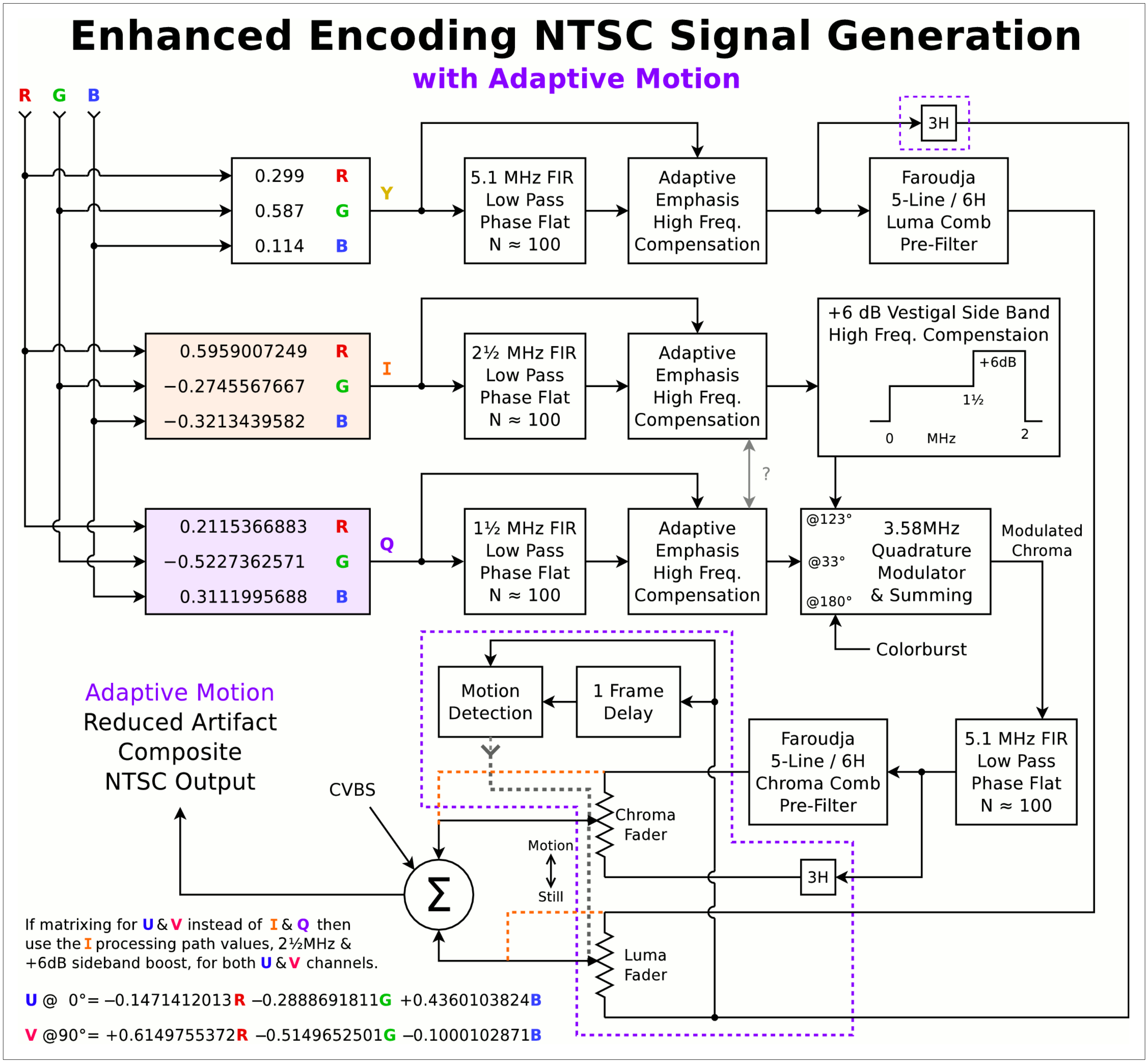
relationship of the image signal has been altered. In the beginning of vestigial sideband TV broadcast and well into the 1970s this is how the signal was transmitted and was compensated for in the receiver using the IF filter slope to equalize it, as shown in the image to the right, Fig. 187/13-3. This produces a –6dB S/N loss for the higher frequencies when using IF receiver compensation. Along the way whether or not pre-transmission equalization was adopted along with a receiver's IF having a flat passband response is questionable. If it didn't happen then it was a missed opportunity to improve signal coverage and reception quality. Plotting data for these two graphs courtesy of **SAMS PHOTOFACT® Television Course** ℗rintings 1949/1974.



Using pre-transmission equalization is the way to go as it provides a +6dB S/N improvement in high frequency image detail areas, which are weaker in the first place compared to the lower frequencies, along with the chroma which is above the vestigial sideband cutoff point. Combine this with running in a suppressed carrier mode will add another +6dB providing up to a +12dB advantage. This means that a signal will travel twice as far with the same amount of power while still providing the same S/N ratio and quadruple the coverage area.

The pre-transmission equalization must be done properly and must have an amplitude and phase/group delay flat response below the transition cutoff point for quadrature modulation to work properly. This applies to the main carrier as well as the chroma signal if it also is running in vestigial sideband mode. One way to do this is to use an amplitude and phase/group delay flat high pass filter on the signal with the output Hilbert transformed to obtain the 90° shift which will then be applied to the **Q** modulator while the **I** modulator will receive the full bandwidth signal. Whether the upper or lower sideband will be eliminated will be determined by the polarity of the Hilbert transformed portion, ±90°. Without the high pass filter this is the phasing method used for single sideband generation and this also effectively transfers the energy from the vestigial sideband to the other sideband properly equalizing a vestigial sideband signal. In a double sideband signal the lower sideband modulation leads by +45° while the upper sideband modulation lags by –45° and when combined produce a 0° phase response. Eliminating one of the sidebands causes a ±45° phase shift depending which one is eliminated. This not an issue for audio but for video it is, where there is an amplitude and phase/group delay relationship between the fundamental and harmonics of a square wave, and this must be preserved in order to prevent waveform distortion. To accomplish this the output of the Hilbert transform should be ±45°, not 0° & 90°, where the ±45° signals will be sent to each of the **I** & **Q** modulators. The polarity phase of the signals will determine whether the upper or lower sideband will be reduced. Digital signal processing using a phase flat low pass FIR filter is a way to approach this. In the drawing to the right illustrates this process. Applying this to the chroma signal is more complex but the process is essentially the same.



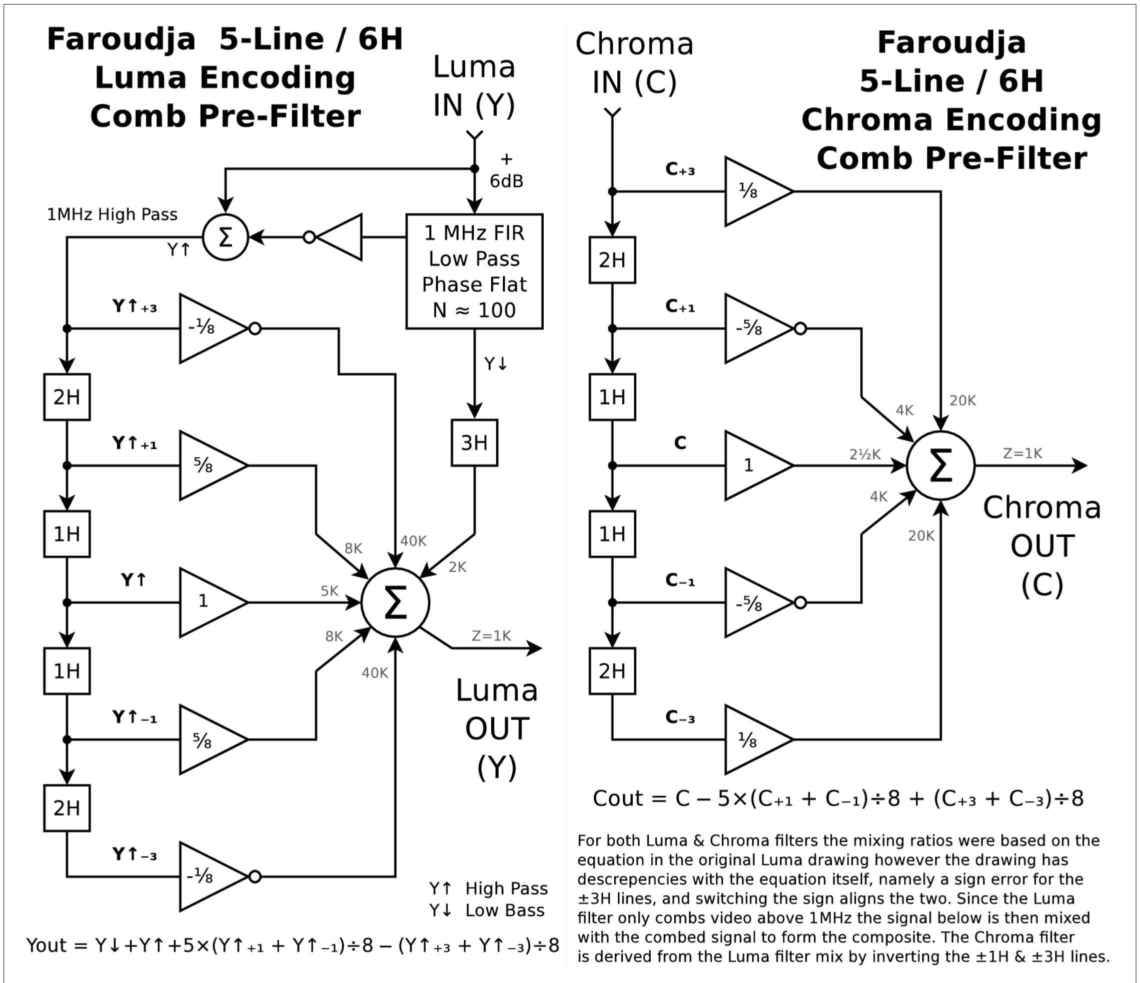


Above is a block flow chart of NTSC advanced encoding. After matrixing into **Y**, **I** & **Q** they are then low pass filtered at 5.1, 2½ & 1½ MHz respectively.

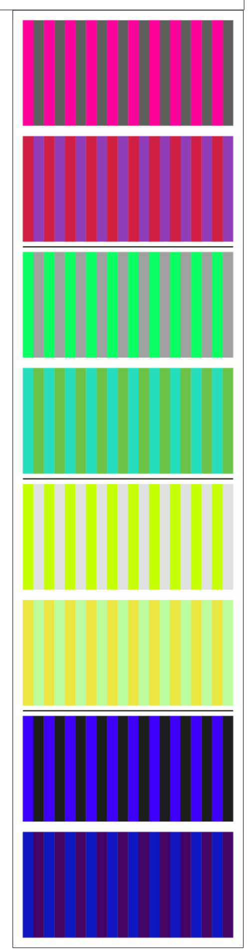
Adaptive Emphasis High Frequency Compensation, [1]pg11 – This circuit boosts signal levels of higher frequencies that lack the harmonics necessary to produce sharp edges. A square wave contains the fundamental and odd harmonics to produce sharp image edges. A filtered square wave with all harmonics removed contains a sine wave that is only $2/\pi$ of peak. This will boost the sine wave peak to the same level of the square wave. It does not increase sharpness but it does restore peak contrast and if circuits in the receiver square it up it will return the signal close to its original form.

Vestigial Sideband on **I** Channel – When eliminating one sideband there is a 6dB loss in envelope modulation for frequencies above the cutoff frequency. To compensate those frequencies above the cutoff will need a 6dB boost to restore a flat response.

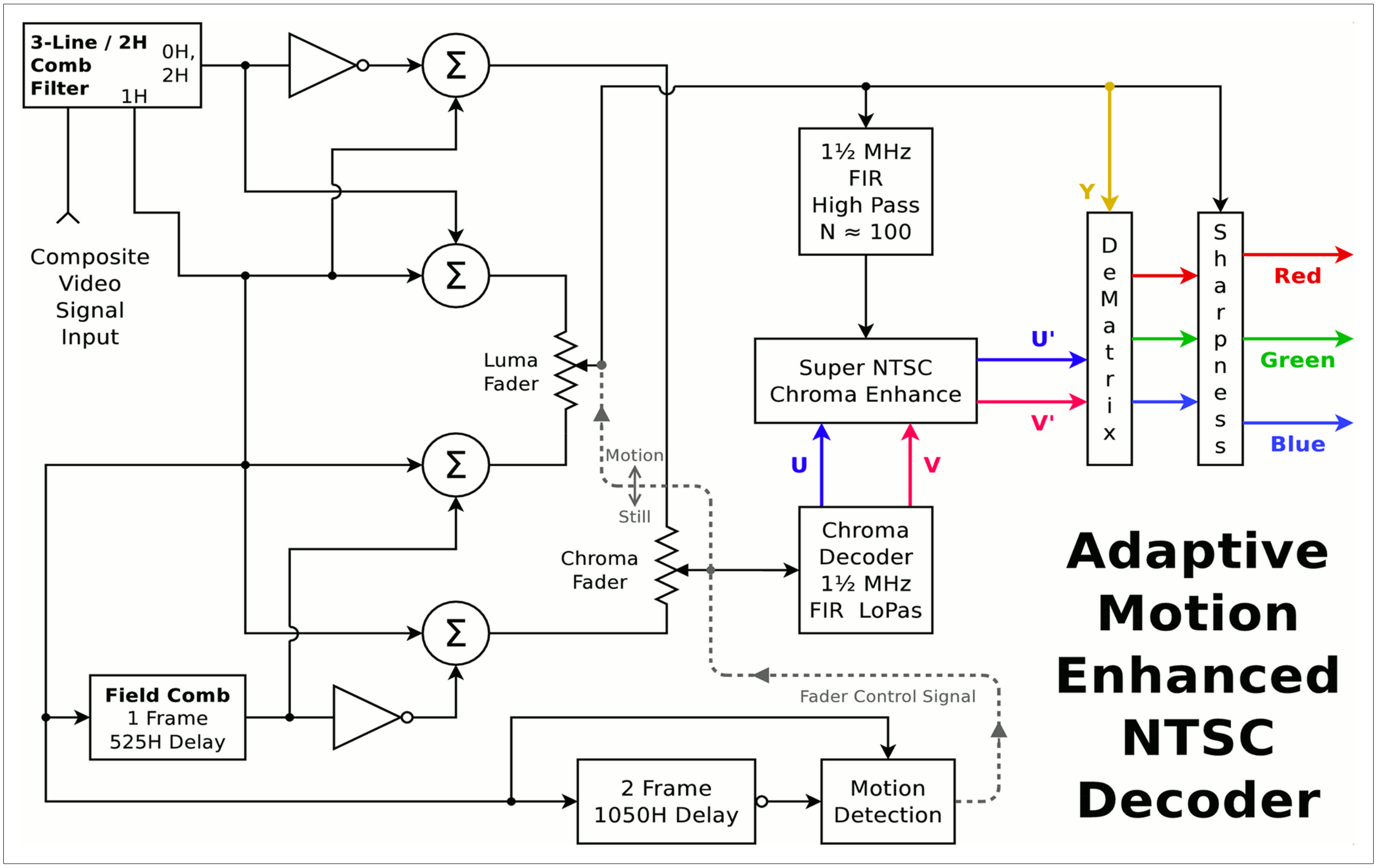
Luma & **Chroma** Adaptive Pre-Combing, [1]pg11 – In order to reduce cross color and hanging dots during comb mesh failure or for receivers with poor **Luma** & **Chroma** separation pre-combing will reduce those spectral components to a tolerable level that will make them minimally visual. The choice of using this only for areas of motion is to optimize it for larger screen receivers that also use adaptive motion (purple dotted line). Combing can reduce resolution and for still areas and this is noticeable on larger screens. Using adaptive motion provides the best performance for larger screens but for smaller screens that may or may not use a 3-line comb filter the artifacts may be noticeable in still areas. Full non-adaptive combing (orange dotted line) will reduce artifacts for all screen sizes but does not offer the best performance for larger screens. Since this advanced processing is mostly beneficial for larger screens and of limited benefit to existing smaller screens implementing adaptive motion seems to be the prudent choice. For still areas a field comb of 1 frame delay in the receiver will provide complete artifact free Luma/Chroma separation. Not using pre-combing for still areas offers the sharpest images for larger screens.



NTSC was designed to use **I** & **Q** chroma channels under the belief that a QAM signal could only properly carry the higher frequencies of only one of the channels so it was chosen to assign the wider bandwidth channel to flesh tones. However this was a mistake that produces improper colors for signals from ½ to 1½MHz falling 45° between the **I** & **Q** channels. For signals that fall on either **I** or **Q** the hue will be correct but as hues approach the 45° mark the hue error increases to its maximum. The reason for this is that the **I** channel portion will contain modulation that the **Q** channel does not. With a 50/50 duty cycle the filtered **Q** channel output will be an average 50% of the peak modulation. The resulting modulated hue output will bounce between two hues on either side of the original hue, hence the earned moniker **N**ever **T**he **S**ame **C**olor. To the right are four sets of patterns that represent the four vectors that are 45° to the **I** & **Q** axes in a before and after arrangement. The input, above, is fully saturated and at full brightness that alternates between its **Luma** equivalent with no color. The output is just below. From top to bottom the 45° vector order is: **I** & **Q**, –**I** & –**Q**, **I** & –**Q**, –**I** & **Q**.



For a higher bandwidth **Chroma** using vestigial sideband QAM modulation for both **U** & **V** channels is the better option. The two **Chroma** channels are usually thought of as being separate but in reality they are a Cartesian representation of a polar signal, **R** being saturation and **θ** being hue. With this in mind the QAM signal should be able to carry the higher frequencies well of both channels, [2]pg11. This has probably been employed on PAL-B/G that uses a 7MHz channel space where the **Luma** has been reduced to 5MHz and thus the **Chroma** USB has been reduced to ⅗MHz. Take for instance a **Green**–**Magenta** color bar pattern. The vestigial sideband **Chroma** signal generated has 0° phase shift and resembles a suppressed carrier signal from a single modulator similar to the **Luma** signal. It is off axis to the **U** & **V** channels which represent its Cartesian co-ordinates. Upon de-matrixing into **RGB** sharper transitions are produced compared to what is seen on the NTSC test pattern. It should be safe to assume that the non vestigial sideband portion should do a good job on chroma modulation that contains hue changes. This dual band filtering of **I** & **Q** which produces improper colors should be abandoned in favor of the **U** & **V** scheme. A dual **I** / **Q** bandwidth receiver will still produce hue errors on a wideband **U** & **V** signal but the outcome may be slightly different. On sets that use ⅗MHz **Chroma** this is a non-issue.



Above is a block flow diagram of advanced receiver decoding. Adaptive processing switches between a field comb for still image areas to a 3-line comb for motion which is controlled by comparing a two frame delay signal to the current to detect motion which then drives the fader controls. The faders are necessary to transition the wipe over several pixels to avoid sharp transitions that would be noticeable. The **Chroma** output is SuperNTSC, [1]pg11, processed to square up the signal by using the higher **Luma** frequencies above the **Chroma** cutoff frequency. This requires proper amplitude and phase adjustments to the high frequencies before being added to the **Chroma** signals.

Advanced reading:

1. NTSC and Beyond – Yves Faroudja – IEEE Transactions on Consumer Electronics, Vol.34#1 2/88
2. The Engineer's Guide to Decoding & Encoding – John Watkinson – Snell & Wilcox Handbook Series
3. A Handbook for the Digital Engineer – Keith Jack – Newnes Elsevier
4. Improved Television Systems: NTSC & Beyond – William F. Schreiber
5. Design of FIR Filters – Elena Punskaya

Horizontal & Vertical Blank & Sync Timings & Structure

Regarding the horizontal blank & sync components, front porch, sync, back porch and colorburst the dot clock optimized timings are:

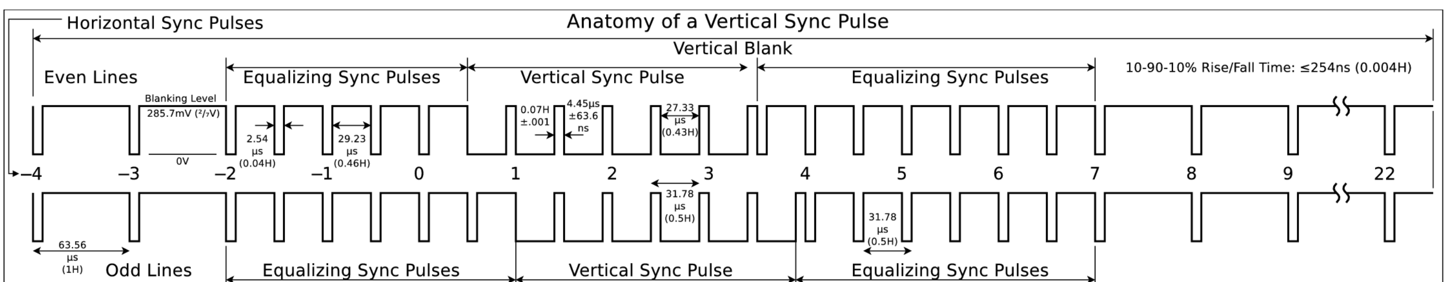
```
Horizontal Blank: 10.9µs
     Front Porch:  1½µs
            Sync:  4.7µs
      Back Porch:  4.7µs
      Colorburst:  2⅘µs, 10 cycles
```

Horizontal Blank Structure available in Composite Video Scope Image on page 4.

The timings on page 6 reflect these within the tolerances that the dot clock, the chroma 8× oscillator, can produce. When generating the signal these values should be adhearded to. For better compliance with PAL-M, and instead of centering the colorburst on the back porch, the minimum breezeway between sync and burst is 381ns, the average space after centering is ~1µs, so this space can be reduced to the mimimum allowing for greater time for the **V** switch to complete its operation. Using 419ns (1½ cycles) with a 10 cycle colorburst leaves 1½µs of time for the **V** switch to complete its opertaion within the blank.

However specification tolerances are a bit looser and any decoding must accommidate these ranges.

```
       Horizontal Blank: 10.487µs (0.165H) min
            Front Porch:  1.271µs (0.020H) min
                   Sync:  4.449µs (0.070H) min
                          5.084µs (0.080H) max
      Breezeway Spacing:    381ns (0.006H) min
Sync Start to Burst End:  7.94 µs (0.125H) max
 Sync Start to Blank End:  9.215µs (0.145H) min
             Colorburst:  2.234µs (0.035H) min ( 8cycles)
                          3.073µs (0.048H) max (11cycles)
             Back Porch:  4.131µs (0.065H) min
```



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 horizintal 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.

Existing TV Set Conversion

To the right is a synchronous adapter converter diagram for existing NTSC sets. Depending on circuit accessibility most sets should be able to be converted. Luma and Chroma circuit bandwidths may need to be widened to >5MHz & >1½MHz respectively. For sets with an S-Video input bandwidth should be sufficient but the Chroma IF, prior to detection may need to be widened to >3MHz. The 'Sound Under' the video at 275kHz on the **Q** channel is heterodyned up to 4½MHz, similar to the 'Color Under' method used in VHS playback. This allows the sound process conversion to be as seamless as possible. Since video bandwidth and horizontal sample count is optimized for a 3:2 aspect ratio it is desirable to reduce vertical size so the correct aspect ratio is displayed and doesn't appear vertically stretched. This letterboxes the image with 0.9” black bars on top and bottom of a 27” set. The alternative is to increase the horizontal size by 12½% cutting off the left and right pillars so the image doesn't appear horizontally squeezed.