Chapter 8

NTSC, PAL, and SECAM Overview

To fully understand the NTSC, PAL, and SECAM encoding and decoding processes, it is helpful to review the background of these standards and how they came about.

NTSC Overview

The first color television system was developed in the United States, and on December 17, 1953, the Federal Communications Commission (FCC) approved the transmission standard, with broadcasting approved to begin January 23, 1954. Most of the work for developing a color transmission standard that was compatible with the (then current) 525-line, 60-field-per-second, 2:1 interlaced monochrome standard was done by the National Television System Committee (NTSC).

Luminance Information

The monochrome luminance (Y) signal is derived from gamma-corrected red, green, and blue (R′G′B′) signals:

$$Y = 0.299R' + 0.587G' + 0.114B'$$

Due to the sound subcarrier at 4.5 MHz, a requirement was made that the color signal fit within the same bandwidth as the monochrome video signal (0–4.2 MHz).

For economic reasons, another requirement was made that monochrome receivers must be able to display the black and white portion of a color broadcast and that color receivers must be able to display a monochrome broadcast.

Color Information

The eye is most sensitive to spatial and temporal variations in luminance; therefore, luminance information was still allowed the entire bandwidth available (0–4.2 MHz). Color information, to which the eye is less sensitive and therefore requires less bandwidth, is represented as hue and saturation information.

The hue and saturation information is transmitted using a 3.58-MHz subcarrier, encoded so that the receiver can separate the hue, saturation, and luminance information and convert them back to RGB signals for display. Although this allows the transmission of color signals within the same bandwidth as monochrome signals, the problem still remains as to how to cost-effectively separate the color and luminance information, since they occupy the same portion of the frequency spectrum.

To transmit color information, U and V or I and Q "color difference" signals are used:

$$R' - Y = 0.701R' - 0.587G' - 0.114B'$$

$$B' - Y = -0.299R' - 0.587G' + 0.886B'$$

$$U = 0.492(B' - Y)$$

$$V = 0.877(R' - Y)$$

$$\begin{aligned} I &= 0.596R' - 0.275G' - 0.321B' \\ &= V\cos 33° - U\sin 33° \\ &= 0.736(R' - Y) - 0.268(B' - Y) \end{aligned}$$

$$\begin{aligned} Q &= 0.212R' - 0.523G' + 0.311B' \\ &= V\sin 33° + U\cos 33° \\ &= 0.478(R' - Y) + 0.413(B' - Y) \end{aligned}$$

The scaling factors to generate U and V from (B′ – Y) and (R′ – Y) were derived due to overmodulation considerations during transmission. If the full range of (B′ – Y) and (R′ – Y) were used, the modulated chrominance levels would exceed what the monochrome transmitters were capable of supporting. Experimentation determined that modulated subcarrier amplitudes of 20% of the Y signal amplitude could be permitted above white and below black. The scaling factors were then selected so that the maximum level of 75% color would be at the white level.

I and Q were initially selected since they more closely related to the variation of color acuity than U and V. The color response of the eye decreases as the size of viewed objects decreases. Small objects, occupying frequencies of 1.3–2.0 MHz, provide little color sensation. Medium objects, occupying the 0.6–1.3 MHz frequency range, are acceptable if reproduced along the orange-cyan axis. Larger objects, occupying the 0–0.6 MHz frequency range, require full three-color reproduction.

The I and Q bandwidths were chosen accordingly, and the preferred color reproduction axis was obtained by rotating the U and V axes by 33°. The Q component, representing the green-purple color axis, was band-limited to about 0.6 MHz. The I component, representing the orange-cyan color axis, was band-limited to about 1.3 MHz.

Another advantage of limiting the I and Q bandwidths to 1.3 MHz and 0.6 MHz, respectively, is to minimize crosstalk due to asymmetrical sidebands as a result of lowpass filtering the composite video signal to about 4.2 MHz. Q is a double sideband signal; however, I is asymmetrical, bringing up the possibility of crosstalk between I and Q. The symmetry of Q avoids crosstalk into I; since Q is bandwidth limited to 0.6 MHz, I crosstalk falls outside the Q bandwidth.

Advances in electronics have prompted changes. U and V, both bandwidth-limited to 1.3 MHz, are now commonly used instead of I and Q. A greater amount of processing is required in the decoder due to both U and V being asymmetrical about the color subcarrier.

The UV and IQ vector diagram is shown in Figure 8.1.

Color Modulation

I and Q (or U and V) are used to modulate a 3.58-MHz color subcarrier using two balanced modulators operating in phase quadrature: one modulator is driven by the subcarrier at sine phase, the other modulator is driven by the subcarrier at cosine phase. The outputs of the modulators are added together to form the modulated chrominance signal:

$$C = Q \sin(\omega t + 33°) + I \cos(\omega t + 33°)$$

$$\omega = 2\pi F_{SC}$$

$$F_{SC} = 3.579545 \text{ MHz } (\pm 10 \text{ Hz})$$

or, if U and V are used instead of I and Q:

$$C = U \sin \omega t + V \cos \omega t$$

Hue information is conveyed by the chrominance phase relative to the subcarrier. Saturation information is conveyed by chrominance amplitude. In addition, if an object has no color (such as a white, gray, or black object), the subcarrier is suppressed.

Composite Video Generation

The modulated chrominance is added to the luminance information along with appropriate horizontal and vertical sync signals, blanking information, and color burst information, to generate the composite color video waveform shown in Figure 8.2.

$$\text{composite NTSC} = Y + Q \sin(\omega t + 33°) + I \cos(\omega t + 33°) + \text{timing}$$

or, if U and V are used instead of I and Q:

$$\text{composite NTSC} = Y + U \sin \omega t + V \cos \omega t + \text{timing}$$

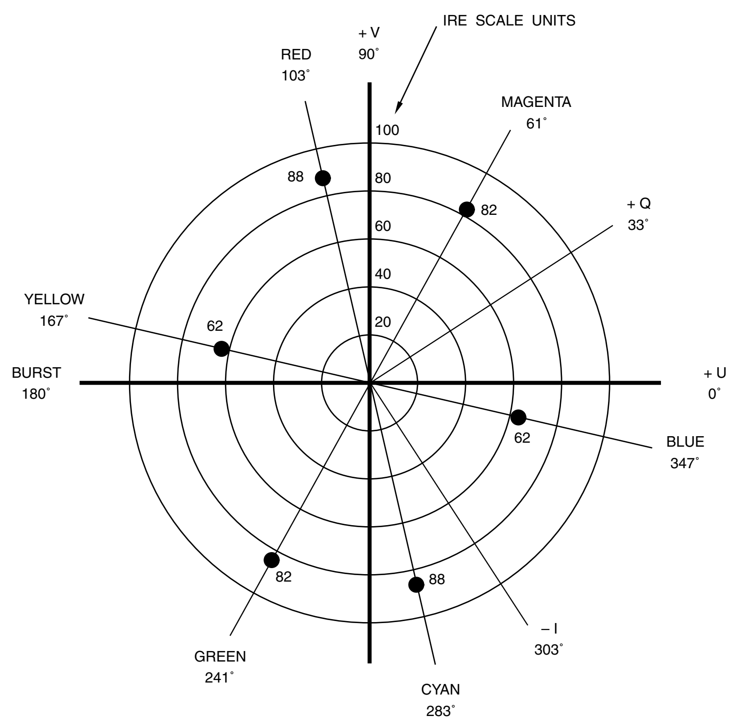

Figure 8.1. UV and IQ Vector Diagram for 75% Color Bars.

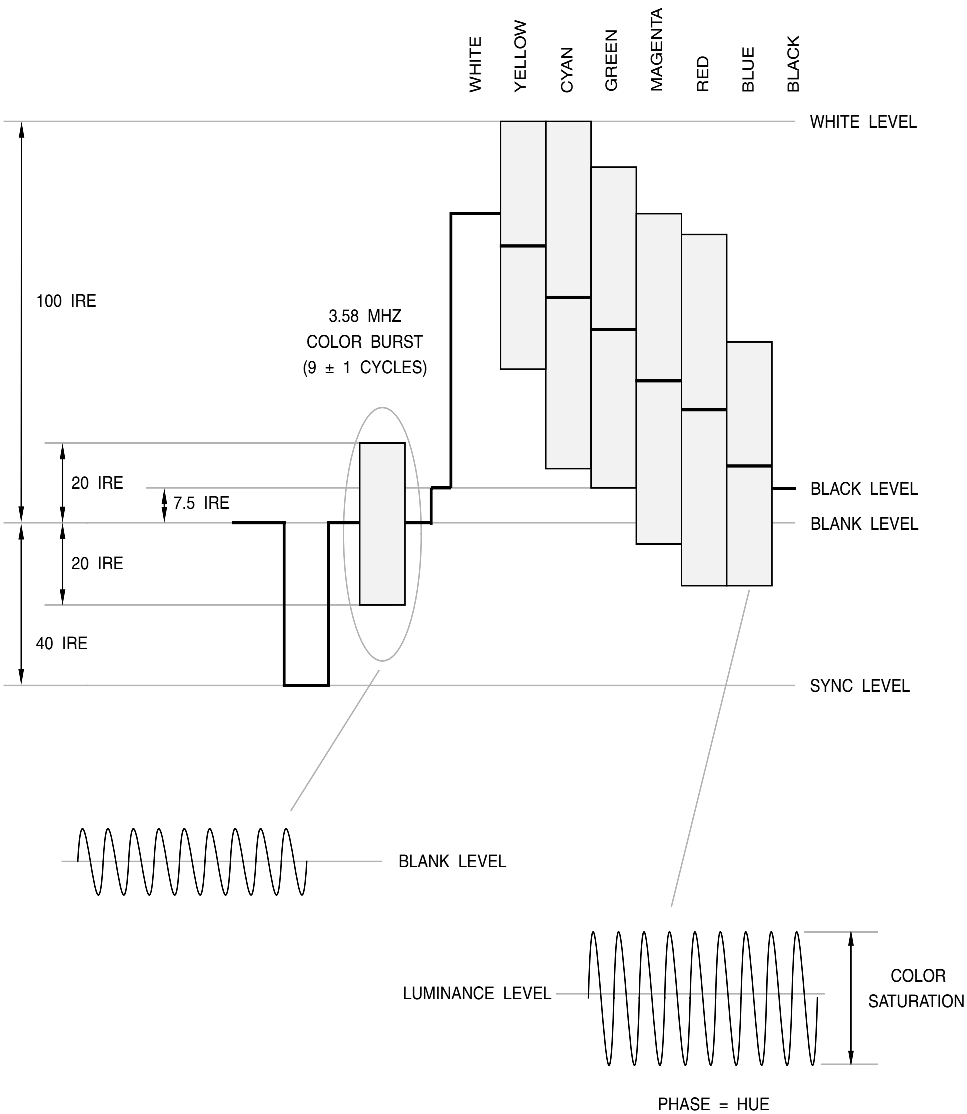

Figure 8.2. (M) NTSC Composite Video Signal for 75% Color Bars.

The bandwidth of the resulting composite video signal is shown in Figure 8.3.

The I and Q (or U and V) information can be transmitted without loss of identity as long as the proper color subcarrier phase relationship is maintained at the encoding and decoding process. A color burst signal, consisting of nine cycles of the subcarrier frequency at a specific phase, follows most horizontal sync pulses, and provides the decoder a reference signal so as to be able to properly recover the I and Q (or U and V) signals. The color burst phase is defined to be along the –U axis as shown in Figure 8.1.

Color Subcarrier Frequency

The specific choice for the color subcarrier frequency was dictated by several factors. The first was the need to provide horizontal interlace to reduce the visibility of the subcarrier, requiring that the subcarrier frequency, F_{SC}, be an odd multiple of one-half the horizontal line rate. The second factor was selection of a frequency high enough that it generated a fine interference pattern having low visibility. Third, double sidebands for I and Q (or U and V) bandwidths below 0.6 MHz had to be allowed.

The choice of the frequencies is:

$$F_H = (4.5 \times 10^6/286)\ \text{Hz} = 15{,}734.27\ \text{Hz}$$

$$F_V = F_H/(525/2) = 59.94\ \text{Hz}$$

$$F_{SC} = ((13 \times 7 \times 5)/2) \times F_H = (455/2) \times F_H = 3.579545\ \text{MHz}$$

The resulting F_V (field) and F_H (line) rates were slightly different from the monochrome standards, but fell well within the tolerance ranges and were therefore acceptable. Figure 8.4 illustrates the resulting spectral interleaving.

The luminance (Y) components are modulated due to the horizontal blanking process, resulting in bunches of luminance information spaced at intervals of F_H. These signals are further modulated by the vertical blanking process, resulting in luminance frequency components occurring at $NF_H \pm MF_V$. N has a maximum value of about 277 with a 4.2-MHz bandwidth-limited luminance. Thus, luminance information is limited to areas about integral harmonics of the line frequency (F_H), with additional spectral lines offset from NF_H by the 29.97-Hz vertical frame rate.

The area in the spectrum between luminance groups, occurring at odd multiples of one-half the line frequency, contains minimal spectral energy and is therefore used for the transmission of chrominance information. The harmonics of the color subcarrier are separated from each other by F_H since they are odd multiples of one-half F_H, providing a half-line offset and resulting in an interlace pattern that moves upward. Four complete fields are required to repeat a specific sample position, as shown in Figure 8.5.

NTSC Variations

There are three common variations of NTSC, as shown in Figures 8.6 and 8.7.

The first, called “NTSC 4.43”, is commonly used for multistandard analog VCRs. The horizontal and vertical timing is the same as (M) NTSC; color encoding uses the PAL modulation format and a 4.43361875 MHz color subcarrier frequency.

The second, “NTSC–J”, is used in Japan. It is the same as (M) NTSC, except there is no blanking pedestal during active video. Thus, active video has a nominal amplitude of 714 mV.

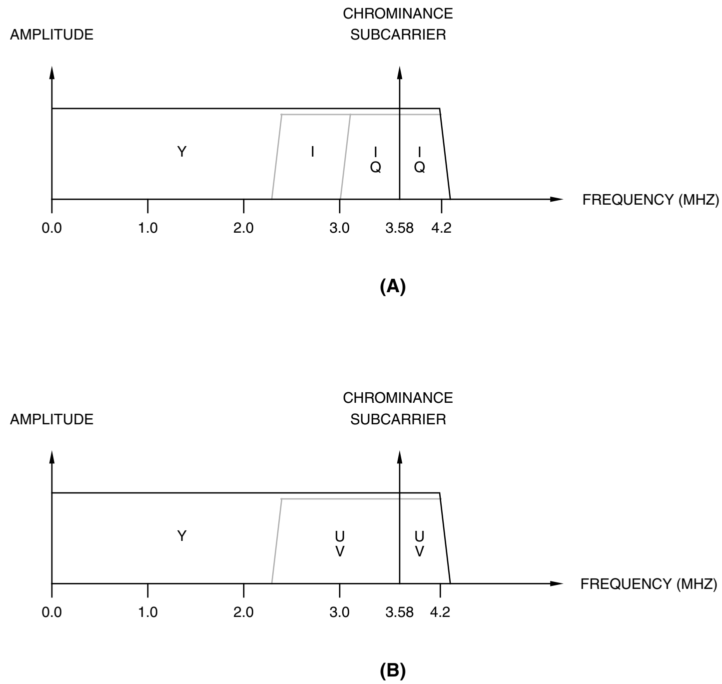

Figure 8.3. Video Bandwidths of Baseband (M) NTSC Video. (a) Using 1.3-MHz I and 0.6-MHz Q signals. (b) Using 1.3-MHz U and V signals.

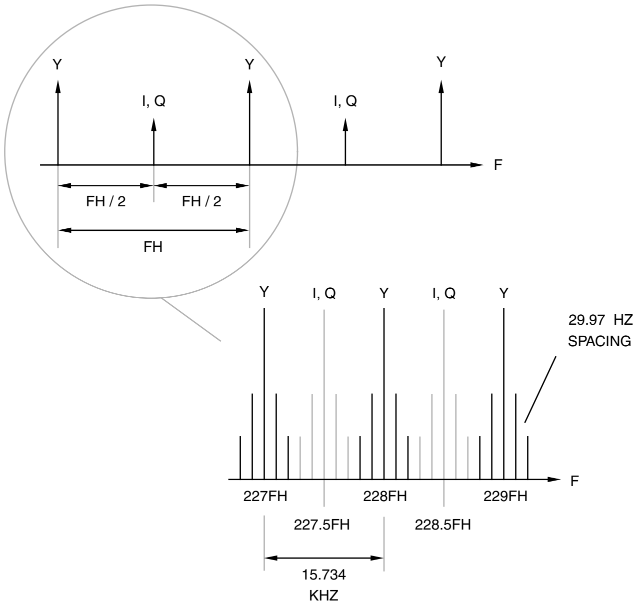

Figure 8.4. Luma and Chroma Frequency Interleave Principle. Note that $227.5F_H = F_{SC}$.

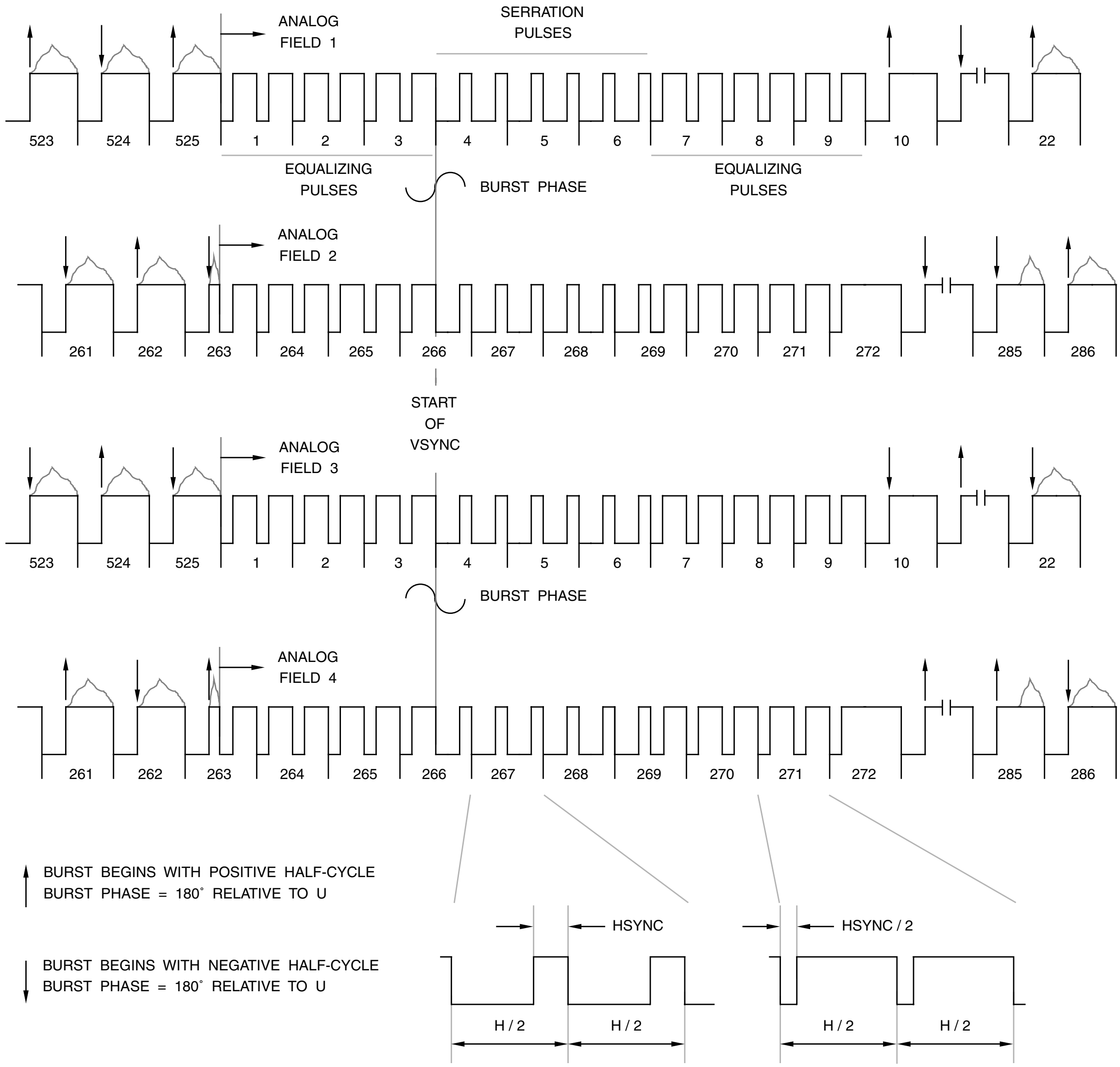

Figure 8.5. Four-field (M) NTSC Sequence and Burst Blanking.

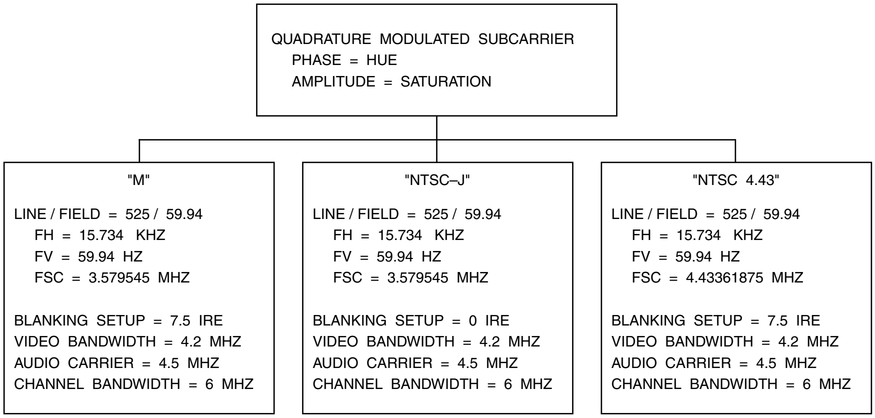

Figure 8.6. Common NTSC Systems.

The third, called “noninterlaced NTSC,” is a 262-line, 60 frames-per-second version of NTSC, as shown in Figure 8.7. This format is identical to standard (M) NTSC, except that there are 262 lines per frame.

RF Modulation

Figures 8.8, 8.9, and 8.10 illustrate the basic process of converting baseband (M) NTSC composite video to a RF (radio frequency) signal.

Figure 8.8a shows the frequency spectrum of a baseband composite video signal. It is similar to Figure 8.3, however, Figure 8.3 only shows the upper sideband for simplicity. The “video carrier” notation at 0 MHz serves only as a reference point for comparison with Figure 8.8b.

Figure 8.8b shows the audio/video signal as it resides within a 6-MHz channel (such as channel 3). The video signal has been lowpass filtered, most of the lower sideband has been removed, and audio information has been added.

Figure 8.8c details the information present on the audio subcarrier for stereo (BTSC) operation.

As shown in Figures 8.9 and 8.10, back porch clamping of the analog video signal ensures that the back porch level is constant, regardless of changes in the average picture level. White clipping of the video signal prevents the modulated signal from going below 10%; below 10% may result in overmodulation and “buzzing” in television receivers. The video signal is then lowpass filtered to 4.2 MHz and drives the AM (amplitude modulation) video modulator. The sync level corresponds to 100% modulation, the blanking corresponds to 75%, and the white level corresponds to 10%. (M) NTSC systems use an IF (intermediate frequency) for the video of 45.75 MHz.

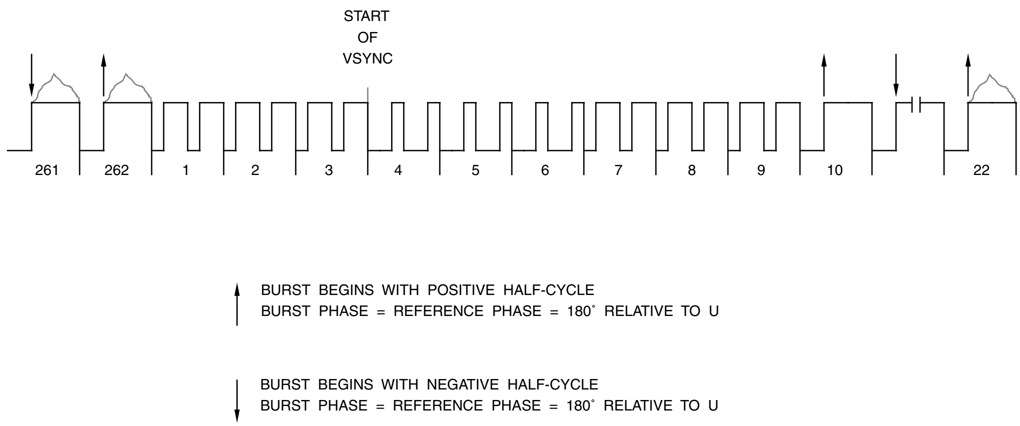

Figure 8.7. Noninterlaced NTSC Frame Sequence.

At this point, audio information is added on a subcarrier at 41.25 MHz. A monaural audio signal is processed as shown in Figure 8.9 and drives the FM (frequency modulation) modulator. The output of the FM modulator is added to the IF video signal.

The SAW filter, used as a vestigial sideband filter, provides filtering of the IF signal. The mixer, or up converter, mixes the IF signal with the desired broadcast frequency. Both sum and difference frequencies are generated by the mixing process, so the difference signal is extracted by using a bandpass filter.

Stereo Audio (Analog)

BTSC

The implementation of stereo audio, known as the BTSC system (Broadcast Television Systems Committee), is shown in Figure 8.10. Countries that use this system include the United States, Canada, Mexico, Brazil, and Taiwan.

To enable stereo, L–R information is transmitted using a suppressed AM subcarrier. A SAP (secondary audio program) channel may also be present, commonly used to transmit a second language or commentary. A professional channel may be present, allowing communication with remote equipment and people.

Zweiton M

This implementation for analog stereo audio (ITU-R BS.707) is similar to that used for PAL. The L+R information is transmitted on a FM subcarrier at 4.5 MHz. The R information is transmitted on a second FM subcarrier at (4.5 MHz + $15.5F_H$) or 4.72 MHz. This system is used in South Korea.

EIA-J

This implementation for analog stereo audio is similar to BTSC, and is used in Japan. The L–R signal, or a second L+R signal, is transmitted on a second FM subcarrier.

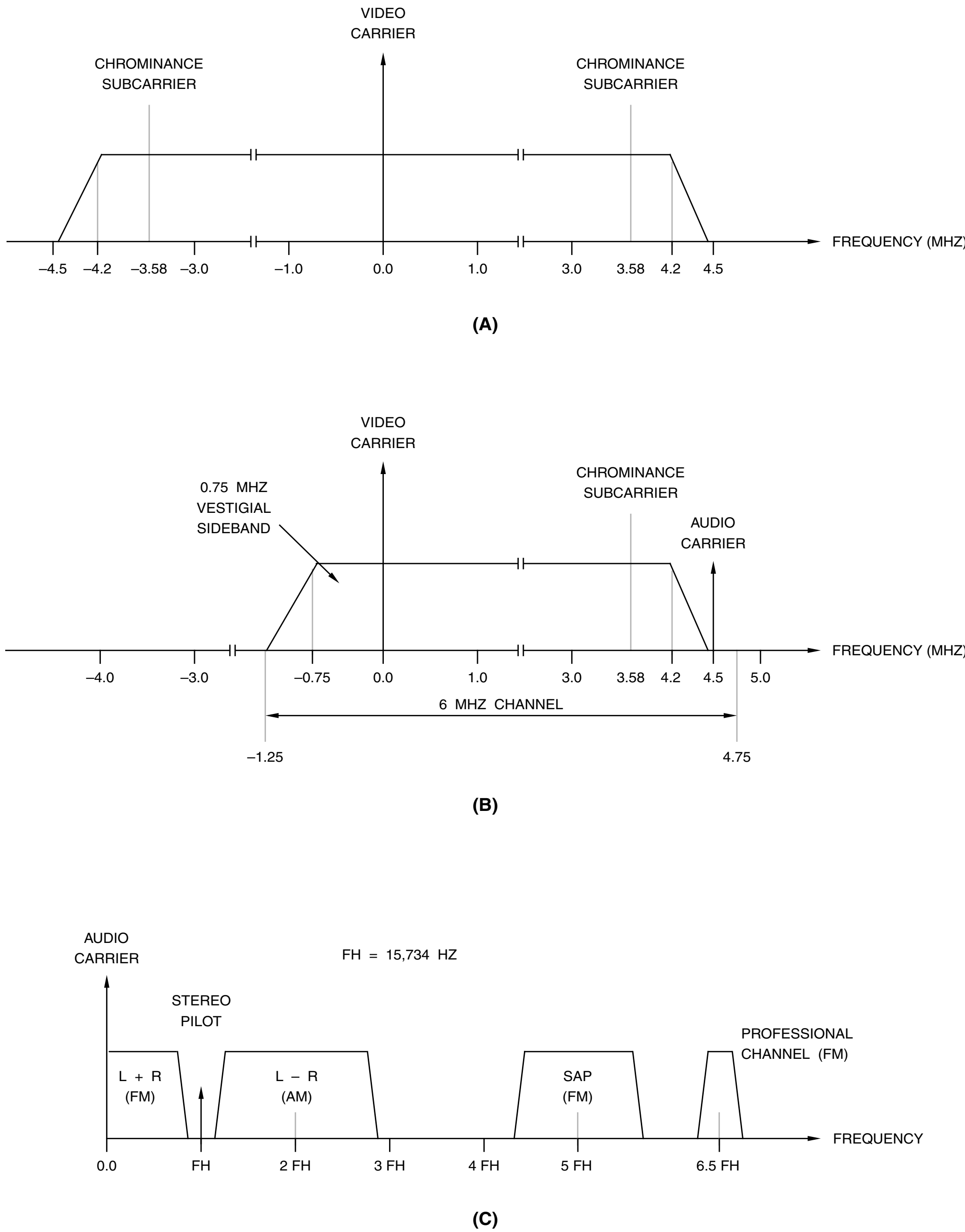

Figure 8.8. Transmission Channel for (M) NTSC. (a) Frequency spectrum of baseband composite video. (b) Frequency spectrum of typical channel including audio information. (c) Detailed frequency spectrum of BTSC stereo audio information.

Analog Channel Assignments

Tables 8.1 through 8.4 list the typical channel assignments for VHF, UHF, and cable for various NTSC systems.

Note that cable systems routinely reassign channel numbers to alternate frequencies to minimize interference and provide multiple levels of programming (such as two versions of a premium movie channel: one for subscribers, and one for nonsubscribers during pre-view times).

Use by Country

Figure 8.6 shows the common designations for NTSC systems. The letter "M" refers to the monochrome standard for line and field rates (525/59.94), a video bandwidth of 4.2 MHz, an audio carrier frequency 4.5 MHz above the video carrier frequency, and a RF channel bandwidth of 6 MHz. The "NTSC" refers to the technique to add color information to the monochrome signal. Detailed timing parameters can be found in Table 8.9.

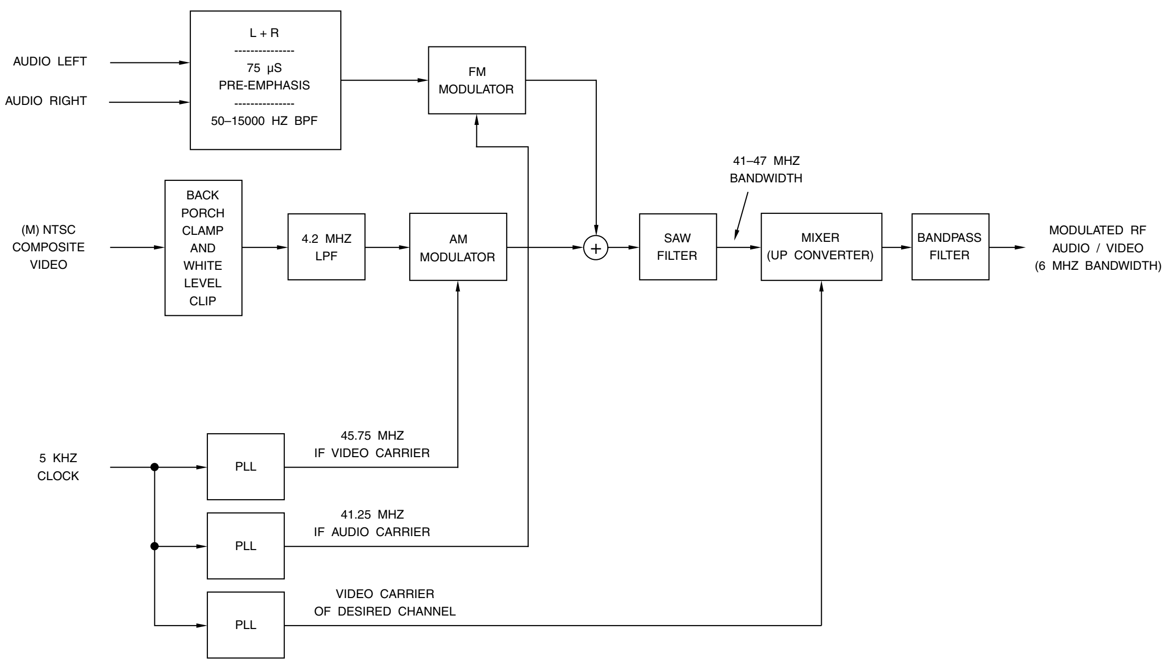

Figure 8.9. Typical RF Modulation Implementation for (M) NTSC: Mono Audio.

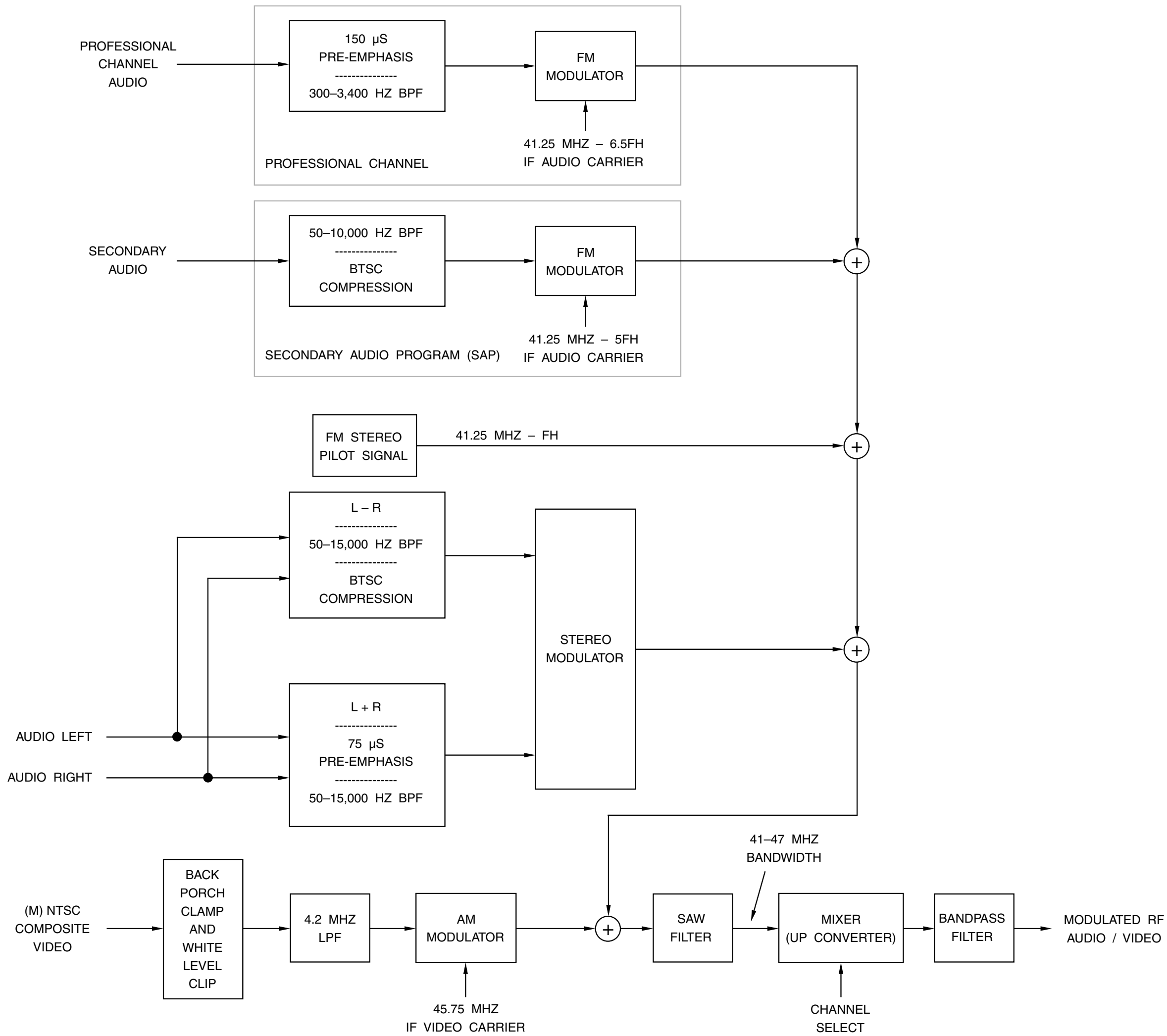

Figure 8.10. Typical RF Modulation Implementation for (M) NTSC: BTSC Stereo Audio.

Broadcast Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)	Broadcast Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)
–	–	–	–	40	627.25	631.75	626–632
–	–	–	–	41	633.25	637.75	632–638
2	55.25	59.75	54–60	42	639.25	643.75	638–644
3	61.25	65.75	60–66	43	645.25	649.75	644–650
4	67.25	71.75	66–72	44	651.25	655.75	650–656
5	77.25	81.75	76–82	45	657.25	661.75	656–662
6	83.25	87.75	82–88	46	663.25	667.75	662–668
7	175.25	179.75	174–180	47	669.25	673.75	668–674
8	181.25	185.75	180–186	48	675.25	679.75	674–680
9	187.25	191.75	186–192	49	681.25	685.75	680–686
10	193.25	197.75	192–198	50	687.25	691.75	686–692
11	199.25	203.75	198–204	51	693.25	697.75	692–698
12	205.25	209.75	204–210	52	699.25	703.75	698–704
13	211.25	215.75	210–216	53	705.25	709.75	704–710
14	471.25	475.75	470–476	54	711.25	715.75	710–716
15	477.25	481.75	476–482	55	717.25	721.75	716–722
16	483.25	487.75	482–488	56	723.25	727.75	722–728
17	489.25	493.75	488–494	57	729.25	733.75	728–734
18	495.25	499.75	494–500	58	735.25	739.75	734–740
19	501.25	505.75	500–506	59	741.25	745.75	740–746
20	507.25	511.75	506–512	60	747.25	751.75	746–752
21	513.25	517.75	512–518	61	753.25	757.75	752–758
22	519.25	523.75	518–524	62	759.25	763.75	758–764
23	525.25	529.75	524–530	63	765.25	769.75	764–770
24	531.25	535.75	530–536	64	771.25	775.75	770–776
25	537.25	541.75	536–542	65	777.25	781.75	776–782
26	543.25	547.75	542–548	66	783.25	787.75	782–788
27	549.25	553.75	548–554	67	789.25	793.75	788–794
28	555.25	559.75	554–560	68	795.25	799.75	794–800
29	561.25	565.75	560–566	69	801.25	805.75	800–806
30	567.25	571.75	566–572				
31	573.25	577.75	572–578				
32	579.25	583.75	578–584				
33	585.25	589.75	584–590				
34	591.25	595.75	590–596				
35	597.25	601.75	596–602				
36	603.25	607.75	602–608				
37	609.25	613.75	608–614				
38	615.25	619.75	614–620				
39	621.25	625.75	620–626				

Table 8.1. Analog Broadcast Nominal Frequencies for North and South America.

Broadcast Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)	Broadcast Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)
–	–	–	–	40	633.25	637.75	632–638
1	91.25	95.75	90–96	41	639.25	643.75	638–644
2	97.25	101.75	96–102	42	645.25	649.75	644–650
3	103.25	107.75	102–108	43	651.25	655.75	650–656
4	171.25	175.75	170–176	44	657.25	661.75	656–662
5	177.25	181.75	176–182	45	663.25	667.75	662–668
6	183.25	187.75	182–188	46	669.25	673.75	668–674
7	189.25	193.75	188–194	47	675.25	679.75	674–680
8	193.25	197.75	192–198	48	681.25	685.75	680–686
9	199.25	203.75	198–204	49	687.25	691.75	686–692
10	205.25	209.75	204–210	50	693.25	697.75	692–698
11	211.25	215.75	210–216	51	699.25	703.75	698–704
12	217.25	221.75	216–222	52	705.25	709.75	704–710
13	471.25	475.75	470–476	53	711.25	715.75	710–716
14	477.25	481.75	476–482	54	717.25	721.75	716–722
15	483.25	487.75	482–488	55	723.25	727.75	722–728
16	489.25	493.75	488–494	56	729.25	733.75	728–734
17	495.25	499.75	494–500	57	735.25	739.75	734–740
18	501.25	505.75	500–506	58	741.25	745.75	740–746
19	507.25	511.75	506–512	59	747.25	751.75	746–752
20	513.25	517.75	512–518	60	753.25	757.75	752–758
21	519.25	523.75	518–524	61	759.25	763.75	758–764
22	525.25	529.75	524–530	62	765.25	769.75	764–770
23	531.25	535.75	530–536	–	–	–	–
24	537.25	541.75	536–542	–	–	–	–
25	543.25	547.75	542–548	–	–	–	–
26	549.25	553.75	548–554	–	–	–	–
27	555.25	559.75	554–560	–	–	–	–
28	561.25	565.75	560–566	–	–	–	–
29	567.25	571.75	566–572	–	–	–	–
30	573.25	577.75	572–578				
31	579.25	583.75	578–584				
32	585.25	589.75	584–590				
33	591.25	595.75	590–596				
34	597.25	601.75	596–602				
35	603.25	607.75	602–608				
36	609.25	613.75	608–614				
37	615.25	619.75	614–620				
38	621.25	625.75	620–626				
39	627.25	631.75	626–632				

Table 8.2. Analog Broadcast Nominal Frequencies for Japan.

Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)	Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)
–	–	–	–	40	319.25	323.75	318–324
1	73.25	77.75	72–78	41	325.25	329.75	324–330
2	55.25	59.75	54–60	42	331.25	335.75	330–336
3	61.25	65.75	60–66	43	337.25	341.75	336–342
4	67.25	71.75	66–72	44	343.25	347.75	342–348
5	77.25	81.75	76–82	45	349.25	353.75	348–354
6	83.25	87.75	82–88	46	355.25	359.75	354–360
7	175.25	179.75	174–180	47	361.25	365.75	360–366
8	181.25	185.75	180–186	48	367.25	371.75	366–372
9	187.25	191.75	186–192	49	373.25	377.75	372–378
10	193.25	197.75	192–198	50	379.25	383.75	378–384
11	199.25	203.75	198–204	51	385.25	389.75	384–390
12	205.25	209.75	204–210	52	391.25	395.75	390–396
13	211.25	215.75	210–216	53	397.25	401.75	396–402
14	121.25	125.75	120–126	54	403.25	407.75	402–408
15	127.25	131.75	126–132	55	409.25	413.75	408–414
16	133.25	137.75	132–138	56	415.25	419.75	414–420
17	139.25	143.75	138–144	57	421.25	425.75	420–426
18	145.25	149.75	144–150	58	427.25	431.75	426–432
19	151.25	155.75	150–156	59	433.25	437.75	432–438
20	157.25	161.75	156–162	60	439.25	443.75	438–444
21	163.25	167.75	162–168	61	445.55	449.75	444–450
22	169.25	173.75	168–174	62	451.25	455.75	450–456
23	217.25	221.75	216–222	63	457.25	461.75	456–462
24	223.25	227.75	222–228	64	463.25	467.75	462–468
25	229.25	233.75	228–234	65	469.25	473.75	468–474
26	235.25	239.75	234–240	66	475.25	479.75	474–480
27	241.25	245.75	240–246	67	481.25	485.75	480–486
28	247.25	251.75	246–252	68	487.25	491.75	486–492
29	253.25	257.75	252–258	69	493.25	497.75	492–498
30	259.25	263.75	258–264	70	499.25	503.75	498–504
31	265.25	269.75	264–270	71	505.25	509.75	504–510
32	271.25	275.75	270–276	72	511.25	515.75	510–516
33	277.25	281.75	276–282	73	517.25	521.75	516–522
34	283.25	287.75	282–288	74	523.25	527.75	522–528
35	289.25	293.75	288–294	75	529.25	533.75	528–534
36	295.25	299.75	294–300	76	535.25	539.75	534–540
37	301.25	305.75	300–306	77	541.25	545.75	540–546
38	307.25	311.75	306–312	78	547.25	551.75	546–552
39	313.25	317.75	312–318	79	553.25	557.75	552–558

Table 8.3a. Analog Cable TV Nominal Frequencies for USA for Incrementally Related Carrier (IRC) Systems. For Harmonically Related Carrier (HRC) systems, subtract 1.25 MHz.

Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)	Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)
80	559.25	563.75	558–564	120	769.25	773.75	768–774
81	565.25	569.75	564–570	121	775.25	779.75	774–780
82	571.25	575.75	570–576	122	781.25	785.75	780–786
83	577.25	581.75	576–582	123	787.25	791.75	786–792
84	583.25	587.75	582–588	124	793.25	797.75	792–798
85	589.25	593.75	588–594	125	799.25	803.75	798–804
86	595.25	599.75	594–600	126	805.25	809.75	804–810
87	601.25	605.75	600–606	127	811.25	815.75	810–816
88	607.25	611.75	606–612	128	817.25	821.75	816–822
89	613.25	617.75	612–618	129	823.25	827.75	822–828
90	619.25	623.75	618–624	130	829.25	833.75	828–834
91	625.25	629.75	624–630	131	835.25	839.75	834–840
92	631.25	635.75	630–636	132	841.25	845.75	840–846
93	637.25	641.75	636–642	133	847.25	851.75	846–852
94	643.25	647.75	642–648	134	853.25	857.75	852–858
95	91.25	95.75	90–96	135	859.25	863.75	858–864
96	97.25	101.75	96–102	136	865.25	869.75	864–870
97	103.25	107.75	102–108	137	871.25	875.75	870–876
98	109.25	113.75	108–114	138	877.25	881.75	876–882
99	115.25	119.75	114–120	139	883.25	887.75	882–888
100	649.25	653.75	648–654	140	889.25	893.75	888–894
101	655.25	659.75	654–660	141	895.25	899.75	894–900
102	661.25	665.75	660–666	142	901.25	905.75	900–906
103	667.25	671.75	666–672	143	907.25	911.75	906–912
104	673.25	677.75	672–678	144	913.25	917.75	912–918
105	679.25	683.75	678–684	145	919.25	923.75	918–924
106	685.25	689.75	684–690	146	925.25	929.75	924–930
107	691.25	695.75	690–696	147	931.25	935.75	930–936
108	697.25	701.75	696–702	148	937.25	941.75	936–942
109	703.25	707.75	702–708	149	943.25	947.75	942–948
110	709.25	713.75	708–714	150	949.25	953.75	948–954
111	715.25	719.75	714–720	151	955.25	959.75	954–960
112	721.25	725.75	720–726	152	961.25	965.75	960–966
113	727.25	731.75	726–732	153	967.25	971.75	966–972
114	733.25	737.75	732–738	154	973.25	977.75	972–978
115	739.25	743.75	738–744	155	979.25	983.75	978–984
116	745.25	749.75	744–750	156	985.25	989.75	984–990
117	751.25	755.75	750–756	157	991.25	995.75	990–996
118	757.25	761.75	756–762	158	997.25	1001.75	996–1002
119	763.25	767.75	762–768	–	–	–	–
T7	8.25		7–13	T11	32.25		31–37
T8	14.25		13–19	T13	38.25		37–43
T9	20.25		19–25	T13	44.25		43–49
T10	26.25		25–31	–	–		–

Table 8.3b. Analog Cable TV Nominal Frequencies for USA for Incrementally Related Carrier (IRC) Systems. For Harmonically Related Carrier (HRC) systems, subtract 1.25 MHz. T channels are reverse (return) channels for two-way applications.

Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)	Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)
–	–	–	–	40	325.25	329.75	324–330
–	–	–	–	41	331.25	335.75	330–336
–	–	–	–	42	337.25	341.75	336–342
13	109.25	113.75	108–114	46	343.25	347.75	342–348
14	115.25	119.75	114–120	44	349.25	353.75	348–354
15	121.25	125.75	120–126	45	355.25	359.75	354–360
16	127.25	131.75	126–132	46	361.25	365.75	360–366
17	133.25	137.75	132–138	47	367.25	371.75	366–372
18	139.25	143.75	138–144	48	373.25	377.75	372–378
19	145.25	149.75	144–150	49	379.25	383.75	378–384
20	151.25	155.75	150–156	50	385.25	389.75	384–390
21	157.25	161.75	156–162	51	391.25	395.75	390–396
22	165.25	169.75	164–170	52	397.25	401.75	396–402
23	223.25	227.75	222–228	53	403.25	407.75	402–408
24	231.25	235.75	230–236	54	409.25	413.75	408–414
25	237.25	241.75	236–242	55	415.25	419.75	414–420
26	243.25	247.75	242–248	56	421.25	425.75	420–426
27	249.25	253.75	248–254	57	427.25	431.75	426–432
28	253.25	257.75	252–258	58	433.25	437.75	432–438
29	259.25	263.75	258–264	59	439.25	443.75	438–444
30	265.25	269.75	264–270	60	445.25	449.75	444–450
31	271.25	275.75	270–276	61	451.25	455.75	450–456
32	277.25	281.75	276–282	62	457.25	461.75	456–462
33	283.25	287.75	282–288	63	463.25	467.75	462–468
34	289.25	293.75	288–294	–	–	–	–
35	295.25	299.75	294–300	–	–	–	–
36	301.25	305.75	300–306	–	–	–	–
37	307.25	311.75	306–312	–	–	–	–
38	313.25	317.75	312–318	–	–	–	–
39	319.25	323.75	318–324	–	–	–	–

Table 8.4. Analog Cable TV Nominal Frequencies for Japan.

The following countries use the (M) NTSC standard.

Antigua	Japan (NTSC–J)
Aruba	Korea, South
Bahamas	Mexico
Barbados	Montserrat
Belize	Myanmar
Bermuda	Nicaragua
Bolivia	Panama
Canada	Peru
Chile	Philippines
Colombia	Puerto Rico
Costa Rica	St. Kitts and Nevis
Cuba	Samoa
Curacao	Suriname
Dominican Republic	Taiwan
Ecuador	Trinidad/Tobago
El Salvador	United States of America
Guam	Venezuela
Guatemala	Virgin Islands
Honduras	
Jamaica	

Luminance Equation Derivation

The equation for generating luminance from RGB is determined by the chromaticities of the three primary colors used by the receiver and what color white actually is.

The chromaticities of the RGB primaries and reference white (CIE illuminate C) were specified in the 1953 NTSC standard to be:

R: $x_r = 0.67$ $y_r = 0.33$ $z_r = 0.00$

G: $x_g = 0.21$ $y_g = 0.71$ $z_g = 0.08$

B: $x_b = 0.14$ $y_b = 0.08$ $z_b = 0.78$

white: $x_w = 0.3101$ $y_w = 0.3162$ $z_w = 0.3737$

where x and y are the specified CIE 1931 chromaticity coordinates; z is calculated by knowing that x + y + z = 1.

Luminance is calculated as a weighted sum of RGB, with the weights representing the actual contributions of each of the RGB primaries in generating the luminance of reference white. We find the linear combination of RGB that gives reference white by solving the equation:

$$\begin{bmatrix} x_r & x_g & x_b \\ y_r & y_g & y_b \\ z_r & z_g & z_b \end{bmatrix} \begin{bmatrix} K_r \\ K_g \\ K_b \end{bmatrix} = \begin{bmatrix} x_w/y_w \\ 1 \\ z_w/y_w \end{bmatrix}$$

Rearranging to solve for K_r, K_g, and K_b yields:

$$\begin{bmatrix} K_r \\ K_g \\ K_b \end{bmatrix} = \begin{bmatrix} x_w/y_w \\ 1 \\ z_w/y_w \end{bmatrix} \begin{bmatrix} x_r & x_g & x_b \\ y_r & y_g & y_b \\ z_r & z_g & z_b \end{bmatrix}^{-1}$$

Substituting the known values gives us the solution for K_r, K_g, and K_b:

$$\begin{bmatrix} K_r \\ K_g \\ K_b \end{bmatrix} = \begin{bmatrix} 0.3101/0.3162 \\ 1 \\ 0.3737/0.3162 \end{bmatrix} \begin{bmatrix} 0.67 & 0.21 & 0.14 \\ 0.33 & 0.71 & 0.08 \\ 0.00 & 0.08 & 0.78 \end{bmatrix}^{-1}$$

$$= \begin{bmatrix} 0.9807 \\ 1 \\ 1.1818 \end{bmatrix} \begin{bmatrix} 1.730 & -0.482 & -0.261 \\ -0.814 & 1.652 & -0.023 \\ 0.083 & -0.169 & 1.284 \end{bmatrix}$$

$$= \begin{bmatrix} 0.906 \\ 0.827 \\ 1.430 \end{bmatrix}$$

Y is defined to be

$$Y = (K_r y_r)R' + (K_g y_g)G' + (K_b y_b)B'$$
$$= (0.906)(0.33)R' + (0.827)(0.71)G' + (1.430)(0.08)B'$$

or

$$Y = 0.299R' + 0.587G' + 0.114B'$$

Modern receivers use a different set of RGB phosphors, resulting in slightly different chromaticities of the RGB primaries and reference white (CIE illuminate D_{65}):

R: $x_r = 0.630$ $y_r = 0.340$ $z_r = 0.030$

G: $x_g = 0.310$ $y_g = 0.595$ $z_g = 0.095$

B: $x_b = 0.155$ $y_b = 0.070$ $z_b = 0.775$

white: $x_w = 0.3127$ $y_w = 0.3290$ $z_w = 0.3583$

where x and y are the specified CIE 1931 chromaticity coordinates; z is calculated by knowing that x + y + z = 1. Once again, substituting the known values gives us the solution for K_r, K_g, and K_b:

$$\begin{bmatrix} K_r \\ K_g \\ K_b \end{bmatrix} = \begin{bmatrix} 0.3127/0.3290 \\ 1 \\ 0.3583/0.3290 \end{bmatrix} \begin{bmatrix} 0.630 & 0.310 & 0.155 \\ 0.340 & 0.595 & 0.070 \\ 0.030 & 0.095 & 0.775 \end{bmatrix}^{-1}$$

$$= \begin{bmatrix} 0.6243 \\ 1.1770 \\ 1.2362 \end{bmatrix}$$

Since Y is defined to be

$$Y = (K_r y_r)R' + (K_g y_g)G' + (K_b y_b)B'$$
$$= (0.6243)(0.340)R' + (1.1770)(0.595)G' + (1.2362)(0.070)B'$$

this results in:

$$Y = 0.212R' + 0.700G' + 0.086B'$$

However, the standard $Y = 0.299R' + 0.587G' + 0.114B'$ equation is still used. Adjustments are in the receiver to minimize color errors.

PAL Overview

Europe delayed adopting a color television standard, evaluating various systems between 1953 and 1967 that were compatible with their 625-line, 50-field-per-second, 2:1 interlaced monochrome standard. The NTSC specification was modified to overcome the high order of phase and amplitude integrity required during broadcast to avoid color distortion. The Phase Alternation Line (PAL) system implements a line-by-line reversal of the phase of one of the color components, originally relying on the eye to average any color distortions to the correct color. Broadcasting began in 1967 in Germany and the United Kingdom, with each using a slightly different variant of the PAL system.

Luminance Information

The monochrome luminance (Y) signal is derived from R′G′B′:

$$Y = 0.299R' + 0.587G' + 0.114B'$$

As with NTSC, the luminance signal occupies the entire video bandwidth. PAL has several variations, depending on the video bandwidth and placement of the audio subcarrier. The composite video signal has a bandwidth of 4.2, 5.0, 5.5, or 6.0 MHz, depending on the specific PAL standard.

Color Information

To transmit color information, U and V are used:

$$U = 0.492(B' - Y)$$

$$V = 0.877(R' - Y)$$

U and V have a typical bandwidth of 1.3 MHz.

Color Modulation

As in the NTSC system, U and V are used to modulate the color subcarrier using two balanced modulators operating in phase quadrature: one modulator is driven by the subcarrier at sine phase, the other modulator is driven by the subcarrier at cosine phase. The outputs of the modulators are added together to form the modulated chrominance signal:

$$C = U \sin \omega t \pm V \cos \omega t$$

$$\omega = 2\pi F_{SC}$$

F_{SC} = 4.43361875 MHz (± 5 Hz) for (B, D, G, H, I, N) PAL

F_{SC} = 3.58205625 MHz (± 5 Hz) for (N_C) PAL

F_{SC} = 3.57561149 MHz (± 10 Hz) for (M) PAL

In PAL, the phase of V is reversed every other line. V was chosen for the reversal process since it has a lower gain factor than U and therefore is less susceptible to a one-half F_H switching rate imbalance. The result of alternating the V phase at the line rate is that any color subcarrier phase errors produce complementary errors, allowing line-to-line averaging at the receiver to cancel the errors and generate the correct hue with slightly reduced saturation. This technique requires the PAL receiver to be able to determine the correct V phase. This is done using a technique known as AB sync, PAL sync, PAL Switch, or "swinging burst," consisting of alternating the phase of the color burst by ±45° at the line rate. The UV vector diagrams are shown in Figures 8.11 and 8.12.

"Simple" PAL decoders rely on the eye to average the line-by-line hue errors. "Standard" PAL decoders use a 1-H delay line to separate U from V in an averaging process. Both implementations have the problem of Hanover bars, in which pairs of adjacent lines have a real and complementary hue error. Chrominance vertical resolution is reduced as a result of the line averaging process.

Composite Video Generation

The modulated chrominance is added to the luminance information along with appropriate horizontal and vertical sync signals, blanking signals, and color burst signals, to generate the composite color video waveform shown in Figure 8.13.

$$\text{composite PAL} = Y + U \sin \omega t \pm V \cos \omega t + \text{timing}$$

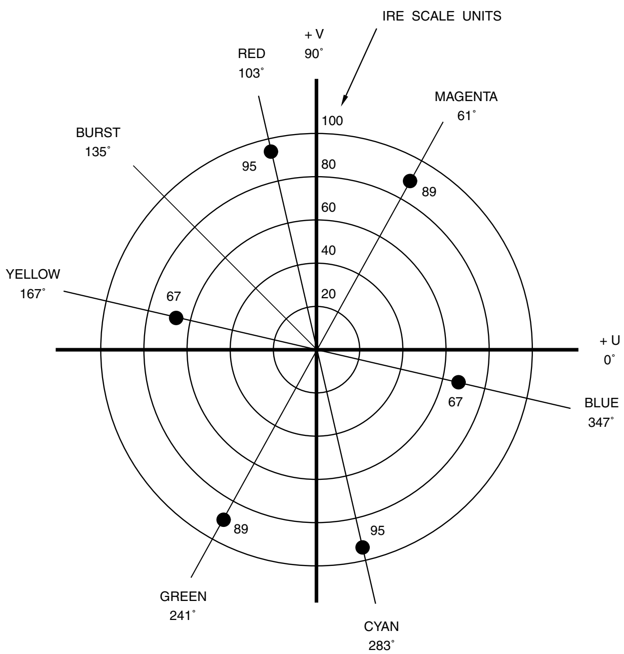

Figure 8.11. UV Vector Diagram for 75% Color Bars. Line [n], PAL Switch = zero.

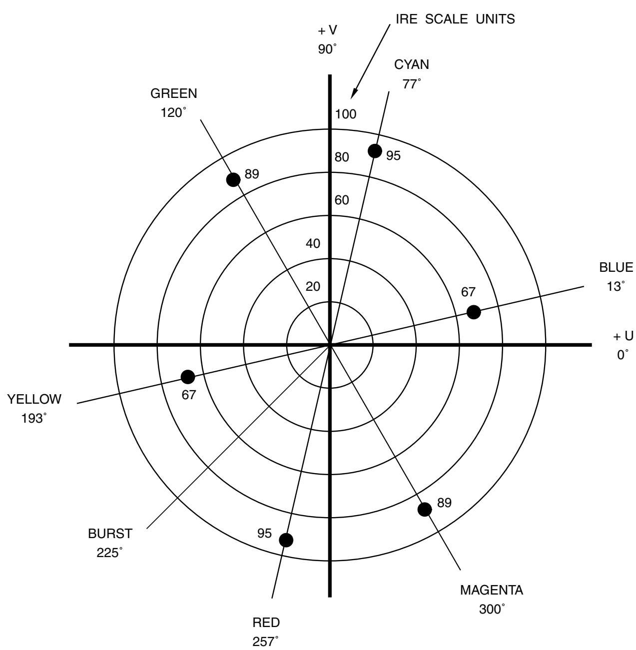

Figure 8.12. UV Vector Diagram for 75% Color Bars. Line [n + 1], PAL Switch = one.

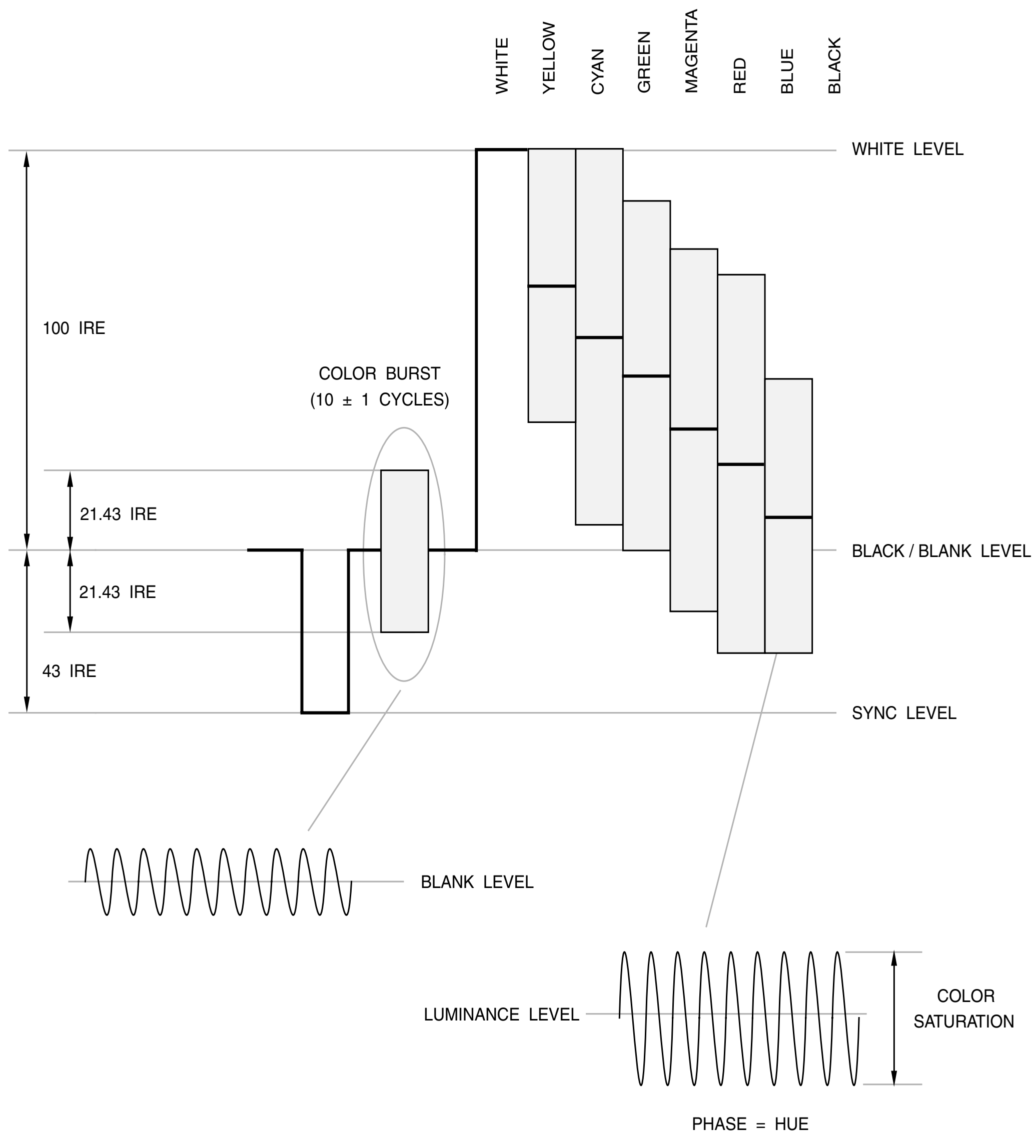

Figure 8.13. (B, D, G, H, I, N_C) PAL Composite Video Signal for 75% Color Bars.

The bandwidth of the resulting composite video signal is shown in Figure 8.14.

Like NTSC, the luminance components are spaced at F_H intervals due to horizontal blanking. Since the V component is switched symmetrically at one-half the line rate, only odd harmonics are generated, resulting in V components that are spaced at intervals of F_H. The V components are spaced at half-line intervals from the U components, which also have F_H spacing. If the subcarrier had a half-line offset like NTSC uses, the U components would be perfectly interleaved, but the V components would coincide with the Y components and thus not be interleaved, creating vertical stationary dot patterns. For this reason, PAL uses a 1/4 line offset for the subcarrier frequency:

$$F_{SC} = ((1135/4) + (1/625))\ F_H$$
for (B, D, G, H, I, N) PAL

$$F_{SC} = (909/4)\ F_H$$
for (M) PAL

$$F_{SC} = ((917/4) + (1/625))\ F_H$$
for (N_C) PAL

The additional (1/625) F_H factor (equal to 25 Hz) provides motion to the color dot pattern, reducing its visibility. Figure 8.15 illustrates the resulting frequency interleaving. Eight complete fields are required to repeat a specific sample position, as shown in Figures 8.16 and 8.17.

PAL Variations

There is a variation of PAL, "noninterlaced PAL", shown in Figure 8.18. It is a 312-line, 50 frames-per-second version of PAL common among video games and on-screen displays. This format is identical to standard PAL, except that there are 312 lines per frame.

The most common PAL standards are shown in Figure 8.19.

RF Modulation

Figures 8.20 and 8.21 illustrate the process of converting baseband (G) PAL composite video to a RF (radio frequency) signal. The process for the other PAL standards is similar, except primarily the different video bandwidths and subcarrier frequencies.

Figure 8.20a shows the frequency spectrum of a (G) PAL baseband composite video signal. It is similar to Figure 8.14, however, Figure 8.14 only shows the upper sideband for simplicity. The "video carrier" notation at 0 MHz serves only as a reference point for comparison with Figure 8.20b.

Figure 8.20b shows the audio/video signal as it resides within an 8-MHz channel. The video signal has been lowpass filtered, most of the lower sideband has been removed, and audio information has been added. Note that (H) and (I) PAL have a vestigial sideband of 1.25 MHz, rather than 0.75 MHz.

Figure 8.20c details the information present on the audio subcarrier for analog stereo operation.

As shown in Figure 8.21, back porch clamping of the analog video signal ensures that the back porch level is constant, regardless of changes in the average picture level. The video signal is then lowpass filtered to 5.0 MHz and drives the AM (amplitude modulation) video modulator. The sync level corresponds to 100% modulation; the blanking and white modulation levels are dependent on the specific version of PAL:

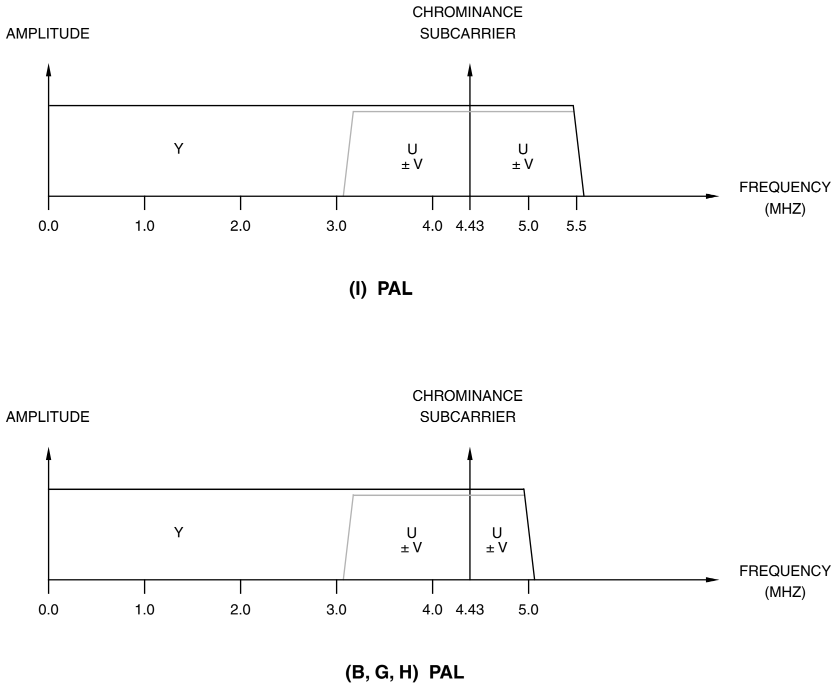

Figure 8.14. Video Bandwidths of Some PAL Systems.

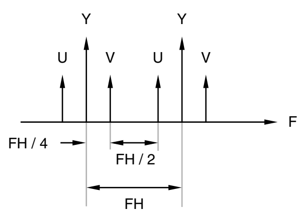

Figure 8.15. Luma and Chroma Frequency Interleave Principle.

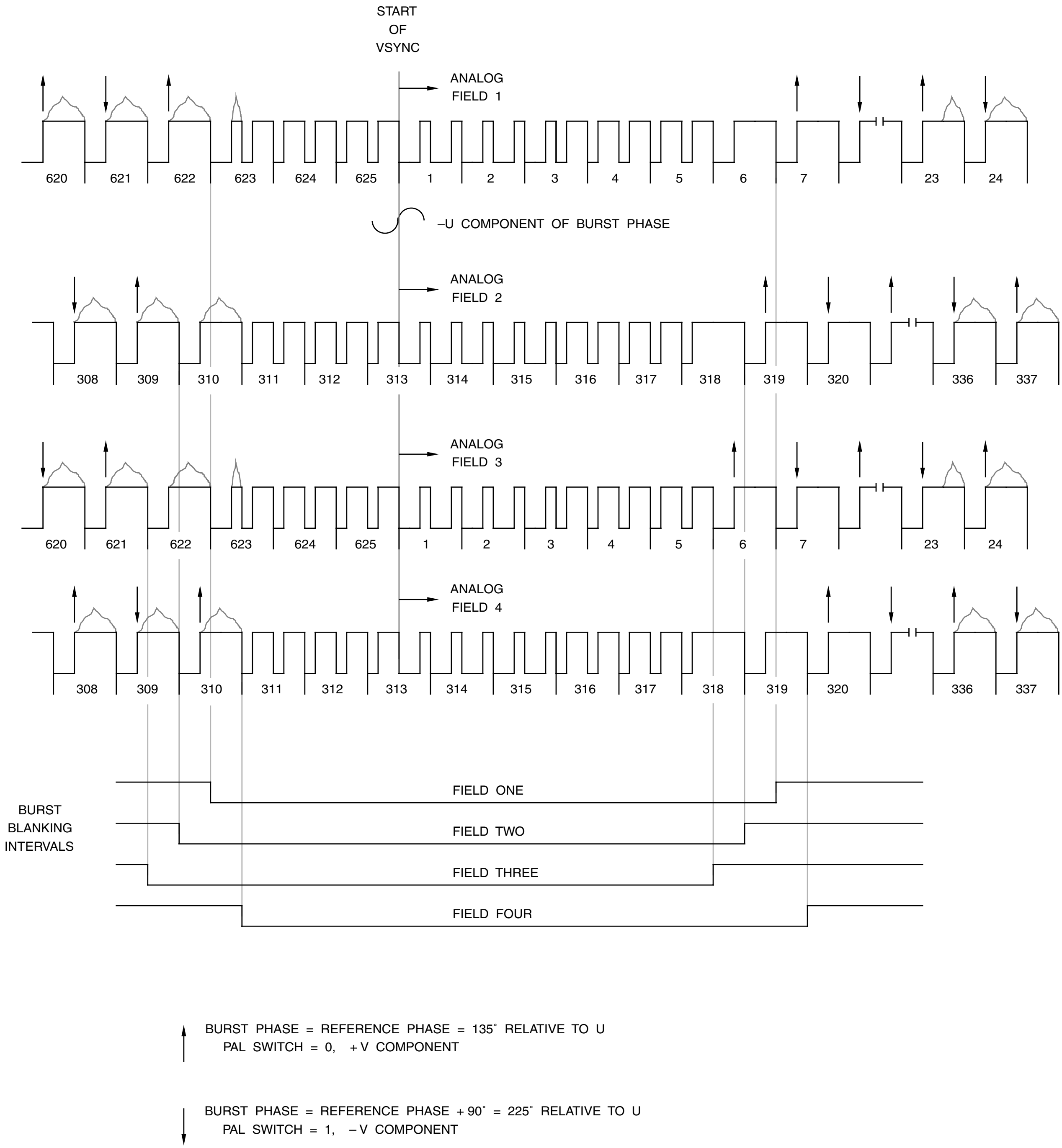

Figure 8.16a. Eight-field (B, D, G, H, I, N_C) PAL Sequence and Burst Blanking. See Figure 8.5 for equalization and serration pulse details.

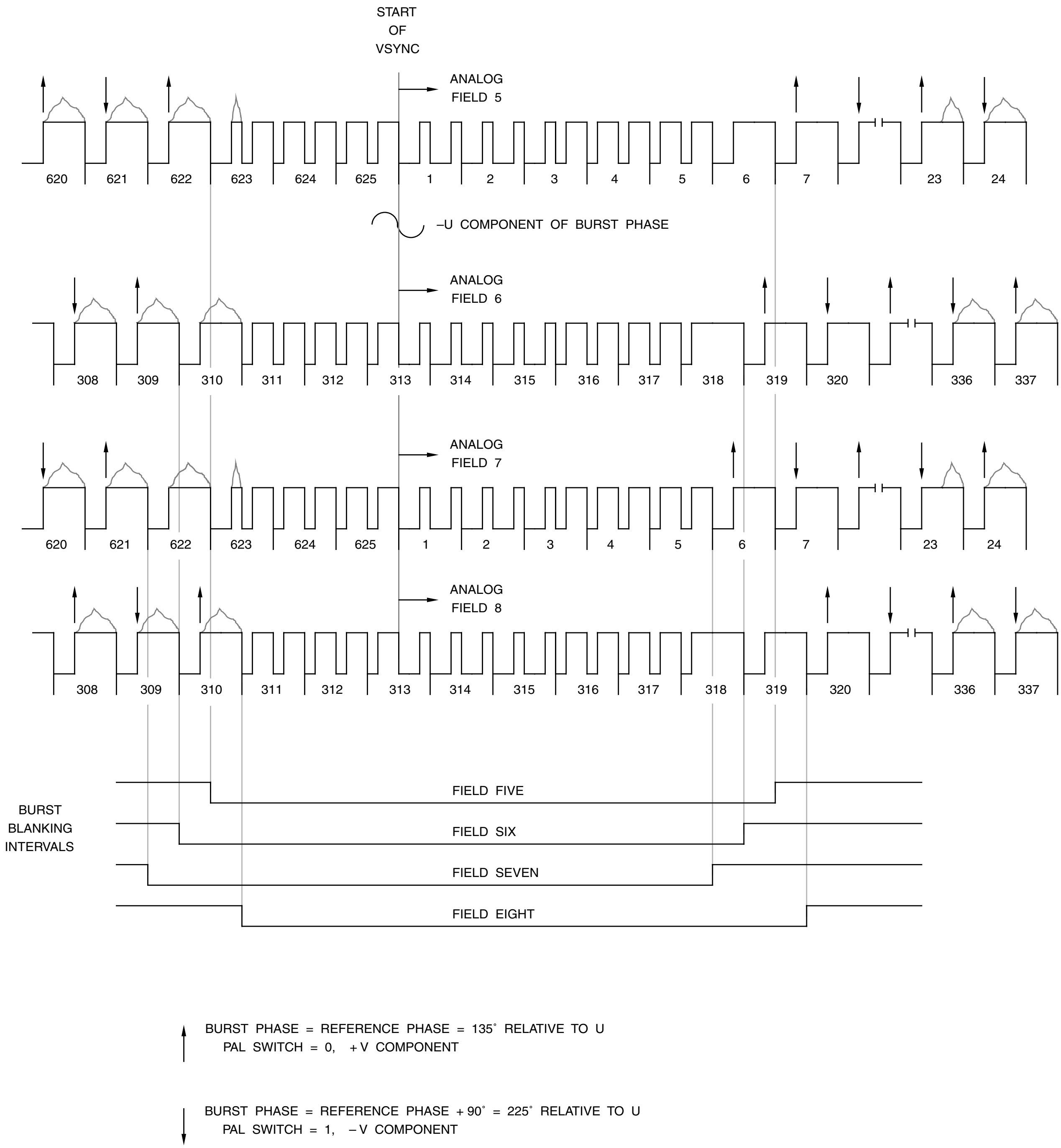

Figure 8.16b. Eight-field (B, D, G, H, I, N_C) PAL Sequence and Burst Blanking. See Figure 8.5 for equalization and serration pulse details.

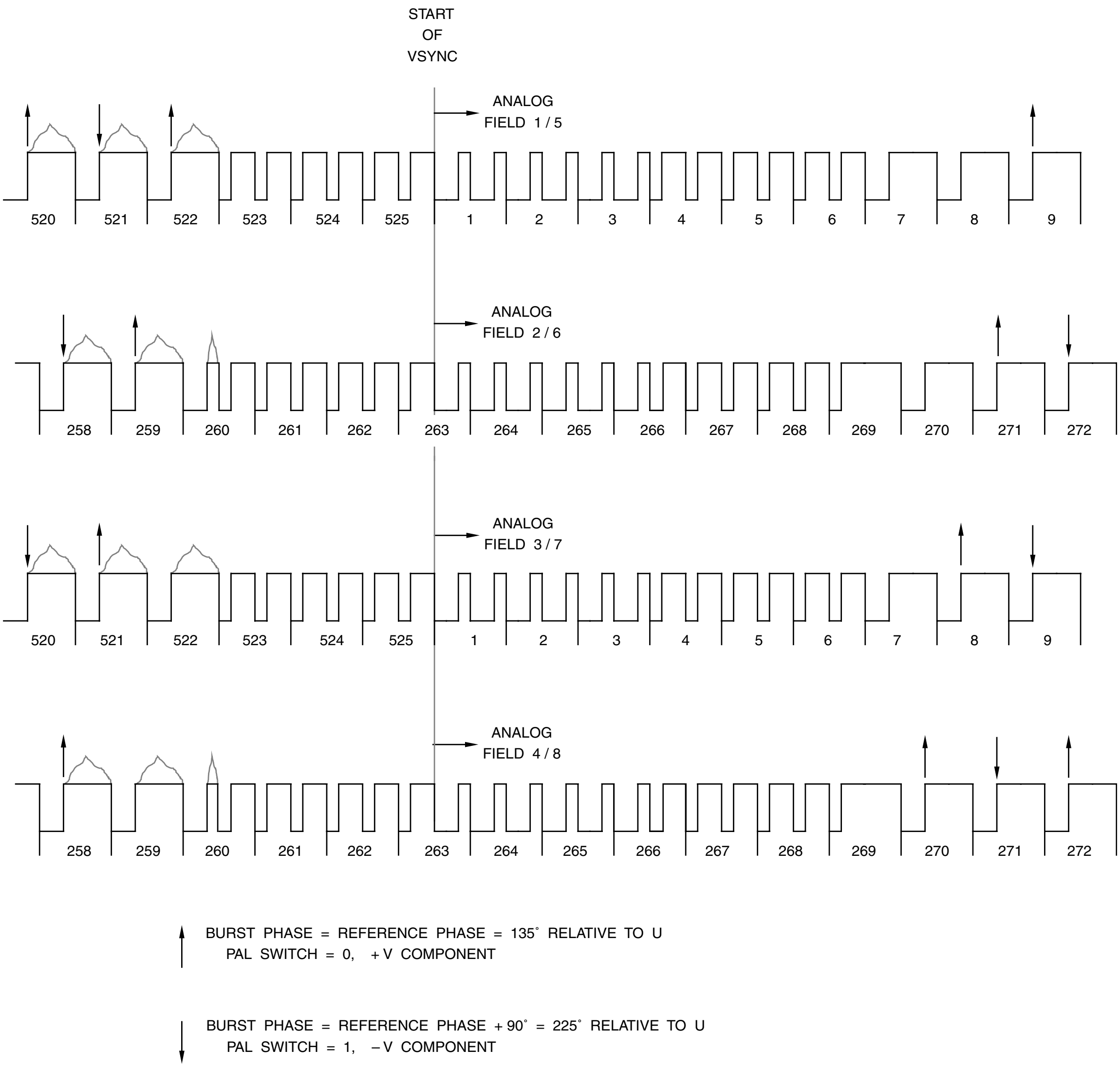

Figure 8.17. Eight-field (M) PAL Sequence and Burst Blanking. See Figure 8.5 for equalization and serration pulse details.

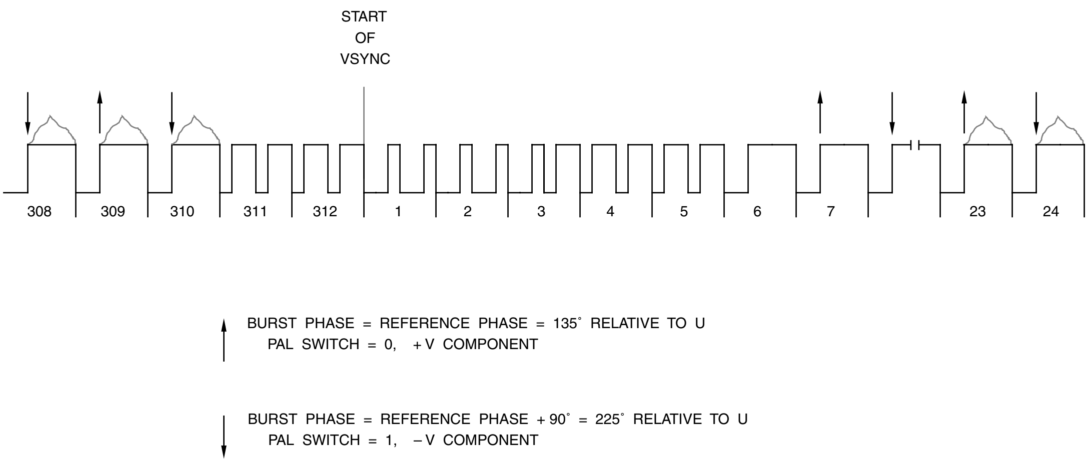

Figure 8.18. Noninterlaced PAL Frame Sequence.

blanking level (% modulation)

B, G	75%
D, H, M, N	75%
I	76%

white level (% modulation)

B, G, H, M, N	10%
D	10%
I	20%

Note that PAL systems use a variety of video and audio IF frequencies (values in MHz):

	video	audio	
B, G	38.900	33.400	
B	36.875	31.375	Australia
D	37.000	30.500	China
D	38.900	32.400	OIRT
I	38.900	32.900	
I	39.500	33.500	U.K.
M, N	45.750	41.250	

At this point, audio information is added on the audio subcarrier. A monaural L+R audio signal is processed as shown in Figure 8.21 and drives the FM (frequency modulation) modulator. The output of the FM modulator is added to the IF video signal.

The SAW filter, used as a vestigial sideband filter, provides filtering of the IF signal. The mixer, or up converter, mixes the IF signal with the desired broadcast frequency. Both sum and difference frequencies are generated by the mixing process, so the difference signal is extracted by using a bandpass filter.

Stereo Audio (Analog)

The implementation of analog stereo audio (ITU-R BS.707), also know as Zweiton, is shown in Figure 8.21. The L+R information is transmitted on a FM subcarrier. The R information, or a second L+R audio signal, is transmitted on a second FM subcarrier at $+15.5F_H$.

If stereo or dual mono signals are present, the FM subcarrier at $+15.5F_H$ is amplitude-

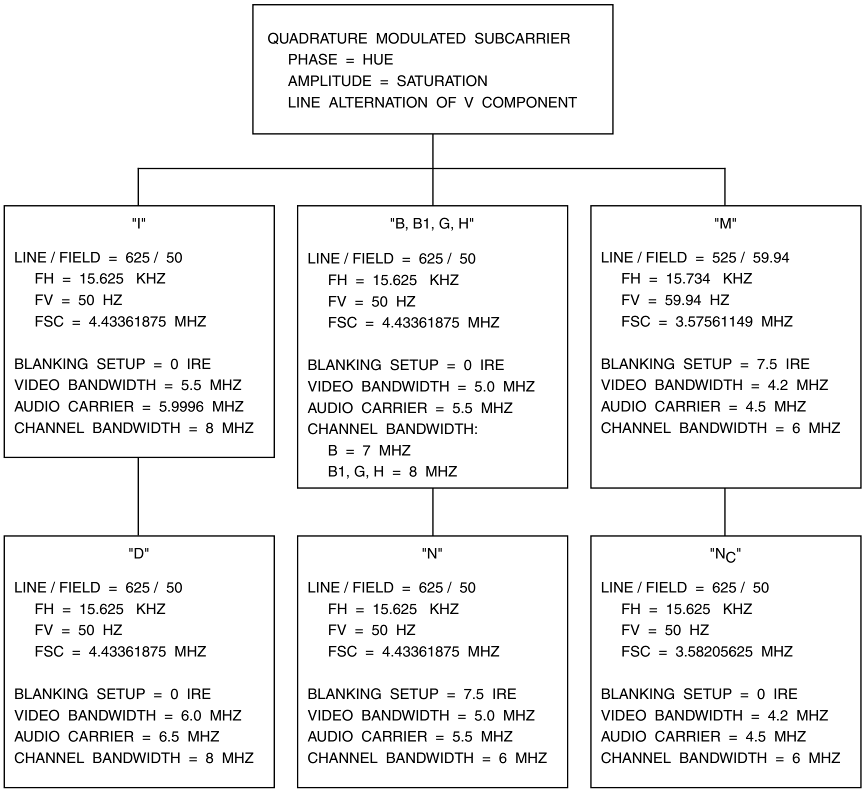

Figure 8.19. Common PAL Systems.

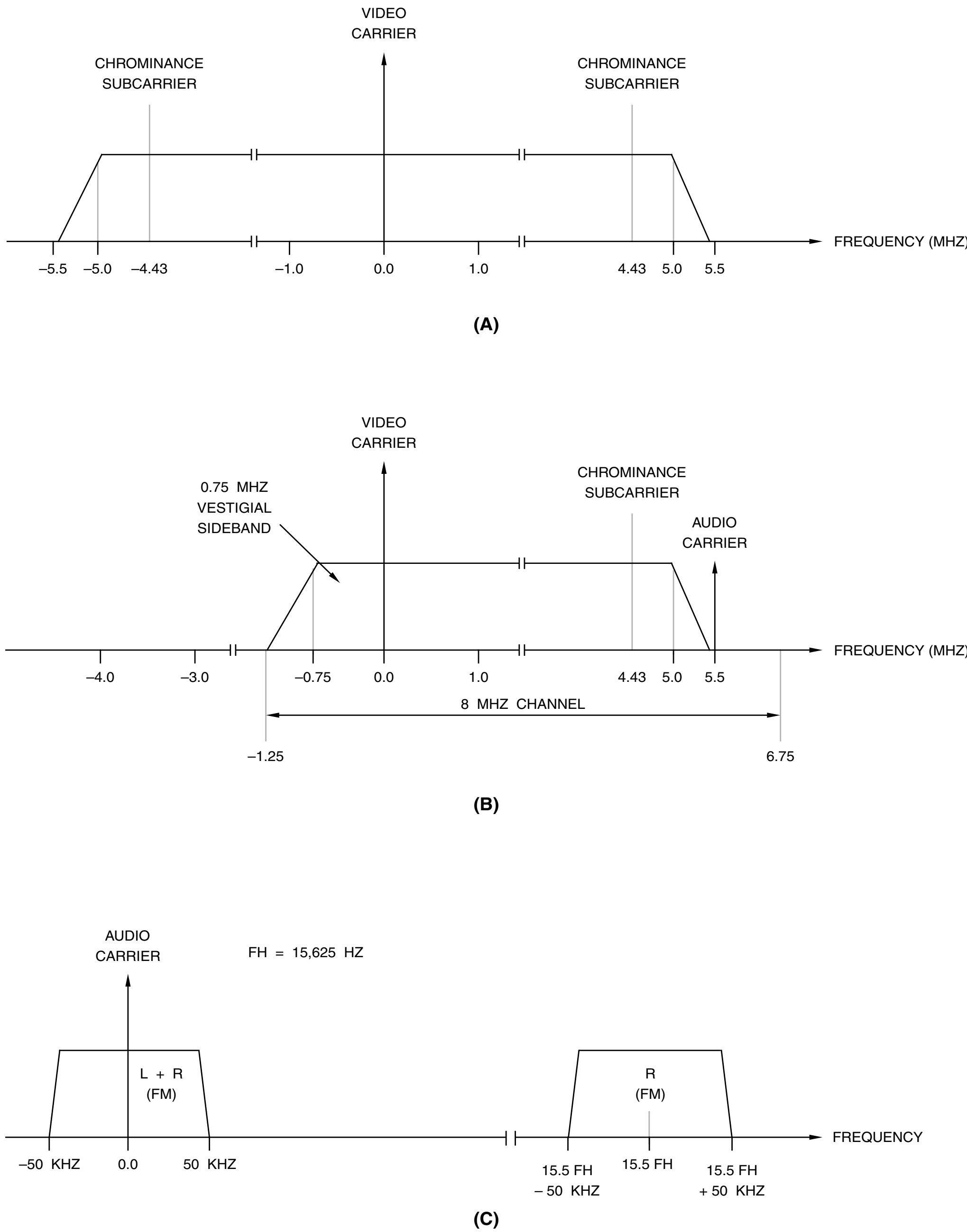

Figure 8.20. Transmission Channel for (G) PAL. (a) Frequency spectrum of baseband composite video. (b) Frequency spectrum of typical channel including audio information. (c) Detailed frequency spectrum of Zweiton analog stereo audio information.

modulated with a 54.6875 kHz (3.5x F_H) subcarrier. This 54.6875 kHz subcarrier is 50% amplitude-modulated at 117.5 Hz (F_H / 133) to indicate stereo audio or 274.1 Hz (F_H / 57) to indicate dual mono audio.

Countries that use this system include Australia, Austria, China, Germany, Italy, Malaysia, Netherlands, Slovenia, and Switzerland.

Stereo Audio (Digital)

The implementation of digital stereo audio uses NICAM 728 (Near Instantaneous Companded Audio Multiplex), discussed within BS.707 and ETSI EN 300163. It was developed by the BBC and IBA to increase sound quality, provide multiple channels of digital sound or data, and be more resistant to transmission interference.

The subcarrier resides either 5.85 MHz above the video carrier for (B, G, H) PAL systems or 6.552 MHz above the video carrier for (I) PAL systems.

Countries that use NICAM 728 include Belgium, Denmark, Finland, France, Hong Kong, New Zealand, Norway, Singapore, South Africa, Spain, Sweden, and the United Kingdom.

NICAM 728 is a digital system that uses a 32-kHz sampling rate and 14-bit resolution. A bit rate of 728 kbps is used, giving it the name NICAM 728. Data is transmitted in frames, with each frame containing 1 ms of audio. As shown in Figure 8.22, each frame consists of:

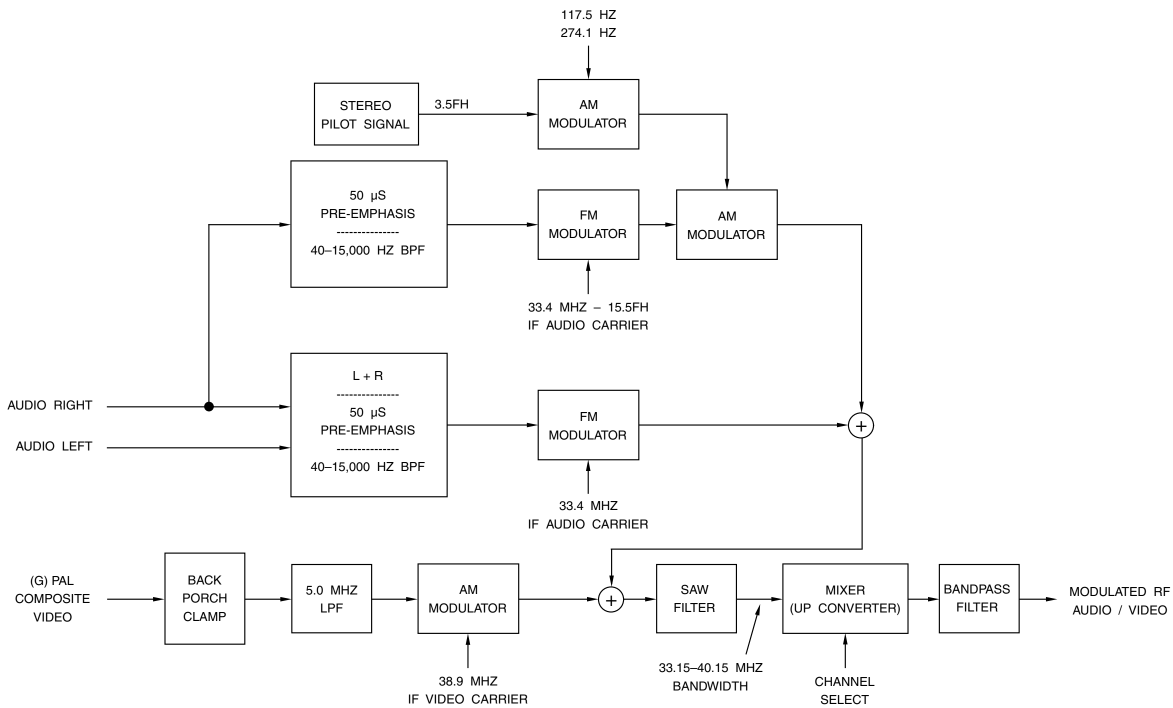

Figure 8.21. Typical RF Modulation Implementation for (G) PAL: Zweiton Stereo Audio.

8-bit frame alignment word (01001110)
5 control bits (C0–C4)
11 undefined bits (AD0–AD10)
704 audio data bits (A000–A703)

C0 is a "1" for eight successive frames and a "0" for the next eight frames, defining a 16-frame sequence. C1–C3 specify the format transmitted: "000" = one stereo signal with the left channel being odd-numbered samples and the right channel being even-numbered samples, "010" = two independent mono channels transmitted in alternate frames, "100" = one mono channel and one 352 kbps data channel transmitted in alternate frames, "110" = one 704 kbps data channel. C4 is a "1" if the analog sound is the same as the digital sound.

Stereo Audio Encoding

The thirty-two 14-bit samples (1 ms of audio, 2's complement format) per channel are pre-emphasized to the ITU-T J.17 curve.

The largest positive or negative sample of the 32 is used to determine which 10 bits of all 32 samples to transmit. Three range bits per channel ($R0_L$, $R1_L$, $R2_L$, and $R0_R$, $R1_R$, $R2_R$) are used to indicate the scaling factor. D13 is the sign bit ("0" = positive).

D13–D0	R2–R0	Bits Used
01xxxxxxxxxxxx	111	D13, D12–D4
001xxxxxxxxxxx	110	D13, D11–D3
0001xxxxxxxxxx	101	D13, D10–D2
00001xxxxxxxxx	011	D13, D9–D1
000001xxxxxxxx	101	D13, D8–D0
0000001xxxxxxx	010	D13, D8–D0
0000000xxxxxxx	00x	D13, D8–D0
1111111xxxxxxx	00x	D13, D8–D0
1111110xxxxxxx	010	D13, D8–D0
111110xxxxxxxx	100	D13, D8–D0
11110xxxxxxxxx	011	D13, D9–D1
1110xxxxxxxxxx	101	D13, D10–D2
110xxxxxxxxxxx	110	D13, D11–D3
10xxxxxxxxxxxx	111	D13, D12–D4

A parity bit for the six MSBs of each sample is added, resulting in each sample being 11 bits. The 64 samples are interleaved, generating L0, R0, L1, R1, L2, R2, ... L31, R31, and numbered 0–63.

The parity bits are used to convey to the decoder what scaling factor was used for each channel ("signalling-in-parity").

If $R2_L$ = "0", even parity for samples 0, 6, 12, 18, ... 48 is used. If $R2_L$ = "1", odd parity is used.

If $R2_R$ = "0", even parity for samples 1, 7, 13, 19, ... 49 is used. If $R2_R$ = "1", odd parity is used.

If $R1_L$ = "0", even parity for samples 2, 8, 14, 20, ... 50 is used. If $R1_L$ = "1", odd parity is used.

If $R1_R$ = "0", even parity for samples 3, 9, 15, 21, ... 51 is used. If $R1_R$ = "1", odd parity is used.

If $R0_L$ = "0", even parity for samples 4, 10, 16, 22, ... 52 is used. If $R0_L$ = "1", odd parity is used.

If $R0_R$ = "0", even parity for samples 5, 11, 17, 23, ... 53 is used. If $R0_R$ = "1", odd parity is used.

The parity of samples 54–63 normally have even parity. However, they may be modified to transmit two additional bits of information:

If CIB0 = "0", even parity for samples 54, 55, 56, 57, and 58 is used. If CIB0 = "1", odd parity is used.

If CIB1 = "0", even parity for samples 59, 60, 61, 62, and 63 is used. If CIB1 = "1", odd parity is used.

The audio data is bit-interleaved as shown in Figure 8.22 to reduce the influence of dropouts. If the bits are numbered 0–703, they are transmitted in the order 0, 44, 88, ... 660, 1, 45, 89, ... 661, 2, 46, 90, ... 703.

The whole frame, except the frame alignment word, is exclusive-ORed with a 1-bit pseudo-random binary sequence (PRBS). The PRBS generator is reinitialized after the frame alignment word of each frame so that the first bit of the sequence processes the C0 bit. The polynomial of the PRBS is $x^9 + x^4 + 1$ with an initialization word of "111111111".

Actual transmission consists of taking bits in pairs from the 728 kbps bitstream, then generating 356k symbols per second using Differential Quadrature Phase-Shift Keying (DQPSK). If the symbol is "00", the subcarrier phase is left unchanged. If the symbol is "01", the subcarrier phase is delayed 90°. If the symbol is "11", the subcarrier phase is inverted. If the symbol is "10", the subcarrier phase is advanced 90°.

Finally, the signal is spectrum-shaped to a –30 dB bandwidth of ~700 kHz for (I) PAL or ~500 kHz for (B, G) PAL.

Stereo Audio Decoding

A PLL locks to the NICAM subcarrier frequency and recovers the phase changes that represent the encoded symbols. The symbols are decoded to generate the 728 kbps bitstream.

The frame alignment word is found and the following bits are exclusive-ORed with a locally-generated PRBS to recover the packet. The C0 bit is tested for 8 frames high, 8 frames low behavior to verify it is a NICAM 728 bitstream.

The bit-interleaving of the audio data is reversed, and the "signalling-in-parity" decoded:

> A majority vote is taken on the parity of samples 0, 6, 12, ... 48. If even, $R2_L$ = "0"; if odd, $R2_L$ = "1".
>
> A majority vote is taken on the parity of samples 1, 7, 13, ... 49. If even, $R2_R$ = "0"; if odd, $R2_R$ = "1".
>
> A majority vote is taken on the parity of samples 2, 8, 14, ... 50. If even, $R1_L$ = "0"; if odd, $R1_L$ = "1".

FRAME ALIGNMENT WORD | CONTROL BITS | ADDITIONAL DATA BITS | 704 BITS AUDIO DATA

0, 1, 0, 0, 1, 1, 1, 0, C0, C1, C2, C3, C4, AD0, AD1, AD2, AD3, AD4, AD5, AD6, AD7, AD8, AD9, AD10,

A000, A044, A088, ... A660,
A001, A045, A089, ... A661,
A002, A046, A090, ... A662,
A003, A047, A091, ... A663,
:
A043, A087, A131, ... A703

Figure 8.22. NICAM 728 Bitstream for One Frame.

A majority vote is taken on the parity of samples 3, 9, 15, ... 51. If even, $R1_R$ = “0”; if odd, $R1_R$ = “1”.

A majority vote is taken on the parity of samples 4, 10, 16, ... 52. If even, $R0_L$ = “0”; if odd, $R0_L$ = “1”.

A majority vote is taken on the parity of samples 5, 11, 17, ... 53. If even, $R0_R$ = “0”; if odd, $R0_R$ = “1”.

A majority vote is taken on the parity of samples 54, 55, 56, 57, and 58. If even, CIB0 = “0”; if odd, CIB0 = “1”.

A majority vote is taken on the parity of samples 59, 60, 61, 62, and 63. If even, CIB1 = “0”; if odd, CIB1 = “1”.

Any samples whose parity disagreed with the vote are ignored and replaced with an interpolated value.

The left channel uses range bits $R2_L$, $R1_L$, and $R0_L$ to determine which bits below the sign bit were discarded during encoding. The sign bit is duplicated into those positions to generate a 14-bit sample.

The right channel is similarly processed, using range bits $R2_R$, $R1_R$, and $R0_R$. Both channels are then de-emphasized using the J.17 curve.

<u>Dual Mono Audio Encoding</u>

Two blocks of thirty-two 14-bit samples (2 ms of audio, 2’s complement format) are pre-emphasized to the ITU-T J.17 specification. As with the stereo audio, three range bits per block ($R0_A$, $R1_A$, $R2_A$, and $R0_B$, $R1_B$, $R2_B$) are used to indicate the scaling factor. Unlike stereo audio, the samples are not interleaved.

If $R2_A$ = “0”, even parity for samples 0, 3, 6, 9, ... 24 is used. If $R2_A$ = “1”, odd parity is used.

If $R2_B$ = “0”, even parity for samples 27, 30, 33, ... 51 is used. If $R2_B$ = “1”, odd parity is used.

If $R1_A$ = “0”, even parity for samples 1, 4, 7, 10, ... 25 is used. If $R1_A$ = “1”, odd parity is used.

If $R1_B$ = “0”, even parity for samples 28, 31, 34, ... 52 is used. If $R1_B$ = “1”, odd parity is used.

If $R0_A$ = “0”, even parity for samples 2, 5, 8, 11, ... 26 is used. If $R0_A$ = “1”, odd parity is used.

If $R0_B$ = “0”, even parity for samples 29, 32, 35, ... 53 is used. If $R0_B$ = “1”, odd parity is used.

The audio data is bit-interleaved, however, odd packets contain 64 samples of audio channel 1 while even packets contain 64 samples of audio channel 2. The rest of the processing is the same as for stereo audio.

Analog Channel Assignments

Tables 8.5 through 8.7 list the channel assignments for VHF, UHF, and cable for various PAL systems.

Note that cable systems routinely reassign channel numbers to alternate frequencies to minimize interference and provide multiple levels of programming (such as two versions of a premium movie channel: one for subscribers, and one for nonsubscribers during pre-view times).

Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)	Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)
(B) PAL, Australia, 7 MHz Channel				(B) PAL, Italy, 7 MHz Channel			
0	46.25	51.75	45–52	A	53.75	59.25	52.5–59.5
1	57.25	62.75	56–63	B	62.25	67.75	61–68
2	64.25	69.75	63–70	C	82.25	87.75	81–88
3	86.25	91.75	85–92	D	175.25	180.75	174–181
4	95.25	100.75	94–101	E	183.75	189.25	182.5–189.5
5	102.25	107.75	101–108	F	192.25	197.75	191–198
5A	138.25	143.75	137–144	G	201.25	206.75	200–207
6	175.25	180.75	174–181	H	210.25	215.75	209–216
7	182.25	187.75	181–188	H–1	217.25	222.75	216–223
8	189.25	194.75	188–195	H–2	224.25	229.75	223–230
9	196.25	201.75	195–202	–	–	–	–
10	209.25	214.75	208–215	–	–	–	–
11	216.25	221.75	215–222	–	–	–	–
12	223.25			–	–	–	–
(I) PAL, Ireland, 8 MHz Channel				(B) PAL, New Zealand, 7 MHz Channel			
1	45.75	51.75	44.5–52.5	1	45.25	50.75	44–51
2	53.75	59.75	52.5–60.5	2	55.25	60.75	54–61
3	61.75	67.75	60.5–68.5	3	62.25	67.75	61–68
4	175.25	181.25	174–182	4	175.25	180.75	174–181
5	183.25	189.25	182–190	5	182.25	187.75	181–188
6	191.25	197.25	190–198	6	189.25	194.75	188–195
7	199.25	205.25	198–206	7	196.25	201.75	195–202
8	207.25	213.25	206–214	8	203.25	208.75	202–209
9	215.25	221.25	214–222	9	210.25	215.75	209–216

Table 8.5. Analog Broadcast and Cable TV Nominal Frequencies for (B, I) PAL in Various Countries.

Broadcast Channel	Video Carrier (MHz)	Audio Carrier (MHz)		Channel Range (MHz)
		(G, H) PAL	(I) PAL	
2[1]	45.75	51.25	51.75	44.5–52.5
3[1]	53.75	59.25	59.75	52.5–60.5
4[1]	61.75	67.25	67.75	60.5–68.5
5[1]	175.25	180.75	181.25	174–182
6[1]	183.25	188.75	189.25	182–190
7[1]	191.25	196.75	197.25	190–198
8[1]	199.25	204.75	205.25	198–206
9[1]	207.25	212.75	213.25	206–214
10[1]	215.25	220.75	221.25	214–222
2[2]	48.25	53.75	–	47–54
3[2]	55.25	60.75	–	54–61
4[2]	62.25	67.75	–	61–68
5[2]	175.25	180.75	–	174–181
6[2]	182.25	187.75	–	181–188
7[2]	189.25	194.75	–	188–195
8[2]	196.25	201.75	–	195–202
9[2]	203.25	208.75	–	202–209
10[2]	210.25	215.75	–	209–216
11[2]	217.25	222.75	–	216–223
12[2]	224.25	229.75	–	223–230
21	471.25	476.75	477.25	470–478
22	479.25	484.75	485.25	478–486
23	487.25	492.75	493.25	486–494
24	495.25	500.75	501.25	494–502
25	503.25	508.75	509.25	502–510
26	511.25	516.75	517.25	510–518
27	519.25	524.75	525.25	518–526
28	527.25	532.75	533.25	526–534
29	535.25	540.75	541.25	534–542
30	543.25	548.75	549.25	542–550
31	551.25	556.75	557.25	550–558
32	559.25	564.75	565.25	558–566
33	567.25	572.75	573.25	566–574
34	575.25	580.75	581.25	574–582
35	583.25	588.75	589.25	582–590
36	591.25	596.75	597.25	590–598
37	599.25	604.75	605.25	598–606
38	607.25	612.75	613.25	606–614
39	615.25	620.75	621.25	614–622

Table 8.6a. Analog Broadcast Nominal Frequencies for the [1]United Kingdom, [1]Ireland, [1]South Africa, [1]Hong Kong, and [2]Western Europe.

Broadcast Channel	Video Carrier (MHz)	Audio Carrier (MHz)		Channel Range (MHz)
		(G, H) PAL	(I) PAL	
40	623.25	628.75	629.25	622–630
41	631.25	636.75	637.25	630–638
42	639.25	644.75	645.25	638–646
43	647.25	652.75	653.25	646–654
44	655.25	660.75	661.25	654–662
45	663.25	668.75	669.25	662–670
46	671.25	676.75	677.25	670–678
47	679.25	684.75	685.25	678–686
48	687.25	692.75	693.25	686–694
49	695.25	700.75	701.25	694–702
50	703.25	708.75	709.25	702–710
51	711.25	716.75	717.25	710–718
52	719.25	724.75	725.25	718–726
53	727.25	732.75	733.25	726–734
54	735.25	740.75	741.25	734–742
55	743.25	748.75	749.25	742–750
56	751.25	756.75	757.25	750–758
57	759.25	764.75	765.25	758–766
58	767.25	772.75	773.25	766–774
59	775.25	780.75	781.25	774–782
60	783.25	788.75	789.25	782–790
61	791.25	796.75	797.25	790–798
62	799.25	804.75	805.25	798–806
63	807.25	812.75	813.25	806–814
64	815.25	820.75	821.25	814–822
65	823.25	828.75	829.25	822–830
66	831.25	836.75	837.25	830–838
67	839.25	844.75	845.25	838–846
68	847.25	852.75	853.25	846–854
69	855.25	860.75	861.25	854–862

Table 8.6b. Analog Broadcast Nominal Frequencies for the United Kingdom, Ireland, South Africa, Hong Kong, and Western Europe.

Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)	Cable Channel	Video Carrier (MHz)	Audio Carrier (MHz)	Channel Range (MHz)
E 2	48.25	53.75	47–54	S 11	231.25	236.75	230–237
E 3	55.25	60.75	54–61	S 12	238.25	243.75	237–244
E 4	62.25	67.75	61–68	S 13	245.25	250.75	244–251
S 01	69.25	74.75	68–75	S 14	252.25	257.75	251–258
S 02	76.25	81.75	75–82	S 15	259.25	264.75	258–265
S 03	83.25	88.75	82–89	S 16	266.25	271.75	265–272
S 1	105.25	110.75	104–111	S 17	273.25	278.75	272–279
S 2	112.25	117.75	111–118	S 18	280.25	285.75	279–286
S 3	119.25	124.75	118–125	S 19	287.25	292.75	286–293
S 4	126.25	131.75	125–132	S 20	294.25	299.75	293–300
S 5	133.25	138.75	132–139	S 21	303.25	308.75	302–310
S 6	140.75	145.75	139–146	S 22	311.25	316.75	310–318
S 7	147.75	152.75	146–153	S 23	319.25	324.75	318–326
S 8	154.75	159.75	153–160	S 24	327.25	332.75	326–334
S 9	161.25	166.75	160–167	S 25	335.25	340.75	334–342
S 10	168.25	173.75	167–174	S 26	343.25	348.75	342–350
–	–	–	–	S 27	351.25	356.75	350–358
–	–	–	–	S 28	359.25	364.75	358–366
–	–	–	–	S 29	367.25	372.75	366–374
E 5	175.25	180.75	174–181	S 30	375.25	380.75	374–382
E 6	182.25	187.75	181–188	S 31	383.25	388.75	382–390
E 7	189.25	194.75	188–195	S 32	391.25	396.75	390–398
E 8	196.25	201.75	195–202	S 33	399.25	404.75	398–406
E 9	203.25	208.75	202–209	S 34	407.25	412.75	406–414
E 10	210.25	215.75	209–216	S 35	415.25	420.75	414–422
E 11	217.25	222.75	216–223	S 36	423.25	428.75	422–430
E 12	224.25	229.75	223–230	S 37	431.25	436.75	430–438
–	–	–	–	S 38	439.25	444.75	438–446
–	–	–	–	S 39	447.25	452.75	446–454
–	–	–	–	S 40	455.25	460.75	454–462
–	–	–	–	S 41	463.25	468.75	462–470

Table 8.7. Analog Cable TV Nominal Frequencies for the United Kingdom, Ireland, South Africa, Hong Kong, and Western Europe.

Use by Country

Figure 8.19 shows the common designations for PAL systems. The letters refer to the monochrome standard for line and field rate, video bandwidth (4.2, 5.0, 5.5, or 6.0 MHz), audio carrier relative frequency, and RF channel bandwidth (6.0, 7.0, or 8.0 MHz). The “PAL” refers to the technique to add color information to the monochrome signal. Detailed timing parameters may be found in Table 8.9.

The following countries use the (I) PAL standard.

Angola	Malawi
Botswana	Namibia
Gambia	Nigeria
Guinea-Bissau	South Africa
Hong Kong	Tanzania
Ireland	United Kingdom
Lesotho	Zanzibar
Macau	

The following countries use the (B) and (G) PAL standards.

Albania	Kenya
Algeria	Kuwait
Austria	Liberia
Bahrain	Libya
Cambodia	Lithuania
Cameroon	Luxembourg
Croatia	Malaysia
Cyprus	Netherlands
Denmark	New Zealand
Egypt	Norway
Equatorial Guinea	Oman
Ethiopia	Pakistan
Finland	Papua New Guinea
Germany	Portugal
Iceland	Qatar
Israel	Sierra Leone
Italy	Singapore
Jordan	Slovenia
Somalia	Syria
Spain	Thailand
Sri Lanka	Turkey
Sudan	Yemen
Sweden	Yugoslavia
Switzerland	

The following countries use the (N) PAL standard. Note that Argentina uses a modified PAL standard, called “N_C.”

Argentina	Paraguay
Aryenuna	Uruguay

The following countries use the (M) PAL standard.

Brazil

The following countries use the (B) PAL standard.

Australia	Maldives
Bangladesh	Malta
Belgium	Nigeria
Brunei Darussalam	Rwandese Republic
Ghana	Sao Tome & Principe
India	Seychelles
Indonesia	Vanuatu

The following countries use the (G) PAL standard.

Hungary	Zambia
Mozambique	Zimbabwe
Romania	

The following countries use the (D) PAL standard.

China	Latvia
Czech Republic	Poland
Hungary	Romania
Korea, North	

The following countries use the (H) PAL standard.

Belgium

Luma Equation Derivation

The equation for generating luminance from RGB information is determined by the chromaticities of the three primary colors used by the receiver and what color white actually is.

The chromaticities of the RGB primaries and reference white (CIE illuminate D_{65}) are:

R: $x_r = 0.64$ $y_r = 0.33$ $z_r = 0.03$

G: $x_g = 0.29$ $y_g = 0.60$ $z_g = 0.11$

B: $x_b = 0.15$ $y_b = 0.06$ $z_b = 0.79$

white: $x_w = 0.3127$ $y_w = 0.3290$ $z_w = 0.3583$

where x and y are the specified CIE 1931 chromaticity coordinates; z is calculated by knowing that $x + y + z = 1$.

As with NTSC, substituting the known values gives us the solution for K_r, K_g, and K_b:

$$\begin{bmatrix} K_r \\ K_g \\ K_b \end{bmatrix} = \begin{bmatrix} 0.3127/0.3290 \\ 1 \\ 0.3583/0.3290 \end{bmatrix} \begin{bmatrix} 0.64 & 0.29 & 0.15 \\ 0.33 & 0.60 & 0.06 \\ 0.03 & 0.11 & 0.79 \end{bmatrix}^{-1}$$

$$= \begin{bmatrix} 0.674 \\ 1.177 \\ 1.190 \end{bmatrix}$$

Y is defined to be

$$Y = (K_r y_r)R' + (K_g y_g)G' + (K_b y_b)B'$$
$$= (0.674)(0.33)R' + (1.177)(0.60)G' + (1.190)(0.06)B'$$

or

$$Y = 0.222R' + 0.706G' + 0.071B'$$

However, the standard $Y = 0.299R' + 0.587G' + 0.114B'$ equation is still used. Adjustments are made in the receiver to minimize color errors.

PALplus

PALplus (ITU-R BT.1197 and ETSI ETS 300731) is the result of a cooperative project started in 1990, undertaken by several European broadcasters. By 1995, they wanted to provide an enhanced definition television system (EDTV), compatible with existing receivers. PALplus has been transmitted by a few broadcasters since 1994.

A PALplus picture has a 16:9 aspect ratio. On conventional TVs, it is displayed as a 16:9 letterboxed image with 430 active lines. On PALplus TVs, it is displayed as a 16:9 picture with 574 active lines, with extended vertical resolution. The full video bandwidth is available for luminance detail. Cross color artifacts are reduced by clean encoding.

Wide Screen Signalling

Line 23 is contains a Widescreen Signalling (WSS) control signal, defined by ITU-R BT.1119 and ETSI EN 300294, used by PALplus TVs. This signal indicates:

Program Aspect Ratio:
- Full Format 4:3
- Letterbox 14:9 Center
- Letterbox 14:9 Top
- Full Format 14:9 Center
- Letterbox 16:9 Center
- Letterbox 16:9 Top
- Full Format 16:9 Anamorphic
- Letterbox > 16:9 Center

Enhanced services:
- Camera Mode
- Film Mode

Subtitles:
- Teletext Subtitles Present
- Open Subtitles Present

PALplus is defined as being Letterbox 16:9 center, camera mode or film mode, helper signals present using modulation, and clean encoding used. Teletext subtitles may or may not be present, and open subtitles may be present only in the active picture area.

During a PALplus transmission, any active video on lines 23 and 623 is blanked prior to encoding. In addition to WSS data, line 23 includes 48 ±1 cycles of a 300 ±9 mV subcarrier with a –U phase, starting 51 µs ±250 ns after 0_H. Line 623 contains a 10 µs ±250 ns white pulse, starting 20 µs ±250 ns after 0_H.

A PALplus TV has the option of deinterlacing a Film Mode signal and displaying it on a 50-Hz progressive-scan display or using field repeating on a 100-Hz interlaced display.

Ghost Cancellation

An optional ghost cancellation signal on line 318, defined by ITU-R BT.1124 and ETSI ETS 300732, allows a suitably adapted TV to measure the ghost signal and cancel any ghosting during the active video. A PALplus TV may or may not support this feature.

Vertical Filtering

All PALplus sources start out as a 16:9 YCbCr anamorphic image, occupying all 576 active scan lines. Any active video on lines 23 and 623 is blanked prior to encoding (since these lines are used for WSS and reference information), resulting in 574 active lines per frame. Lines 24–310 and 336–622 are used for active video.

Before transmission, the 574 active scan lines of the 16:9 image are squeezed into 430 scan lines. To avoid aliasing problems, the vertical resolution is reduced by lowpass filtering.

For Y, vertical filtering is done using a Quadrature Mirror Filter (QMF) highpass and lowpass pair. Using the QMF process allows the highpass and lowpass information to be resampled, transmitted, and later recombined with minimal loss.

The Y QMF lowpass output is resampled into three-quarters of the original height; little information is lost to aliasing. After clean encoding, it is the letterboxed signal that conventional 4:3 TVs display.

The Y QMF highpass output contains the rest of the original vertical frequency. It is used to generate the helper signals that are transmitted using the "black" scan lines not used by the letterbox picture.

Film Mode

A film mode broadcast has both fields of a frame coming from the same image, as is usually the case with a movie scanned on a telecine.

In film mode, the maximum vertical resolution per frame is about 287 cycles per *active* picture height (cph), limited by the 574 active scan lines per frame.

The vertical resolution of Y is reduced to 215 cph so it can be transmitted using only 430 active lines. The QMF lowpass and highpass filters split the Y vertical information into DC–215 cph and 216–287 cph.

The Y lowpass information is re-scanned into 430 lines to become the letterbox image. Since the vertical frequency is limited to a maximum of 215 cph, no information is lost.

The Y highpass output is decimated so only one in four lines are transmitted. These 144 lines are used to transmit the helper signals. Because of the QMF process, no information is lost to decimation.

The 72 lines above and 72 lines below the central 430-line of the letterbox image are used to transmit the 144 lines of the helper signal. This results in a standard 574 active line picture, but with the original image in its correct aspect ratio, centered between the helper signals. The scan lines containing the 300 mV helper signals are modulated using the U subcarrier so they look black and are not visible to the viewer.

After Fixed ColorPlus processing, the 574 scan lines are PAL encoded and transmitted as a standard interlaced PAL frame.

Camera Mode

Camera (or video) mode assumes the fields of a frame are independent of each other, as would be the case when a camera scans a scene in motion. Therefore, the image may have changed between fields. Only intra-field processing is done.

In camera mode, the maximum vertical resolution per field is about 143 cycles per *active* picture height (cph), limited by the 287 active scan lines per field.

The vertical resolution of Y is reduced to 107 cph so it can be transmitted using only 215 active lines. The QMF lowpass and highpass filter pair split the Y vertical information into DC–107 cph and 108–143 cph.

The Y lowpass information is re-scanned into 215 lines to become the letterbox image. Since the vertical frequency is limited to a maximum of 107 cph, no information is lost.

The Y highpass output is decimated so only one in four lines is transmitted. These 72 lines are used to transmit the helper signals. Because of the QMF process, no information is lost to decimation.

The 36 lines above and 36 lines below the central 215-line of the letterbox image are used to transmit the 72 lines of the helper signal. This results in a 287 active line picture, but with the original image in its correct aspect ratio, centered between the helper signals. The scan lines containing the 300 mV helper signals are modulated using the U subcarrier so they look black and are not visible to the viewer.

After either Fixed or Motion Adaptive ColorPlus processing, the 287 scan lines are PAL encoded and transmitted as a standard PAL field.

Clean Encoding

Only the letterboxed portion of the PALplus signal is clean encoded. The helper signals are not actual PAL video. However, they are close enough to video to pass through the transmission path and remain fairly invisible on standard TVs.

ColorPlus Processing

Fixed ColorPlus

Film Mode uses a Fixed ColorPlus technique, making use of the lack of motion between the two fields of the frame.

Fixed ColorPlus depends on the subcarrier phase of the composite PAL signal being of opposite phase when 312 lines apart. If these two lines have the same luminance and chrominance information, it can be separated by adding and subtracting the composite signals from each other. Adding cancels the chrominance, leaving luminance. Subtracting cancels the luminance, leaving chrominance.

In practice, Y information above 3 MHz (Y_{HF}) is intra-frame averaged since it shares the frequency spectrum with the modulated chrominance. For line [n], Y_{HF} is calculated as follows:

$$0 \leq n \leq 214 \text{ for 430-line letterboxed image}$$

$$Y_{HF(60+n)} = 0.5(Y_{HF(372+n)} + Y_{HF(60+n)})$$

$$Y_{HF(372+n)} = Y_{HF(60+n)}$$

Y_{HF} is then added to the low-frequency Y (Y_{LF}) information. The same intra-frame averaging process is also used for Cb and Cr. The 430-line letterbox image is then PAL encoded.

Thus, Y information above 3 MHz, and CbCr information, is the same on lines [n] and [n+312]. Y information below 3 MHz may be different on lines [n] and [n+312]. The full vertical resolution of 287 cph is reconstructed by the decoder with the aid of the helper signals.

Motion Adaptive ColorPlus (MACP)

Camera Mode uses either Motion Adaptive ColorPlus or Fixed ColorPlus, depending on the amount of motion between fields. This requires a motion detector in both the encoder and decoder.

To detect movement, the CbCr data on lines [n] and [n+312] are compared. If they match, no movement is assumed, and Fixed ColorPlus operation is used. If the CbCr data doesn't match, movement is assumed, and Motion Adaptive ColorPlus operation is used.

During Motion Adaptive ColorPlus operation, the amount of Y_{HF} added to Y_{LF} is dependent on the difference between $CbCr_{(n)}$ and $CbCr_{(n+312)}$. For the maximum CbCr difference, no Y_{HF} data for lines [n] and [n+312] is transmitted.

In addition, the amount of intra-frame averaged CbCr data mixed with the direct CbCr data is dependent on the difference between $CbCr_{(n)}$ and $CbCr_{(n+312)}$. For the maximum CbCr difference, only direct CbCr data is transmitted separately for lines [n] and [n+312].

SECAM Overview

SECAM (Sequentiel Couleur Avec Mémoire or Sequential Color with Memory) was developed in France, with broadcasting starting in 1967, by realizing that, if color could be bandwidth-limited horizontally, why not also vertically? The two pieces of color information (Db and Dr) added to the monochrome signal could be transmitted on alternate lines, avoiding the possibility of crosstalk.

The receiver requires memory to store one line so that it is concurrent with the next line, and also requires the addition of a line-switching identification technique.

Like PAL, SECAM is a 625-line, 50-field-per-second, 2:1 interlaced system. SECAM was adopted by other countries; however, many are changing to PAL due to the abundance of professional and consumer PAL equipment.

Luminance Information

The monochrome luminance (Y) signal is derived from R′G′B′:

$$Y = 0.299R' + 0.587G' + 0.114B'$$

As with NTSC and PAL, the luminance signal occupies the entire video bandwidth. SECAM has several variations, depending on the video bandwidth and placement of the audio subcarrier. The video signal has a bandwidth of 5.0 or 6.0 MHz, depending on the specific SECAM standard.

Color Information

SECAM transmits Db information during one line and Dr information during the next line; luminance information is transmitted each line. Db and Dr are scaled versions of B′ – Y and R′ – Y:

$$Dr = -1.902(R' - Y)$$

$$Db = 1.505(B' - Y)$$

Since there is an odd number of lines, any given line contains Db information on one field and Dr information on the next field. The decoder requires a 1-H delay, switched synchronously with the Db and Dr switching, so that Db and Dr exist simultaneously in order to convert to YCbCr or RGB.

Color Modulation

SECAM uses FM modulation to transmit the Db and Dr color difference information, with each component having its own subcarrier.

Db and Dr are lowpass filtered to 1.3 MHz and pre-emphasis is applied. The curve for the pre-emphasis is expressed by:

$$A = \frac{1 + j\left(\frac{f}{85}\right)}{1 + j\left(\frac{f}{255}\right)}$$

where f = signal frequency in kHz.

After pre-emphasis, Db and Dr frequency modulate their respective subcarriers. The frequency of each subcarrier is defined as:

$$F_{OB} = 272\ F_H = 4.250000\ \text{MHz}\ (\pm 2\ \text{kHz})$$

$$F_{OR} = 282\ F_H = 4.406250\ \text{MHz}\ (\pm 2\ \text{kHz})$$

These frequencies represent no color information. Nominal Dr deviation is ±280 kHz and the nominal Db deviation is ±230 kHz. Figure 8.23 illustrates the frequency modulation process of the color difference signals. The choice of frequency shifts reflects the idea of keeping the frequencies representing critical colors away from the upper limit of the spectrum to minimize distortion.

After modulation of Db and Dr, subcarrier pre-emphasis is applied, changing the amplitude of the subcarrier as a function of the frequency deviation. The intention is to reduce the visibility of the subcarriers in areas of low luminance and to improve the signal-to-noise ratio of highly saturated colors. This pre-emphasis is given as:

$$G = M\frac{1 + j16F}{1 + j1.26F}$$

where F = $(f/4286) - (4286/f)$, f = instantaneous subcarrier frequency in kHz, and 2M = 23 ± 2.5% of luminance amplitude.

As shown in Table 8.8 and Figure 8.24, Db and Dr information is transmitted on alternate scan lines. The phase of the subcarriers is also reversed 180° on every third line and between each field to further reduce subcarrier visibility. Note that subcarrier phase information in the SECAM system carries no picture information.

Composite Video Generation

The subcarrier data is added to the luminance along with appropriate horizontal and vertical sync signals, blanking signals, and burst signals to generate composite video.

As with PAL, SECAM requires some means of identifying the line-switching sequence. Modern practice has been to use a F_{OR}/F_{OB} burst after most horizontal syncs to derive the switching synchronization information, as shown in Figure 8.25.

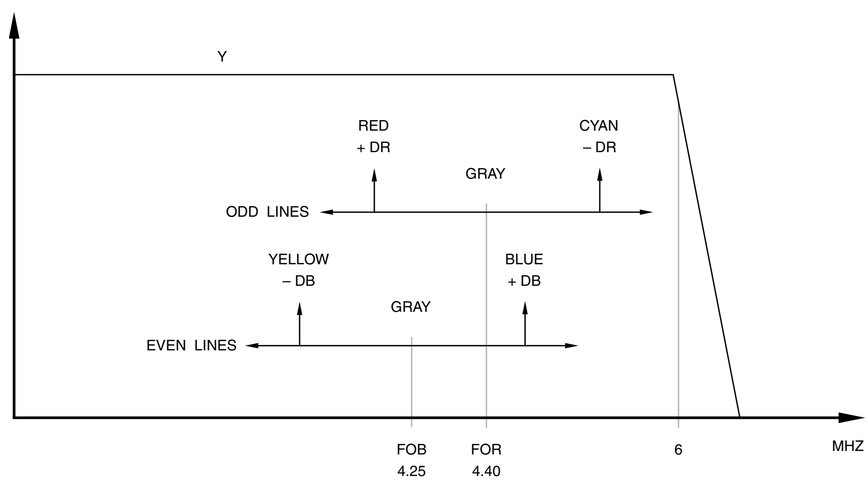

Figure 8.23. SECAM FM Color Modulation.

Field	Line Number		Color		Subcarrier Phase	
odd	N		Dr		0°	
even		N + 313		Db		180°
odd	N + 1		Db		0°	
even		N + 314		Dr		0°
odd	N + 2		Dr		180°	
even		N + 315		Db		180°
odd	N + 3		Db		0°	
even		N + 316		Dr		180°
odd	N + 4		Dr		0°	
even		N + 317		Db		0°
odd	N + 5		Db		180°	
even		N + 318		Dr		180°

Table 8.8. SECAM Color Versus Line and Field Timing.

Use by Country

Figure 8.26 shows the common designations for SECAM systems. The letters refer to the monochrome standard for line and field rates, video bandwidth (5.0 or 6.0 MHz), audio carrier relative frequency, and RF channel bandwidth. The SECAM refers to the technique to add color information to the monochrome signal. Detailed timing parameters may be found in Table 8.9.

The following countries use the (B) and (G) SECAM standards.

Greece	Mauritius
Iran	Morocco
Iraq	Saudi Arabia
Lebanon	Tunisia
Mali	

The following countries use the (D) and (K) SECAM standards.

Azerbaijan	Latvia
Belarus	Lithuania
Bulgaria	Moldova
Estonia	Russia
Georgia	Ukraine
Kazakhstan	Viet Nam

The following countries use the (B) SECAM standard.

Mauritania	Djibouti

The following countries use the (D) SECAM standard.

Afghanistan	Mongolia

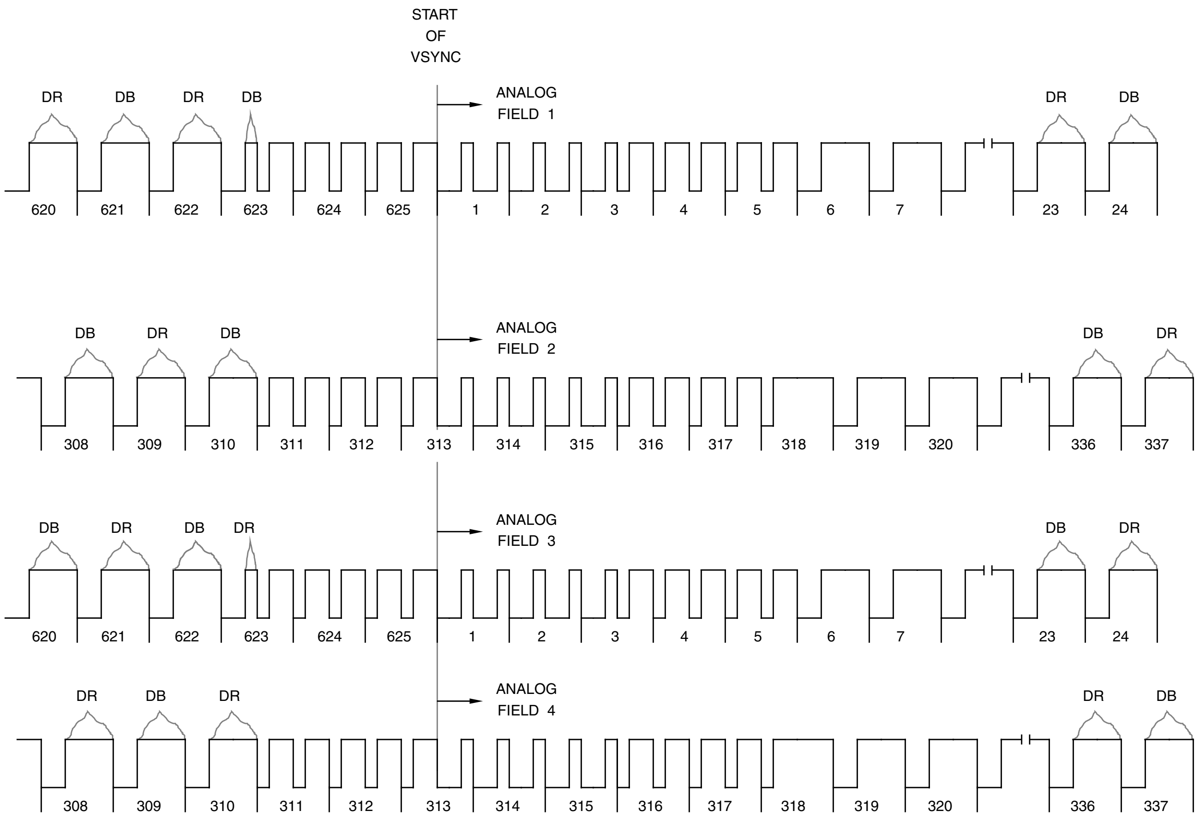

Figure 8.24. Four-field SECAM Sequence. See Figure 8.5 for equalization and serration pulse details.

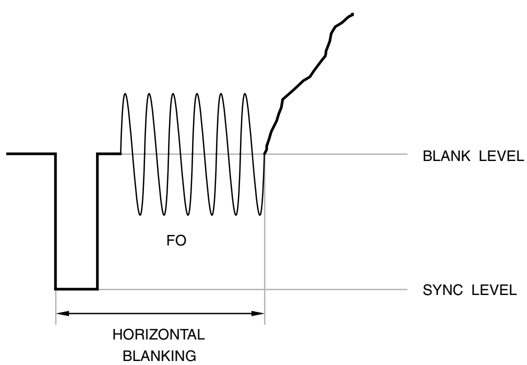

Figure 8.25. SECAM Chroma Synchronization Signals.

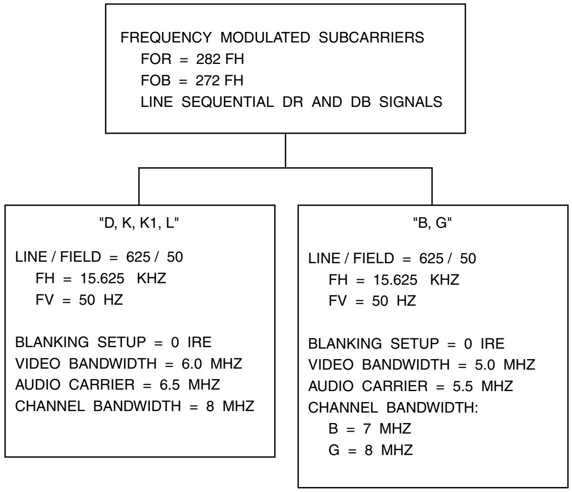

Figure 8.26. Common SECAM Systems.

The following countries use the (K1) SECAM standard.

Benin	Gabon
Burkina Faso	Guadeloupe
Burundi	Madagascar
Cape Verde	Niger
Central African Republic	Senegal
Chad	Togo
Comoros	Zaire
Congo	

The following countries use the (L) SECAM standard.

France	Monaco

Luminance Equation Derivation

The equation for generating luminance from RGB information is determined by the chromaticities of the three primary colors used by the receiver and what color white actually is.

The chromaticities of the RGB primaries and reference white (CIE illuminate D_{65}) are:

R: $x_r = 0.64$ $y_r = 0.33$ $z_r = 0.03$

G: $x_g = 0.29$ $y_g = 0.60$ $z_g = 0.11$

B: $x_b = 0.15$ $y_b = 0.06$ $z_b = 0.79$

white: $x_w = 0.3127$ $y_w = 0.3290$
$z_w = 0.3583$

where x and y are the specified CIE 1931 chromaticity coordinates; z is calculated by knowing that x + y + z = 1. Once again, substituting the known values gives us the solution for K_r, K_g, and K_b:

$$\begin{bmatrix} K_r \\ K_g \\ K_b \end{bmatrix} = \begin{bmatrix} 0.3127/0.3290 \\ 1 \\ 0.3583/0.3290 \end{bmatrix} \begin{bmatrix} 0.64 & 0.29 & 0.15 \\ 0.33 & 0.60 & 0.06 \\ 0.03 & 0.11 & 0.79 \end{bmatrix}^{-1}$$

$$= \begin{bmatrix} 0.674 \\ 1.177 \\ 1.190 \end{bmatrix}$$

Y is defined to be

$$\begin{aligned} Y &= (K_r y_r)R' + (K_g y_g)G' + (K_b y_b)B' \\ &= (0.674)(0.33)R' + (1.177)(0.60)G' \\ &\quad + (1.190)(0.06)B' \end{aligned}$$

or

$$Y = 0.222R' + 0.706G' + 0.071B'$$

However, the standard Y = 0.299R′ + 0.587G′ + 0.114B′ equation is still used. Adjustments are made in the receiver to minimize color errors.

	M	N	B, G	H	I	D, K	K1	L
SCAN LINES PER FRAME	525	625	625					
FIELD FREQUENCY (FIELDS / SECOND)	59.94	50	50					
LINE FREQUENCY (HZ)	15,734	15,625	15,625					
PEAK WHITE LEVEL (IRE)	100	100	100					
SYNC TIP LEVEL (IRE)	–40	–40 (–43)	–43					
SETUP (IRE)	7.5 ± 2.5	7.5 ± 2.5 (0)	0					
PEAK VIDEO LEVEL (IRE)	120		133		133	115	115	125
GAMMA OF RECEIVER	2.2	2.8	2.8	2.8	2.8	2.8	2.8	2.8
VIDEO BANDWIDTH (MHZ)	4.2	5.0 (4.2)	5.0	5.0	5.5	6.0	6.0	6.0
LUMINANCE SIGNAL	Y = 0.299R´ + 0.685G´ + 0.114B´ (RGB ARE GAMMA–CORRECTED)							

[1] Values in parentheses apply to (N_C) PAL used in Argentina.

Table 8.9a. Basic Characteristics of Color Video Signals.

Characteristics	M	N	B, D, G, H, I K, K1, L, N_C
Nominal line period (µs)	63.5555	64	64
Line blanking interval (µs)	10.7 ± 0.1	10.88 ± 0.64	11.85 ± 0.15
0_H to start of active video (µs)	9.2 ± 0.1	9.6 ± 0.64	10.5
Front porch (µs)	1.5 ± 0.1	1.92 ± 0.64	1.65 ± 0.15
Line synchronizing pulse (µs)	4.7 ± 0.1	4.99 ± 0.77	4.7 ± 0.2
Rise and fall time of line blanking (10%, 90%) (ns)	140 ± 20	300 ± 100	300 ± 100
Rise and fall time of line synchronizing pulses (10%, 90%) (ns)	140 ± 20	≤ 250	250 ± 50

Notes
1. 0_H is at 50% point of falling edge of horizontal sync.
2. In case of different standards having different specifications and tolerances, the tightest specification and tolerance is listed.
3. Timing is measured between half-amplitude points on appropriate signal edges.

Table 8.9b. Details of Line Synchronization Signals.

Characteristics	M	N	B, D, G, H, I K, K1, L, N_C
Field period (ms)	16.6833	20	20
Field blanking interval	20 lines	19–25 lines	25 lines
Rise and fall time of field blanking (10%, 90%) (ns)	140 ± 20	≤ 250	300 ± 100
Duration of equalizing and synchronizing sequences	3 H	3 H	2.5 H
Equalizing pulse width (µs)	2.3 ± 0.1	2.43 ± 0.13	2.35 ± 0.1
Serration pulse width (µs)	4.7 ± 0.1	4.7 ± 0.8	4.7 ± 0.1
Rise and fall time of synchronizing and equalizing pulses (10%, 90%) (ns)	140 ± 20	< 250	250 ± 50

Notes

1. In case of different standards having different specifications and tolerances, the tightest specification and tolerance is listed.
2. Timing is measured between half-amplitude points on appropriate signal edges.

Table 8.9c. Details of Field Synchronization Signals.

	M / NTSC	M / PAL	B, D, G, H, I, N / PAL	B, D, G, K, K1, K / SECAM
ATTENUATION OF COLOR DIFFERENCE SIGNALS	U, V, I, Q: < 2 DB AT 1.3 MHZ > 20 DB AT 3.6 MHZ OR Q: < 2 DB AT 0.4 MHZ < 6 DB AT 0.5 MHZ > 6 DB AT 0.6 MHZ	< 2 DB AT 1.3 MHZ > 20 DB AT 3.6 MHZ	< 3 DB AT 1.3 MHZ > 20 DB AT 4 MHZ (> 20 DB AT 3.6 MHZ)	< 3 DB AT 1.3 MHZ > 30 DB AT 3.5 MHZ (BEFORE LOW FREQUENCY PRE–CORRECTION)
START OF BURST AFTER 0H (µS)	5.3 ± 0.07	5.8 ± 0.1	5.6 ± 0.1	
BURST DURATION (CYCLES)	9 ± 1	9 ± 1	10 ± 1 (9 ± 1)	
BURST PEAK AMPLITUDE	40 ± 1 IRE	42.86 ± 4 IRE	42.86 ± 4 IRE	

Note: Values in parentheses apply to (N_C) PAL used in Argentina.

Table 8.9d. Basic Characteristics of Color Video Signals.

Video Test Signals

Many industry-standard video test signals have been defined to help test the relative quality of encoding, decoding, and the transmission path, and to perform calibration. Note that some video test signals cannot be properly generated by providing RGB data to an encoder; in this case, YCbCr data may be used.

If the video standard uses a 7.5-IRE setup, typically only test signals used for visual examination use the 7.5-IRE setup. Test signals designed for measurement purposes typically use a 0-IRE setup, providing the advantage of defining a known blanking level.

Color Bars Overview

Color bars are one of the standard video test signals, and there are several variations, depending on the video standard and application. For this reason, this section reviews the most common color bar formats. Color bars have two major characteristics: amplitude and saturation.

The amplitude of a color bar signal is determined by:

$$amplitude\ (\%) = \frac{max\ (R, G, B)_a}{max\ (R, G, B)_b} \times 100$$

where $max(R,G,B)_a$ is the maximum value of R′G′B′ during colored bars and $max(R,G,B)_b$ is the maximum value of R′G′B′ during reference white.

The saturation of a color bar signal is less than 100% if the minimum value of any one of the R′G′B′ components is not zero. The saturation is determined by:

$$saturation\ (\%) = \left[1 - \left(\frac{min(R, G, B)}{max(R, G, B)}\right)^{\gamma}\right] \times 100$$

where min(R,G,B) and max(R,G,B) are the minimum and maximum values, respectively, of R′G′B′ during colored bars, and γ is the gamma exponent, typically [1/0.45].

NTSC Color Bars

In 1953, it was normal practice for the analog R′G′B′ signals to have a 7.5 IRE setup, and the original NTSC equations assumed this form of input to an encoder. Today, digital R′G′B′ or YCbCr signals typically do not include the 7.5 IRE setup, and the 7.5 IRE setup is added within the encoder.

The different color bar signals are described by four amplitudes, expressed in percent, separated by oblique strokes. 100% saturation is implied, so saturation is not specified. The first and second numbers are the white and black amplitudes, respectively. The third and fourth numbers are the white and black amplitudes from which the color bars are derived.

For example, 100/7.5/75/7.5 color bars would be 75% color bars with 7.5% setup in which the white bar has been set to 100% and the black bar to 7.5%. Since NTSC systems usually have the 7.5% setup, the two common color bars are 75/7.5/75/7.5 and 100/7.5/100/7.5, which are usually shortened to 75% and 100%, respectively. The 75% bars are most commonly used. Television transmitters do not pass information with an amplitude greater than about 120 IRE. Therefore, the 75% color bars are used for transmission testing. The 100% color bars may be used for testing in situations where a direct connection between equipment is possible. The 75/7.5/75/7.5 color bars are a part of the Electronic Industries Association EIA-189-A Encoded Color Bar Standard.

Figure 8.27 shows a typical vectorscope display for full-screen 75% NTSC color bars. Figure 8.28 illustrates the video waveform for 75% color bars.

Tables 8.10 and 8.11 list the luminance and chrominance levels for the two common color bar formats for NTSC.

For reference, the RGB and YCbCr values to generate the standard NTSC color bars are shown in Tables 8.12 and 8.13. RGB is assumed to have a range of 0–255; YCbCr is assumed to have a range of 16–235 for Y and 16–240 for Cb and Cr. It is assumed any 7.5 IRE setup is implemented within the encoder.

PAL Color Bars

Unlike NTSC, PAL does not support a 7.5 IRE setup; the black and blank levels are the same. The different color bar signals are usually described by four amplitudes, expressed in percent, separated by oblique strokes. The first and second numbers are the maximum and minimum percentages, respectively, of R′G′B′ values for an uncolored bar. The third and fourth numbers are the maximum and minimum percentages, respectively, of R′G′B′ values for a colored bar.

Since PAL systems have a 0% setup, the two common color bars are 100/0/75/0 and 100/0/100/0, which are usually shortened to 75% and 100%, respectively. The 75% color bars are used for transmission testing. The 100% color bars may be used for testing in situations where a direct connection between equipment is possible.

The 100/0/75/0 color bars also are referred to as EBU (European Broadcast Union) color bars. All of the color bars discussed in this section are also a part of *Specification of Television Standards for 625-line System-I Transmissions* (1971) published by the Independent Television Authority (ITA) and the British Broadcasting Corporation (BBC), and ITU-R BT.471.

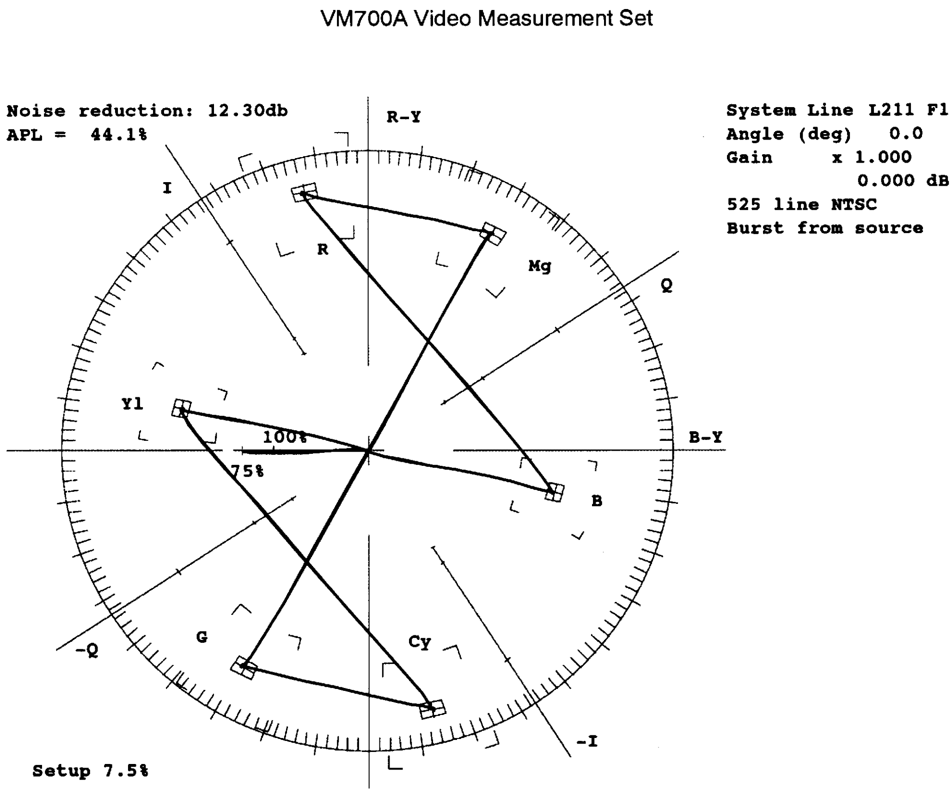

Figure 8.27. Typical Vectorscope Display for 75% NTSC Color Bars.

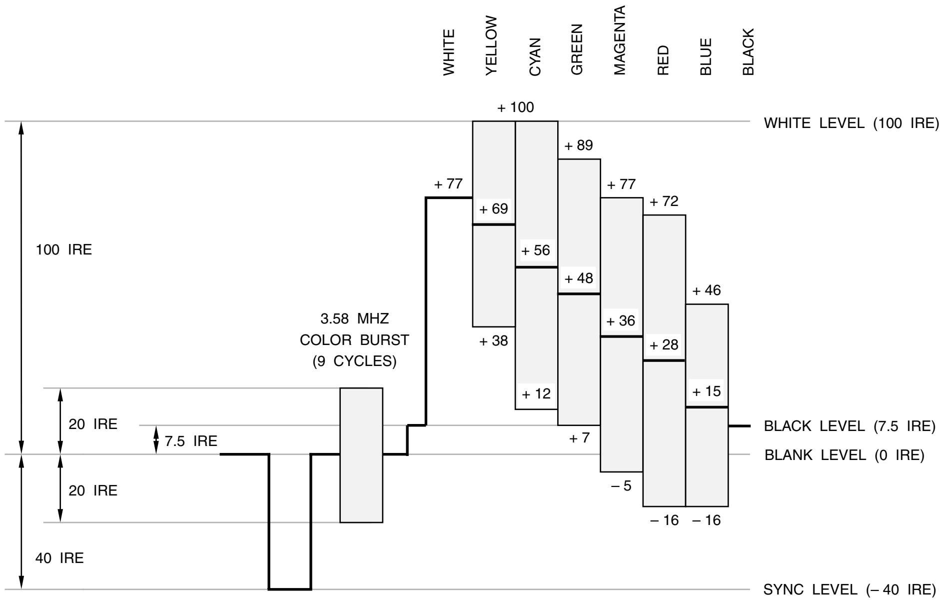

Figure 8.28. IRE Values for 75% NTSC Color Bars.

	Luminance (IRE)	Chrominance Level (IRE)	Minimum Chrominance Excursion (IRE)	Maximum Chrominance Excursion (IRE)	Chrominance Phase (degrees)
white	76.9	0	–	–	–
yellow	69.0	62.1	37.9	100.0	167.1
cyan	56.1	87.7	12.3	100.0	283.5
green	48.2	81.9	7.3	89.2	240.7
magenta	36.2	81.9	–4.8	77.1	60.7
red	28.2	87.7	–15.6	72.1	103.5
blue	15.4	62.1	–15.6	46.4	347.1
black	7.5	0	–	–	–

Table 8.10. 75/7.5/75/7.5 (75%) NTSC Color Bars.

	Luminance (IRE)	Chrominance Level (IRE)	Minimum Chrominance Excursion (IRE)	Maximum Chrominance Excursion (IRE)	Chrominance Phase (degrees)
white	100.0	0	–	–	–
yellow	89.5	82.8	48.1	130.8	167.1
cyan	72.3	117.0	13.9	130.8	283.5
green	61.8	109.2	7.2	116.4	240.7
magenta	45.7	109.2	–8.9	100.3	60.7
red	35.2	117.0	–23.3	93.6	103.5
blue	18.0	82.8	–23.3	59.4	347.1
black	7.5	0	–	–	–

Table 8.11. 100/7.5/100/7.5 (100%) NTSC Color Bars.

	White	Yellow	Cyan	Green	Magenta	Red	Blue	Black
gamma-corrected RGB (gamma = 1/0.45)								
R′	191	191	0	0	191	191	0	0
G′	191	191	191	191	0	0	0	0
B′	191	0	191	0	191	0	191	0
linear RGB								
R	135	135	0	0	135	135	0	0
G	135	135	135	135	0	0	0	0
B	135	0	135	0	135	0	135	0
YCbCr								
Y	180	162	131	112	84	65	35	16
Cb	128	44	156	72	184	100	212	128
Cr	128	142	44	58	198	212	114	128

Table 8.12. RGB and YCbCr Values for 75% NTSC Color Bars.

	White	Yellow	Cyan	Green	Magenta	Red	Blue	Black
gamma-corrected RGB (gamma = 1/0.45)								
R′	255	255	0	0	255	255	0	0
G′	255	255	255	255	0	0	0	0
B′	255	0	255	0	255	0	255	0
linear RGB								
R	255	255	0	0	255	255	0	0
G	255	255	255	255	0	0	0	0
B	255	0	255	0	255	0	255	0
YCbCr								
Y	235	210	170	145	106	81	41	16
Cb	128	16	166	54	202	90	240	128
Cr	128	146	16	34	222	240	110	128

Table 8.13. RGB and YCbCr Values for 100% NTSC Color Bars.

Figure 8.29 illustrates the video waveform for 75% color bars. Figure 8.30 shows a typical vectorscope display for full-screen 75% PAL color bars.

Tables 8.14, 8.15, and 8.16 list the luminance and chrominance levels for the three common color bar formats for PAL.

For reference, the RGB and YCbCr values to generate the standard PAL color bars are shown in Tables 8.17, 8.18, and 8.19. RGB is assumed to have a range of 0–255; YCbCr is assumed to have a range of 16–235 for Y and 16–240 for Cb and Cr.

EIA Color Bars (NTSC)

The EIA color bars (Figure 8.28 and Table 8.10) are a part of the EIA-189-A standard. The seven bars (gray, yellow, cyan, green, magenta, red, and blue) are at 75% amplitude, 100% saturation. The duration of each color bar is 1/7 of the active portion of the scan line. Note that the black bar in Figure 8.28 and Table 8.10 is not part of the standard and is shown for reference only. The color bar test signal allows checking for hue and color saturation accuracy.

	Luminance (volts)	Peak-to-Peak Chrominance			Chrominance Phase (degrees)	
		U axis (volts)	V axis (volts)	Total (volts)	Line n (135° burst)	Line n + 1 (225° burst)
white	0.700	0	–	–	–	–
yellow	0.465	0.459	0.105	0.470	167	193
cyan	0.368	0.155	0.646	0.664	283.5	76.5
green	0.308	0.304	0.541	0.620	240.5	119.5
magenta	0.217	0.304	0.541	0.620	60.5	299.5
red	0.157	0.155	0.646	0.664	103.5	256.5
blue	0.060	0.459	0.105	0.470	347	13.0
black	0	0	0	0	–	–

Table 8.14. 100/0/75/0 (75%) PAL Color Bars.

	Luminance (volts)	Peak-to-Peak Chrominance			Chrominance Phase (degrees)	
		U axis (volts)	V axis (volts)	Total (volts)	Line n (135° burst)	Line n + 1 (225° burst)
white	0.700	0	–	–	–	–
yellow	0.620	0.612	0.140	0.627	167	193
cyan	0.491	0.206	0.861	0.885	283.5	76.5
green	0.411	0.405	0.721	0.827	240.5	119.5
magenta	0.289	0.405	0.721	0.827	60.5	299.5
red	0.209	0.206	0.861	0.885	103.5	256.5
blue	0.080	0.612	0.140	0.627	347	13.0
black	0	0	0	0	–	–

Table 8.15. 100/0/100/0 (100%) PAL Color Bars.

	Luminance (volts)	Peak-to-Peak Chrominance			Chrominance Phase (degrees)	
		U axis (volts)	V axis (volts)	Total (volts)	Line n (135° burst)	Line n + 1 (225° burst)
white	0.700	0	–	–	–	–
yellow	0.640	0.459	0.105	0.470	167	193
cyan	0.543	0.155	0.646	0.664	283.5	76.5
green	0.483	0.304	0.541	0.620	240.5	119.5
magenta	0.392	0.304	0.541	0.620	60.5	299.5
red	0.332	0.155	0.646	0.664	103.5	256.5
blue	0.235	0.459	0.105	0.470	347	13.0
black	0	0	0	0	–	–

Table 8.16. 100/0/100/25 (98%) PAL Color Bars.

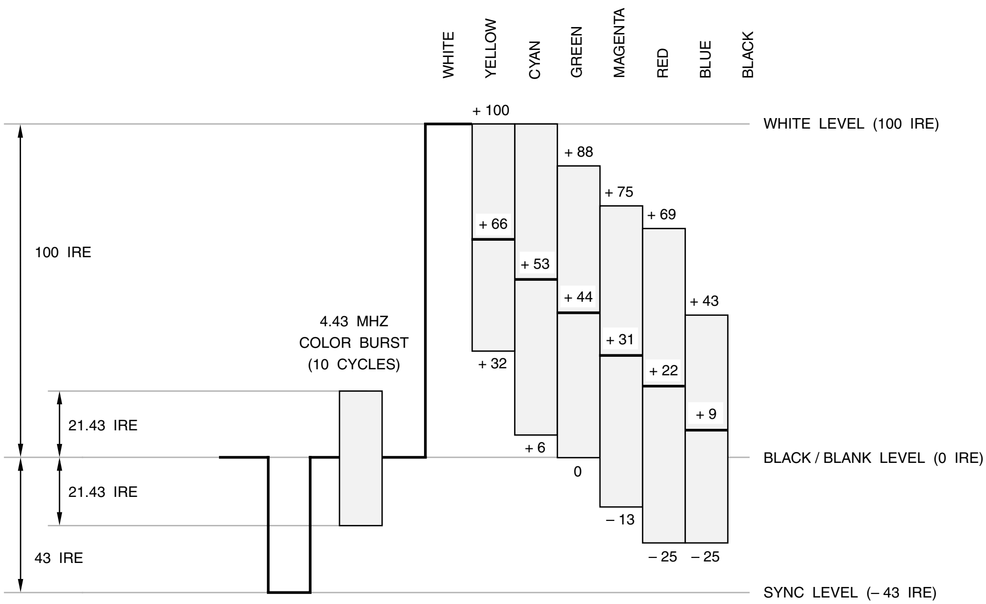

Figure 8.29. IRE Values for 75% PAL Color Bars.

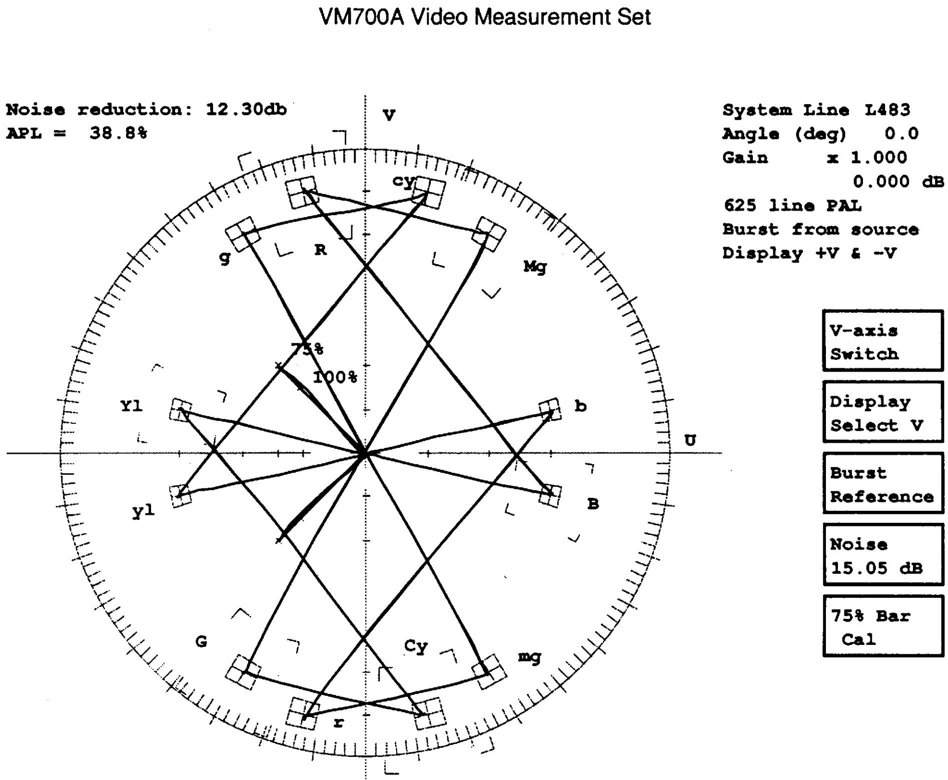

Figure 8.30. Typical Vectorscope Display for 75% PAL Color Bars.

	White	Yellow	Cyan	Green	Magenta	Red	Blue	Black
gamma-corrected RGB (gamma = 1/0.45)								
R′	255	191	0	0	191	191	0	0
G′	255	191	191	191	0	0	0	0
B′	255	0	191	0	191	0	191	0
linear RGB								
R	255	135	0	0	135	135	0	0
G	255	135	135	135	0	0	0	0
B	255	0	135	0	135	0	135	0
YCbCr								
Y	235	162	131	112	84	65	35	16
Cb	128	44	156	72	184	100	212	128
Cr	128	142	44	58	198	212	114	128

Table 8.17. RGB and YCbCr Values for 75% PAL Color Bars.

	White	Yellow	Cyan	Green	Magenta	Red	Blue	Black
gamma-corrected RGB (gamma = 1/0.45)								
R′	255	255	0	0	255	255	0	0
G′	255	255	255	255	0	0	0	0
B′	255	0	255	0	255	0	255	0
linear RGB								
R	255	255	0	0	255	255	0	0
G	255	255	255	255	0	0	0	0
B	255	0	255	0	255	0	255	0
YCbCr								
Y	235	210	170	145	106	81	41	16
Cb	128	16	166	54	202	90	240	128
Cr	128	146	16	34	222	240	110	128

Table 8.18. RGB and YCbCr Values for 100% PAL Color Bars.

	White	Yellow	Cyan	Green	Magenta	Red	Blue	Black
gamma-corrected RGB (gamma = 1/0.45)								
R′	255	255	44	44	255	255	44	44
G′	255	255	255	255	44	44	44	44
B′	255	44	255	44	255	44	255	44
linear RGB								
R	255	255	5	5	255	255	5	5
G	255	255	255	255	5	5	5	5
B	255	5	255	5	255	5	255	5
YCbCr								
Y	235	216	186	167	139	120	90	16
Cb	128	44	156	72	184	100	212	128
Cr	128	142	44	58	198	212	114	128

Table 8.19. RGB and YCbCr Values for 98% PAL Color Bars.

EBU Color Bars (PAL)

The EBU color bars are similar to the EIA color bars, except a 100 IRE white level is used (see Figure 8.29 and Table 8.14). The six colored bars (yellow, cyan, green, magenta, red, and blue) are at 75% amplitude, 100% saturation, while the white bar is at 100% amplitude. The duration of each color bar is 1/7 of the active portion of the scan line. Note that the black bar in Figure 8.29 and Table 8.14 is not part of the standard and is shown for reference only. The color bar test signal allows checking for hue and color saturation accuracy.

SMPTE Bars (NTSC)

This split-field test signal is composed of the EIA color bars for the first 2/3 of the field, the Reverse Blue bars for the next 1/12 of the field, and the PLUGE test signal for the remainder of the field.

Reverse Blue Bars

The Reverse Blue bars are composed of the blue, magenta, and cyan colors bars from the EIA/EBU color bars, but are arranged in a different order—blue, black, magenta, black, cyan, black, and white. The duration of each color bar is 1/7 of the active portion of the scan line. Typically, Reverse Blue bars are used with the EIA or EBU color bar signal in a split-field arrangement, with the EIA/EBU color bars comprising the first 3/4 of the field and the Reverse Blue bars comprising the remainder of the field. This split-field arrangement eases adjustment of chrominance and hue on a color monitor.

PLUGE

PLUGE (Picture Line-Up Generating Equipment) is a visual black reference, with one area blacker-than-black, one area at black, and one area lighter-than-black. The brightness of the monitor is adjusted so that the black and blacker-than-black areas are indistinguishable from each other and the lighter-than-black area is slightly lighter (the contrast should be at the normal setting). Additional test signals, such as a white pulse and modulated IQ signals are usually added to facilitate testing and monitor alignment.

The NTSC PLUGE test signal (shown in Figure 8.31) is composed of a 7.5 IRE (black level) pedestal with a 40 IRE "–I" phase modulation, a 100 IRE white pulse, a 40 IRE "+Q" phase modulation, and 3.5 IRE, 7.5 IRE, and 11.5 IRE pedestals. Typically, PLUGE is used as part of the SMPTE bars.

For PAL, each country has its own slightly different PLUGE configuration, with most differences being the black pedestal level used, and work is being done on a standard test signal. Figure 8.32 illustrates a typical PAL PLUGE test signal. Usually used as a full-screen test signal, it is composed of a 0 IRE

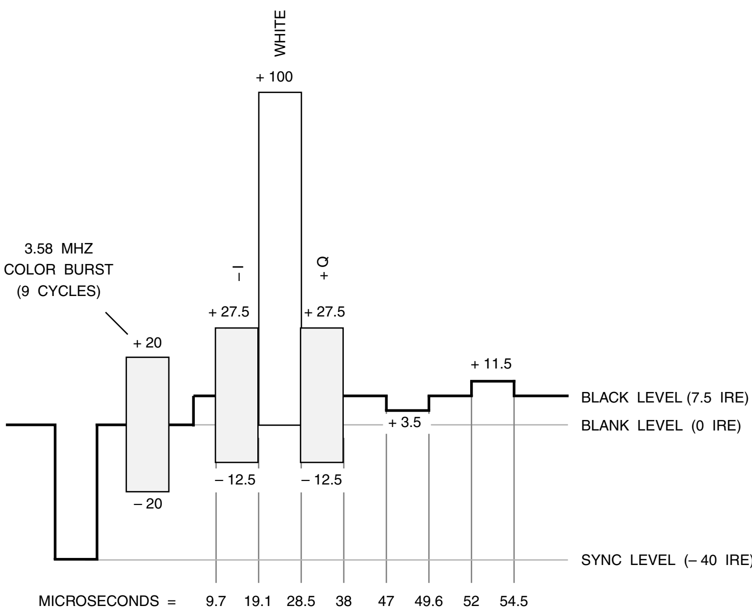

Figure 8.31. PLUGE Test Signal for NTSC. IRE values are indicated.

pedestal with PLUGE (–2 IRE, 0 IRE, and 2 IRE pedestals) and a white pulse. The white pulse may have five levels of brightness (0, 25, 50, 75, and 100 IRE), depending on the scan line number, as shown in Figure 8.32. The PLUGE is displayed on scan lines that have non-zero IRE white pulses. ITU-R BT.1221 discusses considerations for various PAL systems.

Y Bars

The Y bars consist of the luminance-only levels of the EIA/EBU color bars; however, the black level (7.5 IRE for NTSC and 0 IRE for PAL) is included and the color burst is still present. The duration of each luminance bar is therefore 1/8 of the active portion of the scan line. Y bars are useful for color monitor adjustment and measuring luminance nonlinearity. Typically, the Y bars signal is used with the EIA or EBU color bar signal in a split-field arrangement, with the EIA/EBU color bars comprising the first 3/4 of the field and the Y bars signal comprising the remainder of the field.

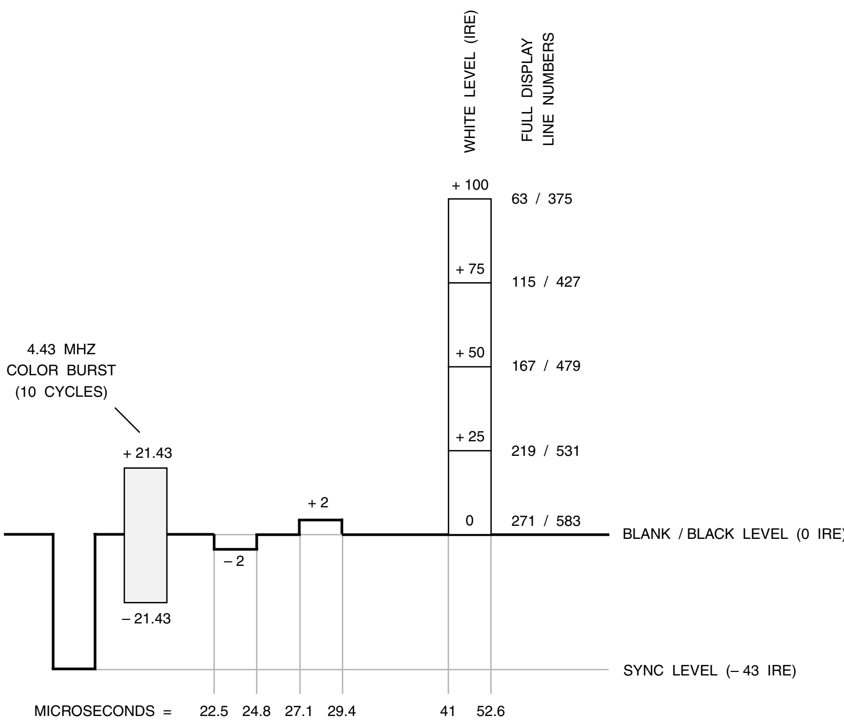

Figure 8.32. PLUGE Test Signal for PAL. IRE values are indicated.

Red Field

The Red Field signal consists of a 75% amplitude, 100% saturation red chrominance signal. This is useful as the human eye is sensitive to static noise intermixed in a red field. Distortions that cause small errors in picture quality can be examined visually for the effect on the picture. Typically, the Red Field signal is used with the EIA/EBU color bars signal in a split-field arrangement, with the EIA/EBU color bars comprising the first 3/4 of the field, and the Red Field signal comprising the remainder of the field.

10-Step Staircase

This test signal is composed of ten unmodulated luminance steps of 10 IRE each, ranging from 0 IRE to 100 IRE, shown in Figure 8.33. This test signal may be used to measure luminance nonlinearity.

Modulated Ramp

The modulated ramp test signal, shown in Figure 8.34, is composed of a luminance ramp from 0 IRE to either 80 or 100 IRE, superimposed with modulated chrominance that has a phase of 0° ±1° relative to the burst. The 80 IRE ramp provides testing of the normal operating range of the system; a 100 IRE ramp may be used to optionally test the entire operating range. The peak-to-peak modulated chrominance is 40 ±0.5 IRE for (M) NTSC and 42.86 ±0.5 IRE for (B, D, G, H, I) PAL. Note a 0 IRE setup is used. The rise and fall times at the start and end of the modulated ramp envelope are 400 ±25 ns (NTSC systems) or approximately 1 µs (PAL systems). This test signal may be used to measure differential gain. The modulated ramp signal is preferred over a 5-step or 10-step modulated staircase signal when testing digital systems.

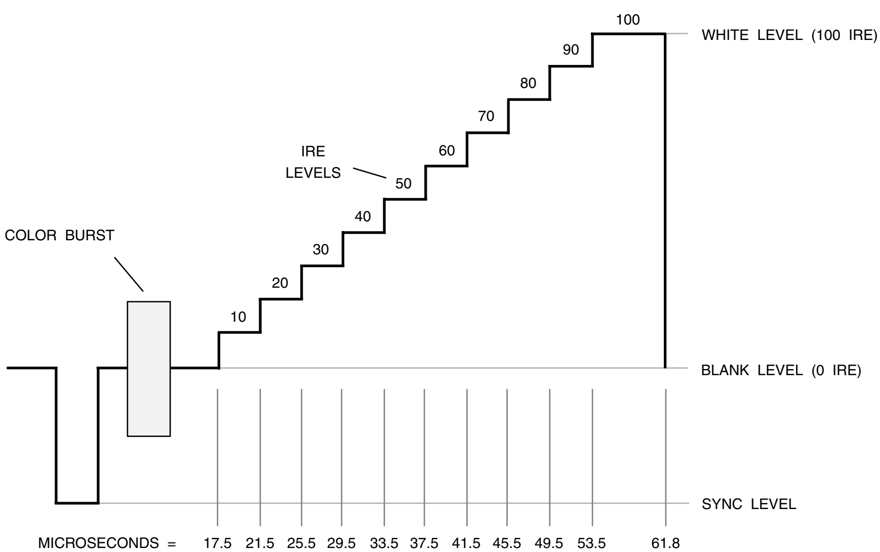

Figure 8.33. Ten-Step Staircase Test Signal for NTSC and PAL.

Modulated Staircase

The 5-step modulated staircase signal (a 10-step version is also used), shown in Figure 8.35, consists of 5 luminance steps, superimposed with modulated chrominance that has a phase of 0° ±1° relative to the burst. The peak-to-peak modulated chrominance amplitude is 40 ±0.5 IRE for (M) NTSC and 42.86 ±0.5 IRE for (B, D, G, H, I) PAL. Note a 0 IRE setup is used. The rise and fall times of each modulation packet envelope are 400 ±25 ns (NTSC systems) or approximately 1 µs (PAL systems). The luminance IRE levels for the 5-step modulated staircase signal are shown in Figure 8.35. This test signal may be used to measure differential gain. The modulated ramp signal is preferred over a 5-step or 10-step modulated staircase signal when testing digital systems.

Modulated Pedestal

The modulated pedestal test signal (also called a three-level chrominance bar), shown in Figure 8.36, is composed of a 50 IRE luminance pedestal, superimposed with three amplitudes of modulated chrominance that has a phase relative to the burst of –90° ±1°. The peak-to-peak amplitudes of the modulated chrominance are 20 ±0.5, 40 ±0.5, and 80 ±0.5 IRE for (M) NTSC and 20 ±0.5, 60 ±0.5, and 100 ±0.5 IRE for (B, D, G, H, I) PAL. Note a 0 IRE setup is used. The rise and fall times of each modulation packet envelope are 400 ±25 ns (NTSC systems) or approximately 1 µs (PAL systems). This test signal may be used to measure chrominance-to-luminance intermodulation and chrominance nonlinear gain.

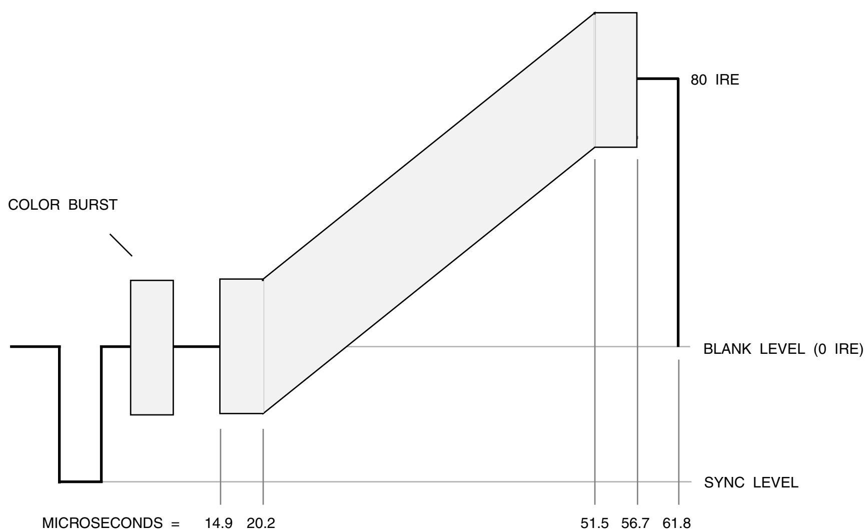

Figure 8.34. 80 IRE Modulated Ramp Test Signal for NTSC and PAL.

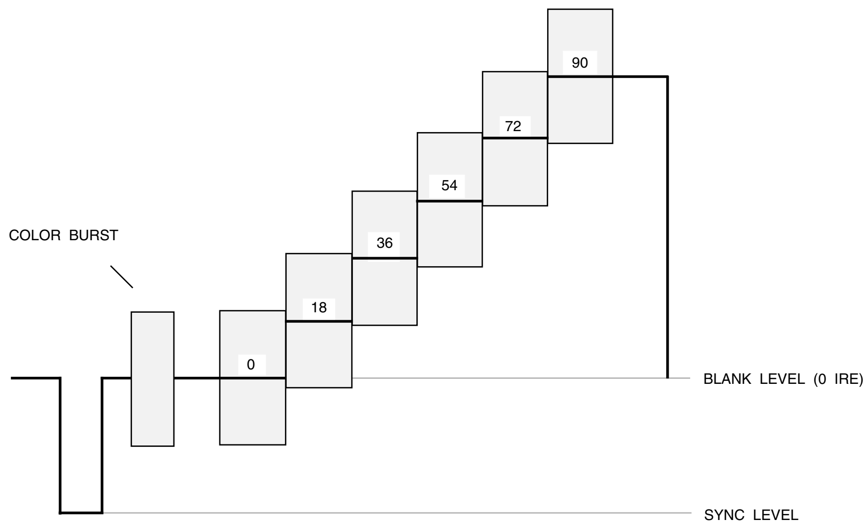

Figure 8.35. Five-Step Modulated Staircase Test Signal for NTSC and PAL.

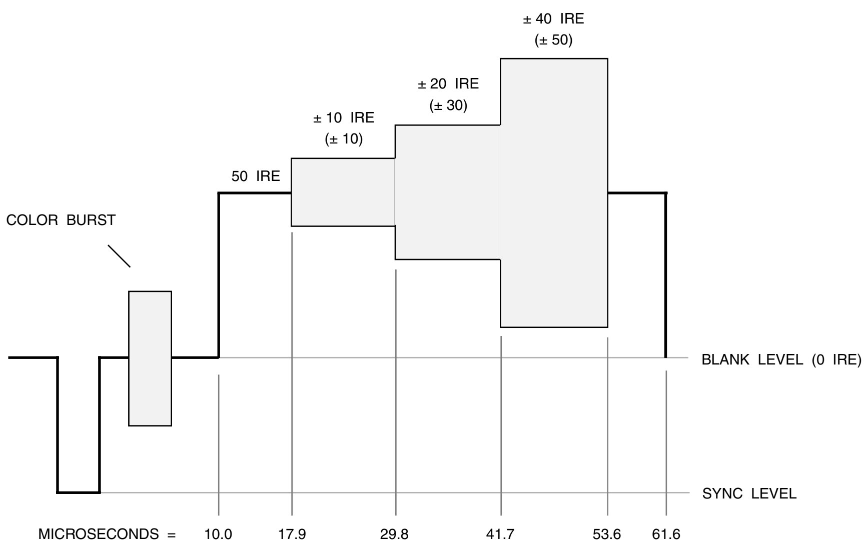

Figure 8.36. Modulated Pedestal Test Signal for NTSC and PAL. PAL IRE values are shown in parentheses.

Multiburst

The multiburst test signal for (M) NTSC, shown in Figure 8.37, consists of a white flag with a peak amplitude of 100 ±1 IRE and six frequency packets, each a specific frequency. The packets have a 40 ±1 IRE pedestal with peak-to-peak amplitudes of 60 ±0.5 IRE. Note a 0 IRE setup is used and the starting and ending point of each packet is at zero phase.

The ITU multiburst test signal for (B, D, G, H, I) PAL, shown in Figure 8.38, consists of a 4 µs white flag with a peak amplitude of 80 ±1 IRE and six frequency packets, each a specific frequency. The packets have a 50 ±1 IRE pedestal with peak-to-peak amplitudes of 60 ±0.5 IRE. Note the starting and ending points of each packet are at zero phase. The gaps between packets are 0.4–2.0 µs. The ITU multiburst test signal may be present on line 18.

The multiburst signals are used to test the frequency response of the system by measuring the peak-to-peak amplitudes of the packets.

Line Bar

The line bar is a single 100 ±0.5 IRE (reference white) pulse of 10 µs (PAL), 18 µs (NTSC), or 25 µs (PAL) that occurs anywhere within the active scan line time (rise and fall times are ≤ 1 µs). Note the color burst is not present, and a 0 IRE setup is used. This test signal is used to measure line time distortion (line tilt or H tilt). A digital encoder or decoder does not generate line time distortion; the distortion is generated primarily by the analog filters and transmission channel.

Multipulse

The (M) NTSC multipulse contains a 2T pulse and 25T and 12.5T pulses with various high-frequency components, as shown in Figure 8.39. The (B, D, G, H, I) PAL multipulse is similar, except 20T and 10T pulses are used, and there is no 7.5 IRE setup. This test signal is typically used to measure the frequency response of the transmission channel.

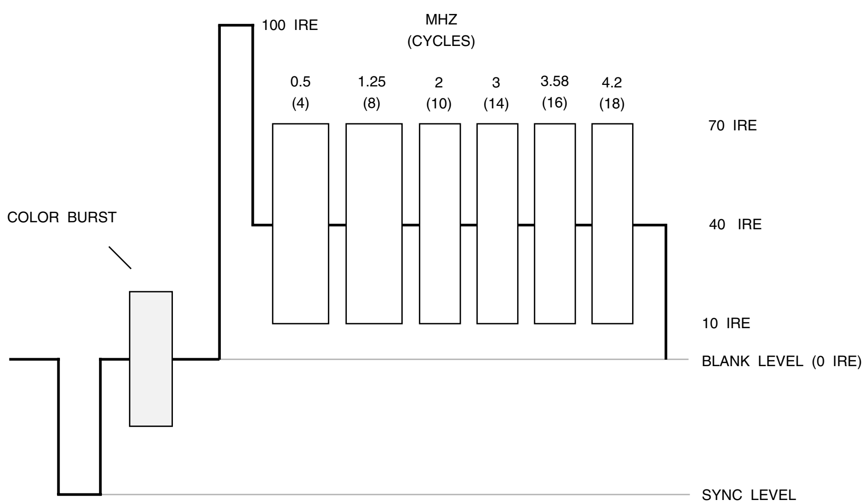

Figure 8.37. Multiburst Test Signal for NTSC.

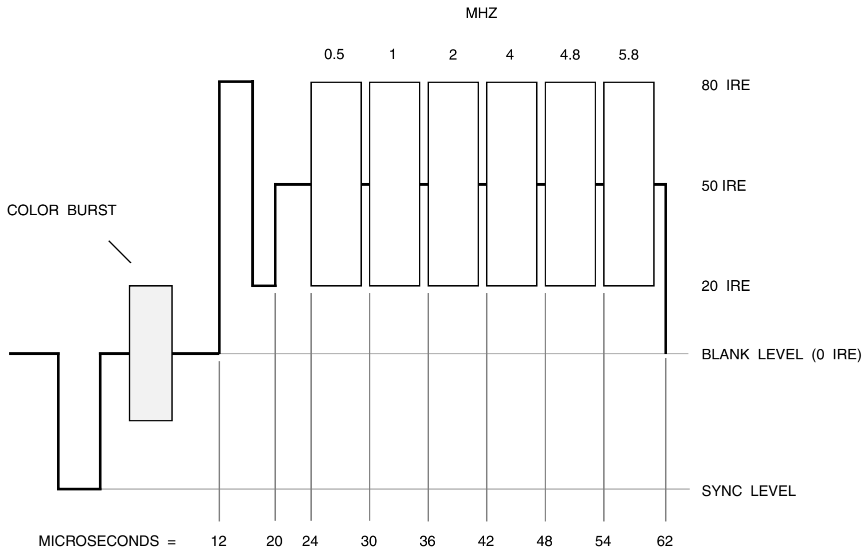

Figure 8.38. ITU Multiburst Test Signal for PAL.

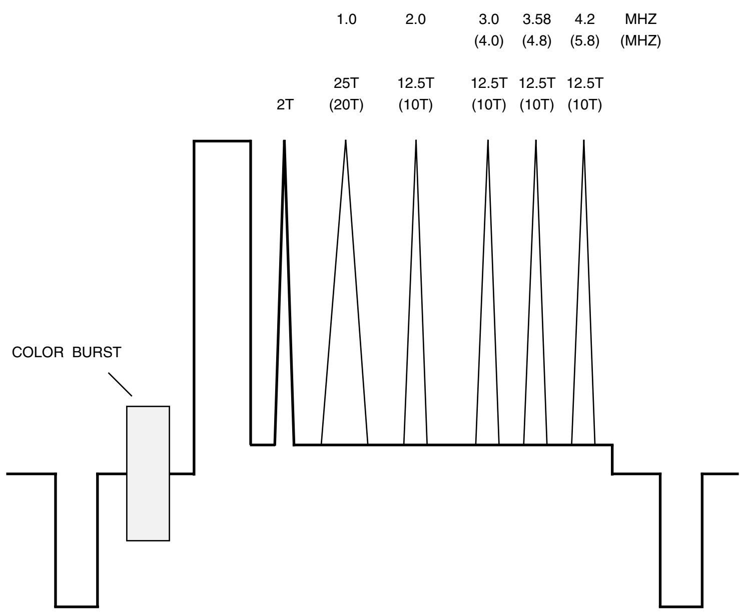

Figure 8.39. Multipulse Test Signal for NTSC and PAL. PAL values are shown in parentheses.

Field Square Wave

The field square wave contains 100 ±0.5 IRE pulses for the entire active line time for odd fields and blanked scan lines for even fields. Note the color burst is not present and a 0 IRE setup is used. This test signal is used to measure field time distortion (field tilt or V tilt). A digital encoder or decoder does not generate field time distortion; the distortion is generated primarily by the analog filters and transmission channel.

Composite Test Signal

NTC-7 Version for NTSC

The NTC (U. S. Network Transmission Committee) has developed a composite test signal that may be used to test several video parameters, rather than using multiple test signals. The NTC-7 composite test signal for NTSC systems (shown in Figure 8.40) consists of a 100 IRE line bar, a 2T pulse, a 12.5T chrominance pulse, and a 5-step modulated staircase signal.

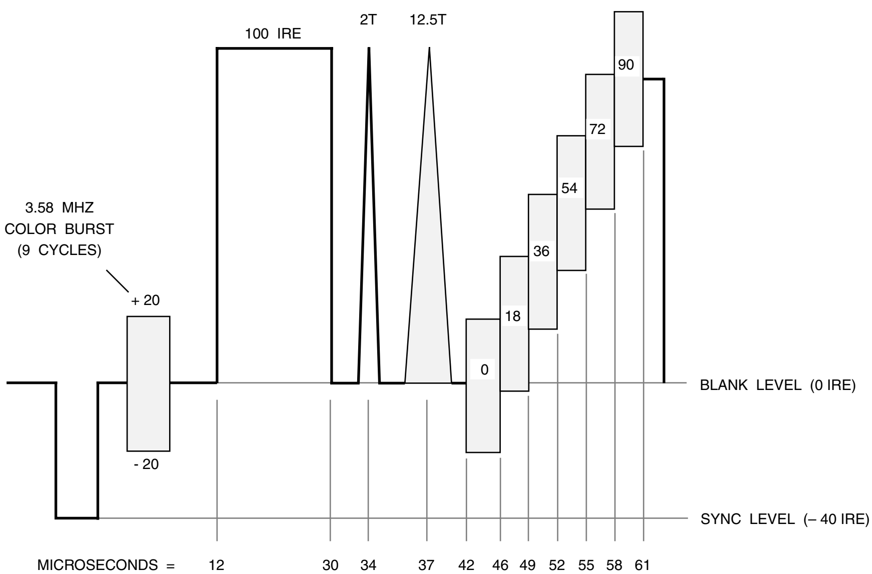

Figure 8.40. NTC-7 Composite Test Signal for NTSC, With Corresponding IRE Values.

The line bar has a peak amplitude of 100 ±0.5 IRE, and 10–90% rise and fall times of 125 ±5 ns with an integrated sine-squared shape. It has a width at the 60 IRE level of 18 µs.

The 2T pulse has a peak amplitude of 100 ±0.5 IRE, with a half-amplitude width of 250 ±10 ns.

The 12.5T chrominance pulse has a peak amplitude of 100 ±0.5 IRE, with a half-amplitude width of 1562.5 ±50 ns.

The 5-step modulated staircase signal consists of 5 luminance steps superimposed with a 40 ±0.5 IRE subcarrier that has a phase of 0° ±1° relative to the burst. The rise and fall times of each modulation packet envelope are 400 ±25 ns.

The NTC-7 composite test signal may be present on line 17.

ITU Version for PAL

The ITU (BT.628 and BT.473) has developed a composite test signal that may be used to test several video parameters, rather than using multiple test signals. The ITU composite test signal for PAL systems (shown in Figure 8.41) consists of a white flag, a 2T pulse, and a 5-step modulated staircase signal.

The white flag has a peak amplitude of 100 ±1 IRE and a width of 10 µs.

The 2T pulse has a peak amplitude of 100 ±0.5 IRE, with a half-amplitude width of 200 ±10 ns.

The 5-step modulated staircase signal consists of 5 luminance steps (whose IRE values are shown in Figure 8.41) superimposed with a 42.86 ±0.5 IRE subcarrier that has a phase of 60° ±1° relative to the U axis. The rise and fall times of each modulation packet envelope are approximately 1 µs.

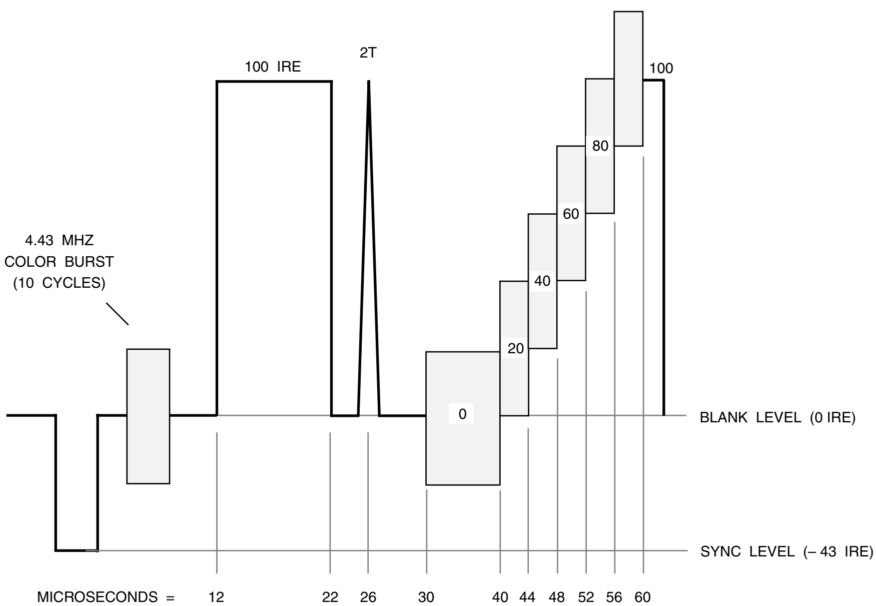

Figure 8.41. ITU Composite Test Signal for PAL, With Corresponding IRE Values.

The ITU composite test signal may be present on line 330.

U.K. Version

The United Kingdom allows the use of a slightly different test signal since the 10T pulse is more sensitive to delay errors than the 20T pulse (at the expense of occupying less chrominance bandwidth). Selection of an appropriate pulse width is a trade-off between occupying the PAL chrominance bandwidth as fully as possible and obtaining a pulse with sufficient sensitivity to delay errors. Thus, the national test signal (developed by the British Broadcasting Corporation and the Independent Television Authority) in Figure 8.42 may be present on lines 19 and 332 for (I) PAL systems in the United Kingdom.

The white flag has a peak amplitude of 100 ±1 IRE and a width of 10 µs.

The 2T pulse has a peak amplitude of 100 ±0.5 IRE, with a half-amplitude width of 200 ±10 ns.

The 10T chrominance pulse has a peak amplitude of 100 ±0.5 IRE.

The 5-step modulated staircase signal consists of 5 luminance steps (whose IRE values are shown in Figure 8.42) superimposed with a 21.43 ±0.5 IRE subcarrier that has a phase of 60° ±1° relative to the U axis. The rise and fall times of each modulation packet envelope is approximately 1 µs.

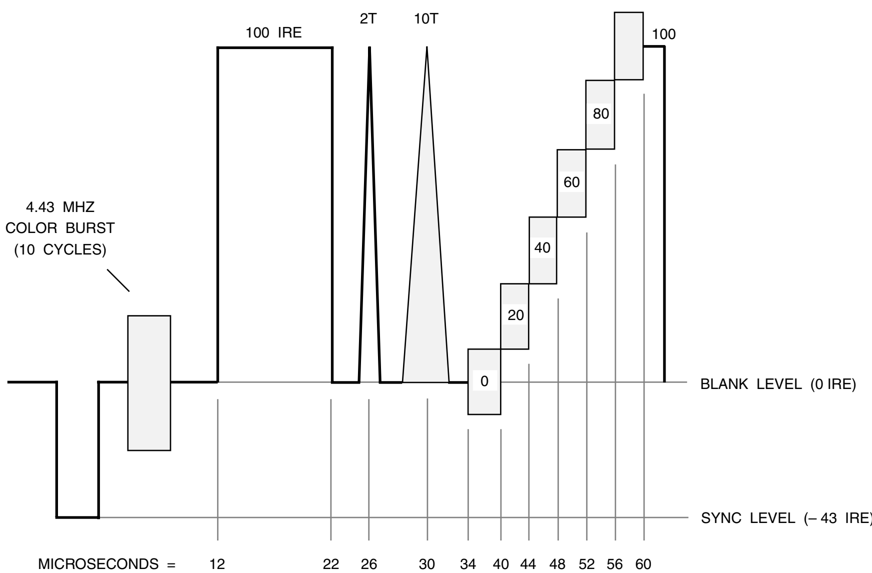

Figure 8.42. United Kingdom (I) PAL National Test Signal #1, With Corresponding IRE Values.

Combination Test Signal

NTC-7 Version for NTSC

The NTC (U. S. Network Transmission Committee) has also developed a combination test signal that may be used to test several video parameters, rather than using multiple test signals. The NTC-7 combination test signal for NTSC systems (shown in Figure 8.43) consists of a white flag, a multiburst, and a modulated pedestal signal.

The white flag has a peak amplitude of 100 ±1 IRE and a width of 4 µs.

The multiburst has a 50 ±1 IRE pedestal with peak-to-peak amplitudes of 50 ±0.5 IRE. The starting point of each frequency packet is at zero phase. The width of the 0.5 MHz packet is 5 µs; the width of the remaining packets is 3 µs.

The 3-step modulated pedestal is composed of a 50 IRE luminance pedestal, superimposed with three amplitudes of modulated chrominance (20 ±0.5, 40 ±0.5, and 80 ±0.5 IRE peak-to-peak) that have a phase of –90° ±1° relative to the burst. The rise and fall times of each modulation packet envelope are 400 ±25 ns.

The NTC-7 combination test signal may be present on line 280.

ITU Version for PAL

The ITU (BT.473) has developed a combination test signal that may be used to test several video parameters, rather than using multiple test signals. The ITU combination test signal for PAL systems (shown in Figure 8.44) consists of a white flag, a 2T pulse, a 20T modulated chrominance pulse, and a 5-step luminance staircase signal.

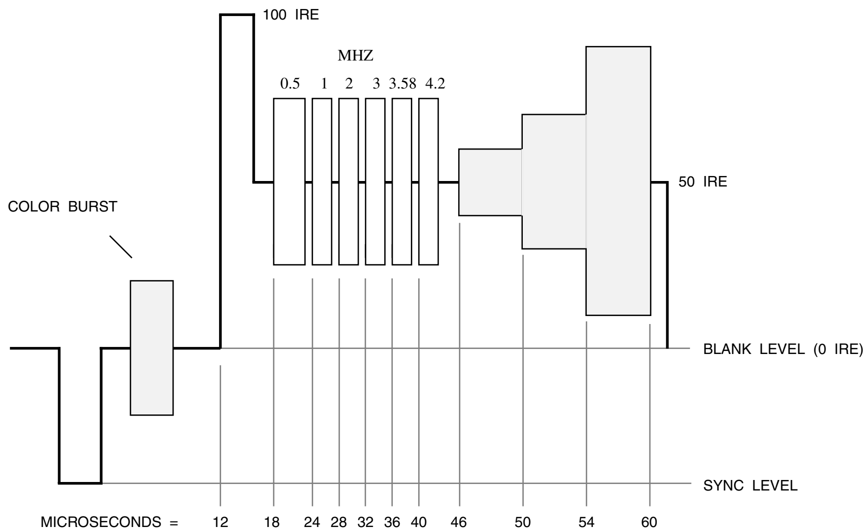

Figure 8.43. NTC-7 Combination Test Signal for NTSC.

The line bar has a peak amplitude of 100 ±1 IRE and a width of 10 µs.

The 2T pulse has a peak amplitude of 100 ±0.5 IRE, with a half-amplitude width of 200 ±10 ns.

The 20T chrominance pulse has a peak amplitude of 100 ±0.5 IRE, with a half-amplitude width of 2.0 ±0.06 µs.

The 5-step luminance staircase signal consists of 5 luminance steps, at 20, 40, 60, 80 and 100 ±0.5 IRE.

The ITU combination test signal may be present on line 17.

ITU ITS Version for PAL

The ITU (BT.473) has developed a combination ITS (insertion test signal) that may be used to test several PAL video parameters, rather than using multiple test signals. The ITU combination ITS for PAL systems (shown in Figure 8.45) consists of a 3-step modulated pedestal with peak-to-peak amplitudes of 20, 60, and 100 ±1 IRE, and an extended subcarrier packet with a peak-to-peak amplitude of 60 ±1 IRE. The rise and fall times of each subcarrier packet envelope are approximately 1 µs. The phase of each subcarrier packet is 60° ±1° relative to the U axis. The tolerance on the 50 IRE level is ±1 IRE.

The ITU composite ITS may be present on line 331.

U. K. Version

The United Kingdom allows the use of a slightly different test signal, as shown in Figure 8.46. It may be present on lines 20 and 333 for (I) PAL systems in the United Kingdom.

The test signal consists of a 50 IRE luminance bar, part of which has a 100 IRE subcarrier superimposed that has a phase of 60° ±1° relative to the U axis, and an extended burst of subcarrier on the second half of the scan line.

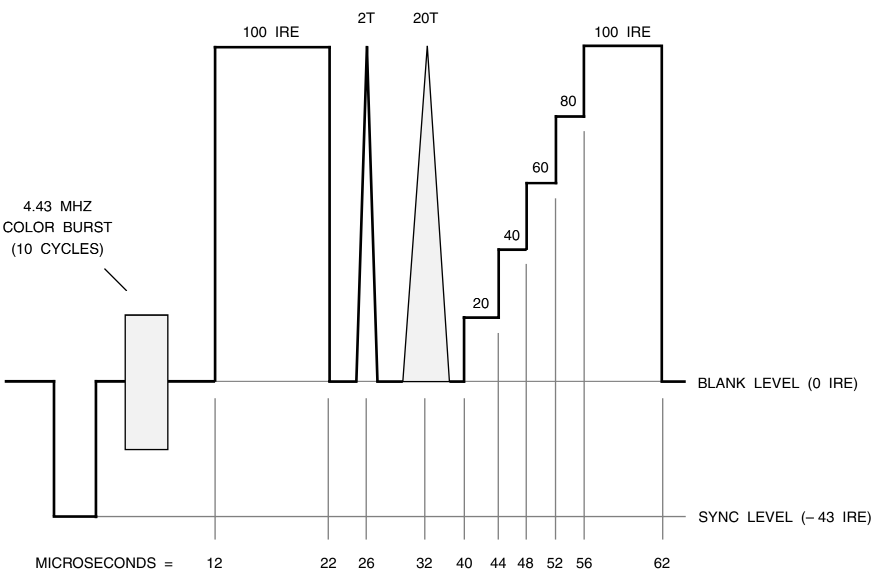

Figure 8.44. ITU Combination Test Signal for PAL.

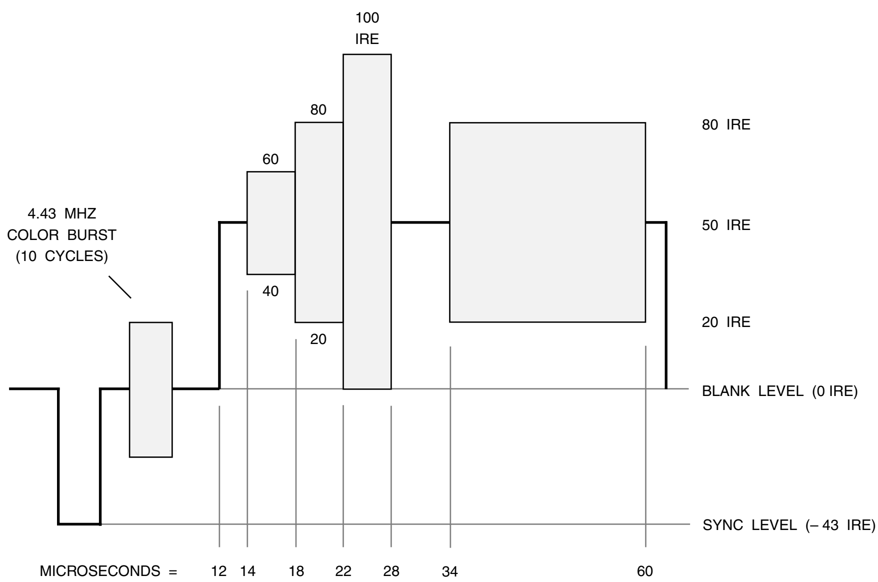

Figure 8.45. ITU Combination ITS Test Signal for PAL.

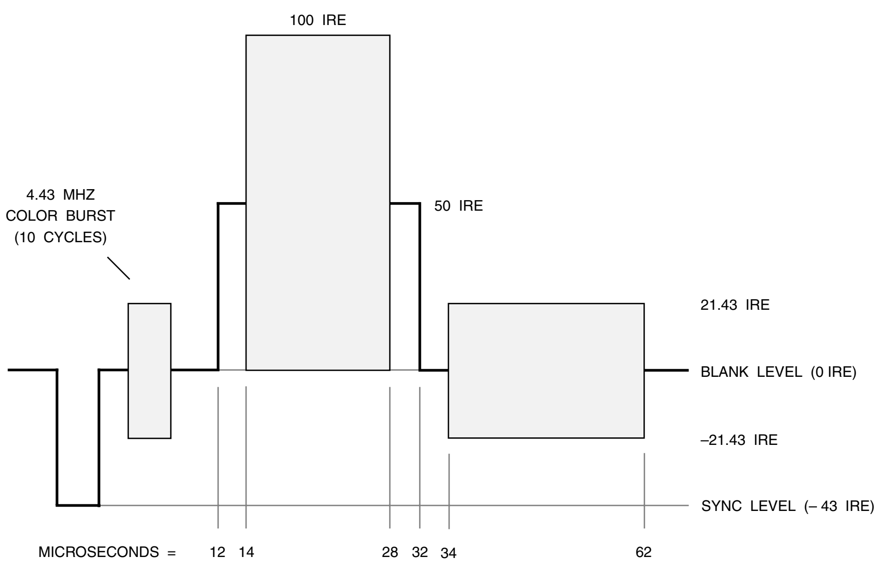

Figure 8.46. United Kingdom (I) PAL National Test Signal #2.

T Pulse

Square waves with fast rise times cannot be used for testing video systems, since attenuation and phase shift of out-of-band components cause ringing in the output signal, obscuring the in-band distortions being measured. T, or $\sin^2$, pulses are bandwidth-limited, so are used for testing video systems.

The 2T pulse is shown in Figure 8.47 and, like the T pulse, is obtained mathematically by squaring a half-cycle of a sine wave. T pulses are specified in terms of half amplitude duration (HAD), which is the pulse width measured at 50% of the pulse amplitude. Pulses with HADs that are multiples of the time interval T are used to test video systems. As seen in Figures 8.39 through 8.44, T, 2T, 12.5T and 25T pulses are common when testing NTSC video systems, whereas T, 2T, 10T, and 20T pulses are common for PAL video systems.

T is the Nyquist interval or

$$1/2F_C$$

where F_C is the cutoff frequency of the video system. For NTSC, F_C is 4 MHz, whereas F_C for PAL systems is 5 MHz. Therefore, T for NTSC systems is 125 ns and for PAL systems it is 100 ns. For a T pulse with a HAD of 125 ns, a 2T pulse has a HAD of 250 ns, and so on. The frequency spectra for the 2T pulse is shown in

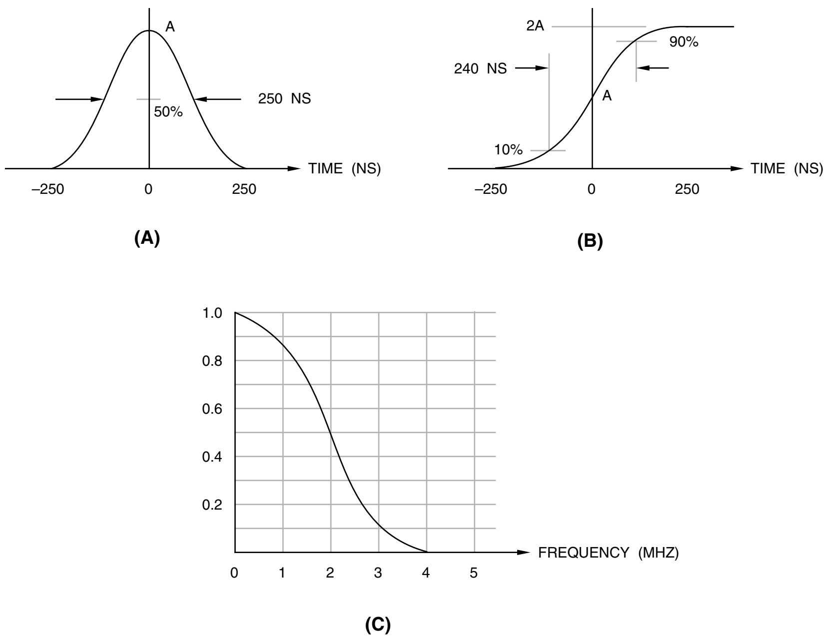

Figure 8.47. The T Pulse. (a) 2T pulse. (b) 2T step. (c) Frequency spectra of the 2T pulse.

Figure 8.47 and is representative of the energy content in a typical character generator waveform.

To generate smooth rising and falling edges of most video signals, a T step (generated by integrating a T pulse) is typically used. T steps have 10–90% rise/fall times of 0.964T and a well-defined bandwidth. The 2T step generated from a 2T pulse is shown in Figure 8.47.

The 12.5T chrominance pulse, illustrated in Figure 8.48, is a good test signal to measure any chrominance-to-luminance timing error since its energy spectral distribution is bunched in two relatively narrow bands. Using this signal detects differences in the luminance and chrominance phase distortion, but not between other frequency groups.

VBI Data

VBI (vertical blanking interval) data may be inserted up to about 5 scan lines into the active picture region to ensure it won't be deleted by equipment replacing the VBI, by DSS MPEG which deletes the VBI, or by cable systems inserting their own VBI data. This is common practice by Neilson and others to ensure their programming and commercial tracking data gets through the distribution systems to the receivers. In most cases, this will be unseen since it is masked by the TV's overscan.

Timecode

Two types of time coding are commonly used, as defined by ANSI/SMPTE 12M and IEC 461:

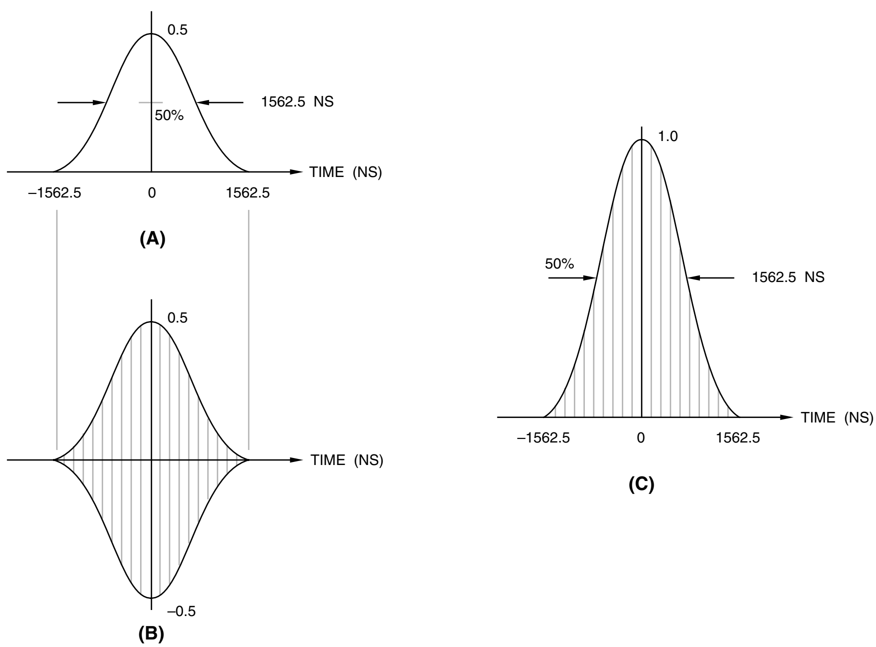

Figure 8.48. The 12.5T Chrominance Pulse. (a) Luma component. (b) Chroma component. (c) Addition of (a) and (b).

longitudinal timecode (LTC) and vertical interval timecode (VITC).

The LTC is recorded on a separate audio track; as a result, the analog VCR must use high-bandwidth amplifiers and audio heads. This is due to the time code frequency increasing as tape speed increases, until the point that the frequency response of the system results in a distorted time code signal that may not be read reliably. At slower tape speeds, the time code frequency decreases, until at very low tape speeds or still pictures, the time code information is no longer recoverable.

The VITC is recorded as part of the video signal; as a result, the time code information is always available, regardless of the tape speed. However, the LTC allows the time code signal to be written without writing a video signal; the VITC requires the video signal to be changed if a change in time code information is required. The LTC therefore is useful for synchronizing multiple audio or audio/video sources.

Frame Dropping

If the field rate is 60/1.001 fields per second, straight counting at 60 fields per second yields an error of about 108 frames for each hour of running time. This may be handled in one of three ways:

> Nondrop frame: During a continuous recording, each time count increases by 1 frame. In this mode, the drop frame flag will be a "0."
>
> Drop frame: To minimize the timing error, the first two frame numbers (00 and 01) at the start of each minute, except for minutes 00, 10, 20, 30, 40, and 50, are omitted from the count. In this mode, the drop frame flag will be a "1."
>
> Drop frame for (M) PAL: To minimize the timing error, the first four frame numbers (00 to 03) at the start of every second minute (even minute numbers) are omitted from the count, except for minutes 00, 20, and 40. In this mode, the drop frame flag will be a "1."

Even with drop framing, there is a long-term error of about 2.26 frames per 24 hours. This error accumulation is the reason timecode generators must be periodically reset if they are to maintain any correlation to the correct time-of-day. Typically, this "reset-to-real-time" is referred to as a "jam sync" procedure. Some jam sync implementations reset the timecode to 00:00:00.00 and, therefore, must occur at midnight; others allow a true re-sync to the correct time-of-day.

One inherent problem with jam sync correction is the interruption of the timecode. Although this discontinuity may be brief, it may cause timecode readers to "hiccup" due to the interruption.

Longitudinal Timecode (LTC)

The LTC information is transferred using a separate serial interface, using the same electrical interface as the AES/EBU digital audio interface standard, and is recorded on a separate track. The basic structure of the time data is based on the BCD system. Tables 8.20 and 8.21 list the LTC bit assignments and arrangement. Note the 24-hour clock system is used.

LTC Timing

The modulation technique is such that a transition occurs at the beginning of every bit period. "1" is represented by a second transition one-half a bit period from the start of the bit. "0" is represented when there is no transition within the bit period (see Figure 8.49).

Bit(s)	Function	Note	Bit(s)	Function	Note
0–3	units of frames		58	flag 5	note 5
4–7	user group 1		59	flag 6	note 6
8–9	tens of frames		60–63	user group 8	
10	flag 1	note 1	64	sync bit	fixed”0”
11	flag 2	note 2	65	sync bit	fixed”0”
12–15	user group 2		66	sync bit	fixed”1”
16–19	units of seconds		67	sync bit	fixed”1”
20–23	user group 3		68	sync bit	fixed”1”
24–26	tens of seconds		69	sync bit	fixed”1”
27	flag 3	note 3	70	sync bit	fixed”1”
28–31	user group 4		71	sync bit	fixed”1”
32–35	units of minutes		72	sync bit	fixed”1”
36–39	user group 5		73	sync bit	fixed”1”
40–42	tens of minutes		74	sync bit	fixed”1”
43	flag 4	note 4	75	sync bit	fixed”1”
44–47	user group 6		76	sync bit	fixed”1”
48–51	units of hours		77	sync bit	fixed”1”
52–55	user group 7		78	sync bit	fixed”0”
56–57	tens of hours		79	sync bit	fixed”1”

Notes

1. Drop frame flag. 525/60 and 1125/60 systems: “1” if frame numbers are being dropped, “0” if no frame dropping is done. 625/50 systems: “0”.
2. Color frame flag. 525/60 systems: “1” if even units of frame numbers identify fields 1 and 2 and odd units of field numbers identify fields 3 and 4. 625/50 systems: “1” if timecode is locked to the video signal in accordance with 8-field sequence and the video signal has the “preferred subcarrier-to-line-sync phase”. 1125/60 systems: “0”.
3. 525/60 and 1125/60 systems: Phase correction. This bit shall be put in a state so that every 80-bit word contains an even number of “0”s. 625/50 systems: Binary group flag 0.
4. 525/60 and 1125/60 systems: Binary group flag 0. 625/50 systems: Binary group flag 2.
5. Binary group flag 1.
6. 525/60 and 1125/60 systems: Binary group flag 2. 625/50 systems: Phase correction. This bit shall be put in a state so that every 80-bit word contains an even number of “0”s.

Table 8.20. LTC Bit Assignments.

Frames (count 0–29 for 525/60 systems, 0–24 for 625/50 systems)	
units of frames (bits 0–3)	4-bit BCD (count 0–9); bit 0 is LSB
tens of frames (bits 8–9)	2-bit BCD (count 0–2); bit 8 is LSB

Seconds	
units of seconds (bits 16–19)	4-bit BCD (count 0–9); bit 16 is LSB
tens of seconds (bits 24–26)	3-bit BCD (count 0–5); bit 24 is LSB

Minutes	
units of minutes (bits 32–35)	4-bit BCD (count 0–9); bit 32 is LSB
tens of minutes (bits 40–42)	3-bit BCD (count 0–5); bit 40 is LSB

Hours	
units of hours (bits 48–51)	4-bit BCD (count 0–9); bit 48 is LSB
tens of hours (bits 56–57)	2-bit BCD (count 0–2); bit 56 is LSB

Table 8.21. LTC Bit Arrangement.

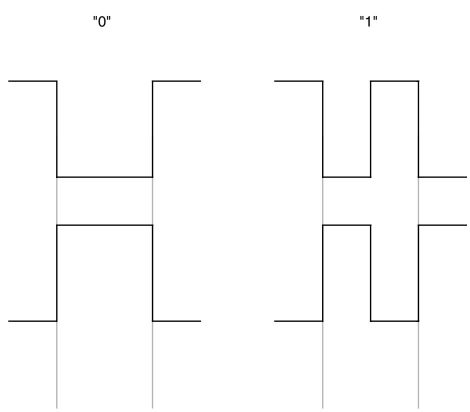

Figure 8.49. LTC Data Bit Transition Format.

The signal has a peak-to-peak amplitude of 0.5–4.5V, with rise and fall times of 40 ±10 µs (10% to 90% amplitude points).

Because the entire frame time is used to generate the 80-bit LTC information, the bit rate (in bits per second) may be determined by:

$$F_C = 80\ F_V$$

where F_V is the vertical frame rate in frames per second. The 80 bits of time code information are output serially, with bit 0 being first. The LTC word occupies the entire frame time, and the data must be evenly spaced throughout this time. The start of the LTC word occurs at the beginning of line 5 ±1.5 lines for 525/60 systems, at the beginning of line 2 ±1.5 lines for 625/50 systems, and at the vertical sync timing reference of the frame ±1 line for 1125/60 systems.

Vertical Interval Time Code (VITC)

The VITC is recorded during the vertical blanking interval of the video signal in both fields. Since it is recorded with the video, it can be read in still mode. However, it cannot be re-recorded (or restriped). Restriping requires dubbing down a generation, deleting and inserting a new time code. For YPbPr and S-video interfaces, VITC is present on the Y signal. For analog RGB interfaces, VITC is present on all three signals.

As with the LTC, the basic structure of the time data is based on the BCD system. Tables 8.22 and 8.23 list the VITC bit assignments and arrangement. Note the 24-hour clock system is used.

<u>VITC Cyclic Redundancy Check</u>

Eight bits (82–89) are reserved for the code word for error detection by means of cyclic redundancy checking. The generating polynomial, $x^8 + 1$, applies to all bits from 0 to 81, inclusive. Figure 8.50 illustrates implementing the polynomial using a shift register. During passage of timecode data, the multiplexer is in position 0 and the data is output while the CRC calculation is done simultaneously by the shift register. After all the timecode data has been output, the shift register contains the CRC value, and switching the multiplexer to position 1 enables the CRC value to be output. When the process is repeated on decoding, the shift register should contain all zeros if no errors exist.

<u>VITC Timing</u>

The modulation technique is such that each state corresponds to a binary state, and a transition occurs only when there is a change in the data between adjacent bits from a “1” to “0” or “0” to “1”. No transitions occur when adjacent bits contain the same data. This is commonly referred to as “non-return to zero” (NRZ). Synchronization bit pairs are inserted throughout the VITC data to assist the receiver in maintaining the correct frequency lock.

The bit rate (F_C) is defined to be:

$$F_C = 115\ F_H \pm 2\%$$

where F_H is the horizontal line frequency. The 90 bits of time code information are output serially, with bit 0 being first. For 625/50 systems, lines 19 and 332 are commonly used for the VITC. For 525/60 systems, lines 14 and 277 are commonly used. To protect the VITC against drop-outs, it may also be present two scan lines later, although any two nonconsecutive scan lines per field may be used.

Figure 8.51 illustrates the timing of the VITC data on the scan line. The data must be evenly spaced throughout the VITC word. The 10% to 90% rise and fall times of the VITC bit data should be 200 ±50 ns (525/60 and 625/50

Bit(s)	Function	Note	Bit(s)	Function	Note
0	sync bit	fixed “1”	42–45	units of minutes	
1	sync bit	fixed “0”	46–49	user group 5	
2–5	units of frames		50	sync bit	fixed “1”
6–9	user group 1		51	sync bit	fixed “0”
10	sync bit	fixed “1”	52–54	tens of minutes	
11	sync bit	fixed “0”	55	flag 4	note 4
12–13	tens of frames		56–59	user group 6	
14	flag 1	note 1	60	sync bit	fixed “1”
15	flag 2	note 2	61	sync bit	fixed”0”
16–19	user group 2		62–65	units of hours	
20	sync bit	fixed “1”	66–69	user group 7	
21	sync bit	fixed “0”	70	sync bit	fixed”1”
22–25	units of seconds		71	sync bit	fixed”0”
26–29	user group 3		72–73	tens of hours	
30	sync bit	fixed “1”	74	flag 5	note 5
31	sync bit	fixed “0”	75	flag 6	note 6
32–34	tens of seconds		76–79	user group 8	
35	flag 3	note 3	80	sync bit	fixed”1”
36–39	user group 4		81	sync bit	fixed”0”
40	sync bit	fixed “1”	82–89	CRC group	
41	sync bit	fixed “0”			

Notes

1. Drop frame flag. 525/60 and 1125/60 systems: “1” if frame numbers are being dropped, “0” if no frame dropping is done. 625/50 systems: “0”.
2. Color frame flag. 525/60 systems: “1” if even units of frame numbers identify fields 1 and 2 and odd units of field numbers identify fields 3 and 4. 625/50 systems: “1” if timecode is locked to the video signal in accordance with 8-field sequence and the video signal has the “preferred subcarrier-to-line-sync phase”. 1125/60 systems: “0”.
3. 525/60 systems: Field flag. “0” during fields 1 and 3, “1” during fields 2 and 4. 625/50 systems: Binary group flag 0. 1125/60 systems: Field flag. “0” during field 1, “1” during field 2.
4. 525/60 and 1125/60 systems: Binary group flag 0. 625/50 systems: Binary group flag 2.
5. Binary group flag 1.
6. 525/60 and 1125/60 systems: Binary group flag 2. 625/50 systems: Field flag. “0” during fields 1, 3, 5, and 7, “1” during fields 2, 4, 6, and 8.

Table 8.22. VITC Bit Assignments.

Frames (count 0–29 for 525/60 systems, 0–24 for 625/50 systems)	
units of frames (bits 2–5)	4-bit BCD (count 0–9); bit 2 is LSB
tens of frames (bits 12–13)	2-bit BCD (count 0–2); bit 12 is LSB

Seconds	
units of seconds (bits 22–25)	4-bit BCD (count 0–9); bit 22 is LSB
tens of seconds (bits 32–34)	3-bit BCD (count 0–5); bit 32 is LSB

Minutes	
units of minutes (bits 42–45)	4-bit BCD (count 0–9); bit 42 is LSB
tens of minutes (bits 52–54)	3-bit BCD (count 0–5); bit 52 is LSB

Hours	
units of hours (bits 62–65)	4-bit BCD (count 0–9); bit 62 is LSB
tens of hours (bits 72–73)	2-bit BCD (count 0–2); bit 72 is LSB

Table 8.23. VITC Bit Arrangement.

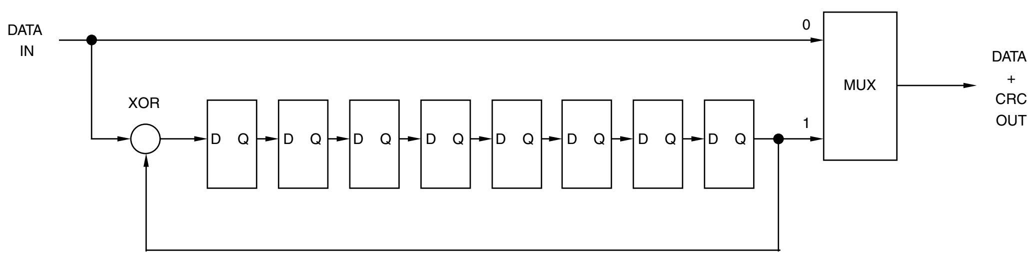

Figure 8.50. VITC CRC Generation.

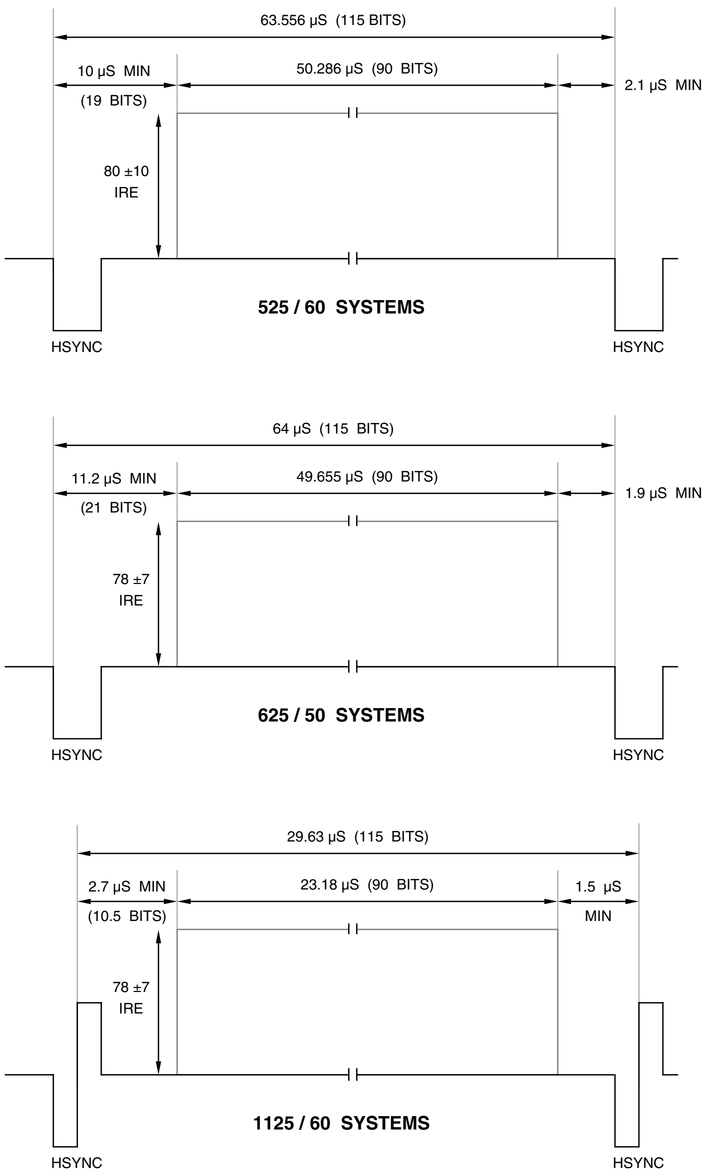

Figure 8.51. VITC Position and Timing.

User Bits Content	Timecode Referenced to External Clock	BGF2	BGF1	BGF0
user defined	no	0	0	0
8-bit character set[1]	no	0	0	1
user defined	yes	0	1	0
reserved	unassigned	0	1	1
date and time zone[3]	no	1	0	0
page / line[2]	no	1	0	1
date and time zone[3]	yes	1	1	0
page / line[2]	yes	1	1	1

[1]Conforming to ISO/IEC 646 or 2022.
[2]Described in SMPTE 262M.
[3]Described in SMPTE 309M. See Tables 8.25 through 8.27.

Table 8.24. LTC and VITC Binary Group Flag (BGF) Bit Definitions.

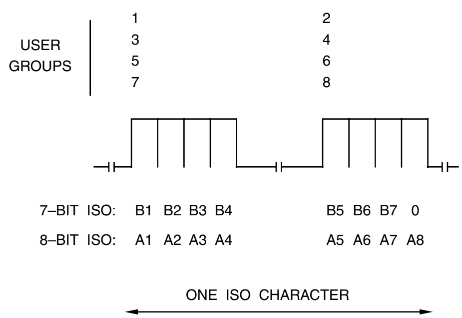

Figure 8.52. Use of Binary Groups to Describe ISO Characters Coded With 7 or 8 Bits.

User Group 8				User Group 7			
Bit 3	Bit 2	Bit 1	Bit 0	Bit 3	Bit 2	Bit 1	Bit 0
MJD Flag	0	time zone offset code 00_H–$3F_H$					

MJD flag: “0” = YYMMDD format, “1” = MJD format.

Table 8.25. Date and Time Zone Format Coding.

User Group	Assignment	Value	Description
1	D	0–9	day units
2	D	0–3	day units
3	M	0–9	month units
4	M	0, 1	month units
5	Y	0–9	year units
6	Y	0–9	year units

Table 8.26. YYMMDD Date Format.

systems) or 100 ±25 ns (1125/60 systems) before adding it to the video signal to avoid possible distortion of the VITC signal by downstream chrominance circuits. In most circumstances, the analog lowpass filters after the video D/A converters should suffice for the filtering.

User Bits

The binary group flag (BGF) bits shown in Table 8.24 specify the content of the 32 user bits. The 32 user bits are organized as eight groups of four bits each.

The user bits are intended for storage of data by users. The 32 bits may be assigned in any manner without restriction, if indicated as user-defined by the binary group flags.

If an 8-bit character set conforming to ISO/IEC 646 or 2022 is indicated by the binary group flags, the characters are to be inserted as shown in Figure 8.52. Note that some user bits will be decoded before the binary group flags are decoded; therefore, the decoder must store the early user data before any processing is done.

Code	Hours	Code	Hours	Code	Hours
00	UTC	16	UTC + 10.00	2C	UTC + 09.30
01	UTC – 01.00	17	UTC + 09.00	2D	UTC + 08.30
02	UTC – 02.00	18	UTC + 08.00	2E	UTC + 07.30
03	UTC – 03.00	19	UTC + 07.00	2F	UTC + 06.30
04	UTC – 04.00	1A	UTC – 06.30	30	TP–1
05	UTC – 05.00	1B	UTC – 07.30	31	TP–0
06	UTC – 06.00	1C	UTC – 08.30	32	UTC + 12.45
07	UTC – 07.00	1D	UTC – 09.30	33	reserved
08	UTC – 08.00	1E	UTC – 10.30	34	reserved
09	UTC – 09.00	1F	UTC – 11.30	35	reserved
0A	UTC – 00.30	20	UTC + 06.00	36	reserved
0B	UTC – 01.30	21	UTC + 05.00	37	reserved
0C	UTC – 02.30	22	UTC + 04.00	38	user defined
0D	UTC – 03.30	23	UTC + 03.00	39	unknown
0E	UTC – 04.30	24	UTC + 02.00	3A	UTC + 05.30
0F	UTC – 05.30	25	UTC + 01.00	3B	UTC + 04.30
10	UTC – 10.00	26	reserved	3C	UTC + 03.30
11	UTC – 11.00	27	reserved	3D	UTC + 02.30
12	UTC – 12.00	28	TP–3	3E	UTC + 01.30
13	UTC + 13.00	29	TP–2	3F	UTC + 00.30
14	UTC + 12.00	2A	UTC + 11.30		
15	UTC + 11.00	2B	UTC + 10.30		

Table 8.27. Time Zone Offset Codes.

When the user groups are used to transfer time zone and date information, user groups 7 and 8 specify the time zone and the format of the date in the remaining six user groups, as shown in Tables 8.25 and 8.27. The date may be either a six-digit YYMMDD format (Table 8.26) or a six-digit modified Julian date (MJD), as indicated by the MJD flag.

Closed Captioning

This section reviews closed captioning for the hearing impaired in the United States. Closed captioning and text are transmitted during the blanked active line-time portion of lines 21 and 284.

Extended data services (XDS) also may be transmitted during the blanked active line-time portion of line 284. XDS may indicate the program name, time into the show, time remaining to the end, and so on.

Note that due to editing before transmission, it may be possible that the caption information is moved down a scan line or two. Therefore, caption decoders should monitor more than just lines 21 and 284 for caption information.

Waveform

The data format for both lines consists of a clock run-in signal, a start bit, and two 7-bit plus parity words of ASCII data (per X3.4-1967). For YPbPr and S-video interfaces, captioning is present on the Y signal. For analog RGB interfaces, captioning is present on all three signals.

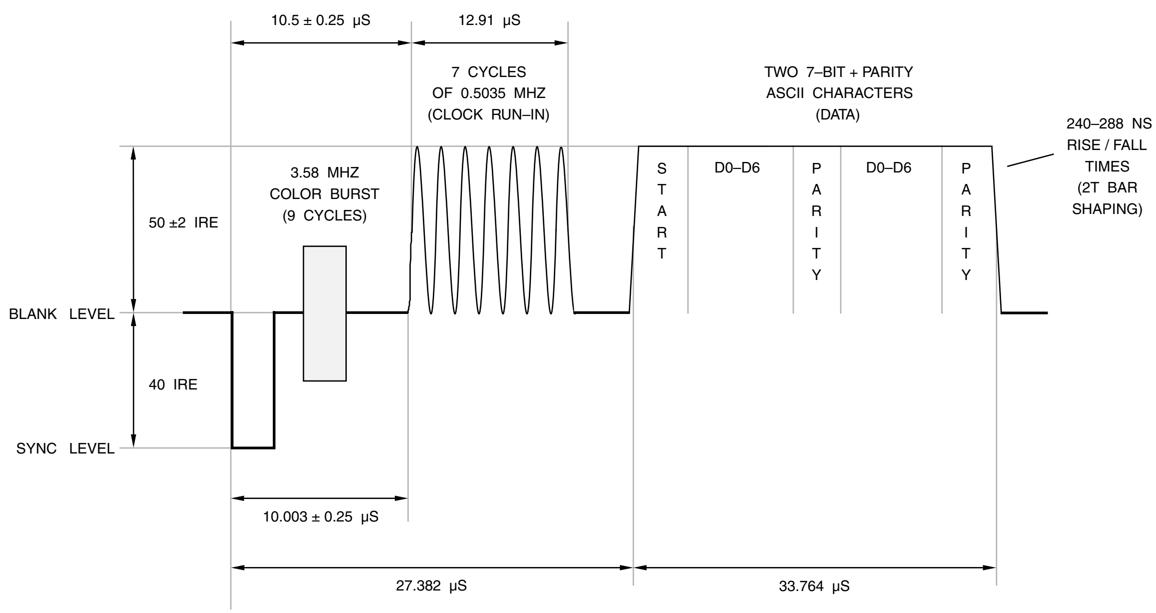

Figure 8.53. NTSC Line 21 and Line 284 Closed Captioning Timing.

Figure 8.53 illustrates the waveform and timing for transmitting the closed captioning and XDS information and conforms to the Television Synchronizing Waveform for Color Transmission in Subpart E, Part 73 of the FCC Rules and Regulations and EIA-608. The clock run-in is a 7-cycle sinusoidal burst that is frequency-locked and phase-locked to the caption data and is used to provide synchronization for the decoder. The nominal data rate is 32× F_H. However, decoders should not rely on this timing relationship due to possible horizontal timing variations introduced by video processing circuitry and VCRs. After the clock run-in signal, the blanking level is maintained for a two data bit duration, followed by a "1" start bit. The start bit is followed by 16 bits of data, composed of two 7-bit + odd parity ASCII characters. Caption data is transmitted using a non–return-to-zero (NRZ) code; a "1" corresponds to the 50 ± 2 IRE level and a "0" corresponds to the blanking level (0–2 IRE). The negative-going crossings of the clock are coherent with the data bit transitions.

Typical decoders specify the time between the 50% points of sync and clock run-in to be 10.5 ±0.5 µs, with a ±3% tolerance on F_H, 50 ±12 IRE for a "1" bit, and –2 to +12 IRE for a "0" bit. Decoders must also handle bit rise/fall times of 240–480 ns.

NUL characters (00_H) should be sent when no display or control characters are being transmitted. This, in combination with the clock run-in, enables the decoder to determine whether captioning or text transmission is being implemented.

If using only line 21, the clock run-in and data do not need to be present on line 284. However, if using only line 284, the clock run-in and data should be present on both lines 21 and 284; data for line 21 would consist of NUL characters.

At the decoder, as shown in Figure 8.54, the display area of a 525-line 4:3 interlaced display is typically 15 rows high and 34 columns wide. The vertical display area begins on lines 43 and 306 and ends on lines 237 and 500. The horizontal display area begins 13 µs and ends 58 µs, after the leading edge of horizontal sync.

In text mode, all rows are used to display text; each row contains a maximum of 32 characters, with at least a one-column wide space on the left and right of the text. The only transparent area is around the outside of the text area.

In caption mode, text usually appears only on rows 1–4 or 12–15; the remaining rows are usually transparent. Each row contains a maximum of 32 characters, with at least a one-column wide space on the left and right of the text.

Some caption decoders support up to 48 columns per row, and up to 16 rows, allowing some customization for the display of caption data.

Basic Services

There are two types of display formats: text and captioning. In understanding the operation of the decoder, it is easier to visualize an invisible cursor that marks the position where the next character will be displayed. Note that if you are designing a decoder, you should obtain the latest FCC Rules and Regulations and EIA-608 to ensure correct operation, as this section is only a summary.

Text Mode

Text mode uses 7–15 rows of the display and is enabled upon receipt of the Resume Text Display or Text Restart code. When text mode has been selected, and the text memory is empty, the cursor starts at the top-most row, character 1 position. Once all the rows of text are displayed, scrolling is enabled.

With each carriage return received, the top-most row of text is erased, the text is rolled up one row (over a maximum time of 0.433 seconds), the bottom row is erased, and the cursor is moved to the bottom row, character 1 position. If new text is received while scrolling, it is seen scrolling up from the bottom of the display area. If a carriage return is received while scrolling, the rows are immediately moved up one row to their final position.

Once the cursor moves to the character 32 position on any row, any text received before a carriage return, preamble address code, or backspace will be displayed at the character 32 position, replacing any previous character at that position. The Text Restart command erases all characters on the display and moves the cursor to the top row, character 1 position.

Captioning Mode

Captioning has several modes available, including roll-up, pop-on, and paint-on.

Roll-up captioning is enabled by receiving one of the miscellaneous control codes to select the number of rows displayed. "Roll-up captions, 2 rows" enables rows 14 and 15; "roll-up captions, 3 rows" enables rows 13–15, "roll-up captions, 4 rows" enables rows 12–15. Regardless of the number of rows enabled, the cursor remains on row 15. Once row 15 is full, the rows are scrolled up one row (at the rate of one dot per frame), and the cursor is moved back to row 15, character 1.

Pop-on captioning may use rows 1–4 or 12–15, and is initiated by the Resume Caption Loading command. The display memory is essentially double-buffered. While memory buffer 1 is displayed, memory buffer 2 is being loaded with caption data. At the receipt of a

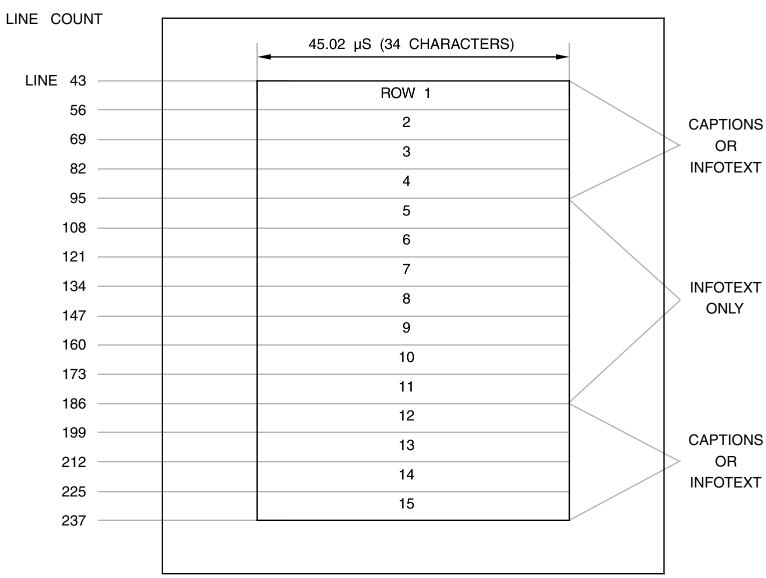

Figure 8.54. Closed Captioning Display Format.

End of Caption code, memory buffer 2 is displayed while memory buffer 1 is being loaded with new caption data.

Paint-on captioning, enabled by the Resume Direct Captioning command, is similar to Pop-on captioning, but no double-buffering is used; caption data is loaded directly into display memory.

Three types of control codes (preamble address codes, midrow codes, and miscellaneous control codes) are used to specify the format, location, and attributes of the characters. Each control code consists of two bytes, transmitted together on line 21 or line 284. On line 21, they are normally transmitted twice in succession to help ensure correct reception. They are not transmitted twice on line 284 to minimize bandwidth used for captioning.

The first byte is a nondisplay control byte with a range of 10_H to $1F_H$; the second byte is a display control byte in the range of 20_H to $7F_H$. At the beginning of each row, a control code is sent to initialize the row. Caption roll-up and text modes allow either a preamble address code or midrow control code at the start of a row; the other caption modes use a preamble address code to initialize a row. The preamble address codes are illustrated in Figure 8.55 and Table 8.28.

The midrow codes are typically used within a row to change the color, italics, underline, and flashing attributes and should occur only between words. Color, italics, and underline are controlled by the preamble address and midrow codes; flash on is controlled by a miscellaneous control code. An attribute remains in effect until another control code is received or the end of row is reached. Each row starts with a control code to set the color and underline attributes (white nonunderlined is the default if no control code is received before the first character on an empty row). The color attribute can be changed only by the midrow code of another color; the italics attribute does not change the color attribute. However, a color attribute turns off the italics attribute. The flash on command does not alter the status of the color, italics, or underline

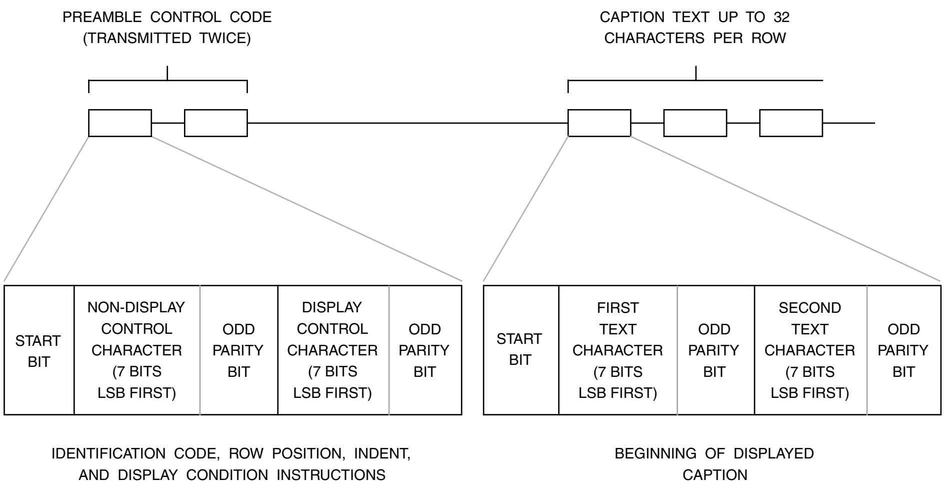

Figure 8.55. Closed Captioning Preamble Address Code Format.

<table>
<tr><th colspan="7">Non-display Control Byte</th><th colspan="7">Display Control Byte</th><th rowspan="2">Row Position</th></tr>
<tr><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th></tr>
<tr><td rowspan="15">0</td><td rowspan="15">0</td><td rowspan="15">1</td><td rowspan="15">CH</td><td rowspan="2">0</td><td rowspan="2">0</td><td rowspan="2">1</td><td>1</td><td>0</td><td rowspan="15">A</td><td rowspan="15">B</td><td rowspan="15">C</td><td rowspan="15">D</td><td rowspan="15">U</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>2</td></tr>
<tr><td rowspan="2">0</td><td rowspan="2">1</td><td rowspan="2">0</td><td>1</td><td>0</td><td>3</td></tr>
<tr><td>1</td><td>1</td><td>4</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">0</td><td rowspan="2">1</td><td>1</td><td>0</td><td>5</td></tr>
<tr><td>1</td><td>1</td><td>6</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">0</td><td>1</td><td>0</td><td>7</td></tr>
<tr><td>1</td><td>1</td><td>8</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">1</td><td>1</td><td>0</td><td>9</td></tr>
<tr><td>1</td><td>1</td><td>10</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>11</td></tr>
<tr><td rowspan="2">0</td><td rowspan="2">1</td><td rowspan="2">1</td><td>1</td><td>0</td><td>12</td></tr>
<tr><td>1</td><td>1</td><td>13</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">0</td><td rowspan="2">0</td><td>1</td><td>0</td><td>14</td></tr>
<tr><td>1</td><td>1</td><td>15</td></tr>
</table>

U: “0” = no underline, “1” = underline
CH: “0” = data channel 1, “1” = data channel 2

A	B	C	D	Attribute
0	0	0	0	white
0	0	0	1	green
0	0	1	0	blue
0	0	1	1	cyan
0	1	0	0	red
0	1	0	1	yellow
0	1	1	0	magenta
0	1	1	1	italics
1	0	0	0	indent 0, white
1	0	0	1	indent 4, white
1	0	1	0	indent 8, white
1	0	1	1	indent 12, white
1	1	0	0	indent 16, white
1	1	0	1	indent 20, white
1	1	1	0	indent 24, white
1	1	1	1	indent 28, white

Table 8.28. Closed Captioning Preamble Address Codes. In text mode, the indent codes may be used to perform indentation; in this instance, the row information is ignored.

attributes. However, a color or italics midrow control code turns off the flash. Note that the underline color is the same color as the character being underlined; the underline resides on dot row 11 and covers the entire width of the character column.

Table 8.29, Figure 8.56, and Table 8.30 illustrate the midrow and miscellaneous control code operation. For example, if it were the end of a caption, the control code could be End of Caption (transmitted twice). It could be followed by a preamble address code (transmitted twice) to start another line of captioning.

Characters are displayed using a dot matrix format. Each character cell is typically 16 samples wide and 26 samples high (16×26), as shown in Figure 8.57. Dot rows 2–19 are usually used for actual character outlines. Dot rows 0, 1, 20, 21, 24, and 25 are usually blanked to provide vertical spacing between characters, and underlining is typically done on dot rows 22 and 23. Dot columns 0, 1, 14 and 15 are blanked to provide horizontal spacing between characters, except on dot rows 22 and 23 when the underline is displayed. This results in 12×18 characters stored in character ROM. Table 8.31 shows the basic character set.

Some caption decoders support multiple character sizes within the 16×26 region, including 13×16, 13×24, 12×20, and 12×26. Not all combinations generate a sensible result due to the limited display area available.

Optional Captioning Features

Three sets of optional features are available for advanced captioning decoders.

Optional Attributes

Additional color choices are available for advanced captioning decoders, as shown in Table 8.32.

Non-display Control Byte							Display Control Byte							
D6	D5	D4	D3	D2	D1	D0	D6	D5	D4	D3	D2	D1	D0	Attribute
0	0	1	CH	0	0	1	0	1	0	0	0	0	U	white
										0	0	1		green
										0	1	0		blue
										0	1	1		cyan
										1	0	0		red
										1	0	1		yellow
										1	1	0		magenta
										1	1	1		italics

U: “0” = no underline, “1” = underline CH: “0” = data channel 1, “1” = data channel 2
Note: Italics is implemented as a two-dot slant to the right over the vertical range of the character. Some decoders implement a one dot slant for every four scan lines. Underline resides on dot rows 22 and 23, and covers the entire column width.

Table 8.29. Closed Captioning Midrow Codes.

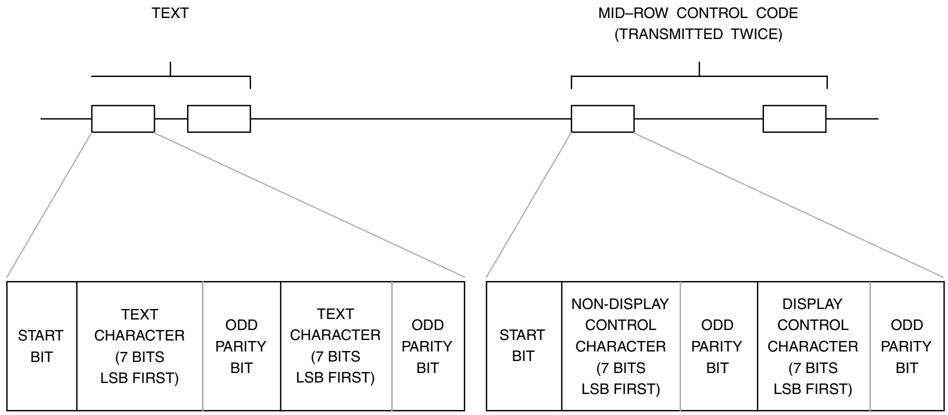

Figure 8.56. Closed Captioning Midrow Code Format. Miscellaneous control codes may also be transmitted in place of the midrow control code.

Non-display Control Byte							Display Control Byte							Command
D6	D5	D4	D3	D2	D1	D0	D6	D5	D4	D3	D2	D1	D0	
0	0	1	CH	1	0	F	0	1	0	0	0	0	0	resume caption loading
										0	0	0	1	backspace
										0	0	1	0	reserved
										0	0	1	1	reserved
										0	1	0	0	delete to end of row
										0	1	0	1	roll-up captions, 2 rows
										0	1	1	0	roll-up captions, 3 rows
										0	1	1	1	roll-up captions, 4 rows
										1	0	0	0	flash on
										1	0	0	1	resume direct captioning
										1	0	1	0	text restart
										1	0	1	1	resume text display
										1	1	0	0	erase displayed memory
										1	1	0	1	carriage return
										1	1	1	0	erase nondisplayed memory
										1	1	1	1	end of caption (flip memories)
0	0	1	CH	1	1	1	0	1	0	0	0	0	1	tab offset (1 column)
										0	0	1	0	tab offset (2 columns)
										0	0	1	1	tab offset (3 columns)

CH: “0” = data channel 1, “1” = data channel 2 F: “0” = line 21, “1” = line 284
Note: “flash on” blanks associated characters for 0.25 seconds once per second.

Table 8.30. Closed Captioning Miscellaneous Control Codes.

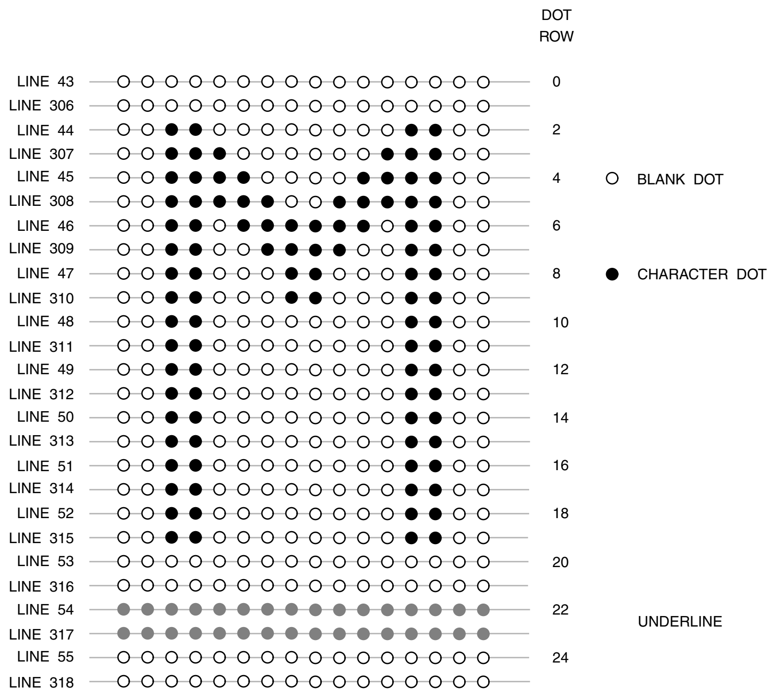

Figure 8.57. Typical 16×26 Closed Captioning Character Cell Format for Row 1.

<table>
<tr><th colspan="7">Nondisplay Control Byte</th><th colspan="7">Display Control Byte</th><th rowspan="2">Special Characters</th></tr>
<tr><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th></tr>
<tr><td rowspan="16">0</td><td rowspan="16">0</td><td rowspan="16">1</td><td rowspan="16">CH</td><td rowspan="16">0</td><td rowspan="16">0</td><td rowspan="16">1</td><td rowspan="16">0</td><td rowspan="16">1</td><td rowspan="16">1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>®</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>°</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>1/2</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>1</td><td>¿</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>™</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>¢</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>£</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>1</td><td>music note</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td><td>à</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>transparent space</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>è</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>1</td><td>â</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>ê</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>î</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td><td>ô</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>û</td></tr>
</table>

D6 D5 D4 D3	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
D2 D1 D0												
000		(	0	8	@	H	P	X	ú	h	p	x
001	!	)	1	9	A	I	Q	Y	a	i	q	y
010	“	á	2	:	B	J	R	Z	b	j	r	z
011	#	+	3	;	C	K	S	[	c	k	s	ç
100	$	,	4	<	D	L	T	é	d	l	t	÷
101	%	–	5	=	E	M	U	]	e	m	u	Ñ
110	&	.	6	>	F	N	V	í	f	n	v	ñ
111	‘	/	7	?	G	O	W	ó	g	o	w	■

Table 8.31. Closed Captioning Basic Character Set.

<table>
<tr><th colspan="7">Non-display Control Byte</th><th colspan="7">Display Control Byte</th><th></th></tr>
<tr><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>Background Attribute</th></tr>
<tr><td rowspan="8">0</td><td rowspan="8">0</td><td rowspan="8">1</td><td rowspan="8">CH</td><td rowspan="8">0</td><td rowspan="8">0</td><td rowspan="8">0</td><td rowspan="8">0</td><td rowspan="8">1</td><td rowspan="8">0</td><td>0</td><td>0</td><td>0</td><td rowspan="8">T</td><td>white</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>green</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>blue</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>cyan</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>red</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>yellow</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>magenta</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>black</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>CH</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>transparent</td></tr>
<tr><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>Foreground Attribute</th></tr>
<tr><td rowspan="2">0</td><td rowspan="2">0</td><td rowspan="2">1</td><td rowspan="2">CH</td><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">0</td><td rowspan="2">1</td><td rowspan="2">0</td><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">1</td><td>0</td><td>black</td></tr>
<tr><td>1</td><td>black underline</td></tr>
</table>

T: "0" = opaque, "1" = semi-transparent   CH: "0" = data channel 1, "1" = data channel 2
Underline resides on dot rows 22 and 23, and covers the entire column width.

Table 8.32. Closed Captioning Optional Attribute Codes.

If a decoder doesn't support semitransparent colors, the opaque colors may be used instead. If a specific background color isn't supported by a decoder, it should default to the black background color. However, if the black foreground color is supported in a decoder, all the background colors should be implemented.

A background attribute appears as a standard space on the display, and the attribute remains in effect until the end of the row or until another background attribute is received.

The foreground attributes provide an eighth color (black) as a character color. As with midrow codes, a foreground attribute code turns off italics and blinking, and the least significant bit controls underlining.

Background and foreground attribute codes have an automatic backspace for backward compatibility with current decoders. Thus, an attribute must be preceded by a standard space character. Standard decoders display the space and ignore the attribute. Extended decoders display the space, and on receiving the attribute, backspace, then display a space that changes the color and opacity. Thus, text formatting remains the same regardless of the type of decoder.

Optional Closed Group Extensions

To support custom features and characters not defined by the standards, the EIA/CEG maintains a set of code assignments requested by various caption providers and decoder manufacturers. These code assignments (currently used to select various character sets) are not compatible with caption decoders in the United States and videos using them should not be distributed in the U. S. market.

Closed group extensions require two bytes. Table 8.33 lists the currently assigned closed group extensions to support captioning in the Asian languages.

Optional Extended Characters

An additional 64 accented characters (eight character sets of eight characters each) may be supported by decoders, permitting the display of other languages such as Spanish, French, Portuguese, German, Danish, Italian, Finnish, and Swedish. If supported, these accented characters are available in all caption and text modes.

Each of the extended characters incorporates an automatic backspace for backward compatibility with current decoders. Thus, an extended character must be preceded by the standard ASCII version of the character. Standard decoders display the ASCII character and ignore the accented character. Extended decoders display the ASCII character, and on receiving the accented character, backspace, then display the accented character. Thus, text formatting remains the same regardless of the type of decoder.

Extended characters require two bytes. The first byte is 12_H or 13_H for data channel one ($1A_H$ or $1B_H$ for data channel two), followed by a value of 20_H–$3F_H$.

<table>
<tr><th colspan="7">Non-display Control Byte</th><th colspan="7">Display Control Byte</th><th></th></tr>
<tr><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>Background Attribute</th></tr>
<tr><td rowspan="7">0</td><td rowspan="7">0</td><td rowspan="7">1</td><td rowspan="7">CH</td><td rowspan="7">1</td><td rowspan="7">1</td><td rowspan="7">1</td><td rowspan="7">0</td><td rowspan="7">1</td><td rowspan="7">0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>standard character set (normal size)</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>standard character set (double size)</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>first private character set</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>1</td><td>second private character set</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td><td>People’s Republic of China character set (GB 2312)</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>Korean Standard character set (KSC 5601-1987)</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>first registered character set</td></tr>
</table>

CH: “0” = data channel 1, “1” = data channel 2

Table 8.33. Closed Captioning Optional Closed Group Extensions.

Extended Data Services

Line 284 may contain extended data service information, interleaved with the caption and text information, as bandwidth is available. In this case, control codes are not transmitted twice, as they may be for the caption and text services.

Information is transmitted as packets and operates as a separate unique data channel. Data for each packet may or may not be contiguous and may be separated into subpackets that can be inserted anywhere space is available in the line 284 information stream.

There are four types of extended data characters:

Control: Control characters are used as a mode switch to enable the extended data mode. They are the first character of two and have a value of 01_F to $0F_H$.

Type: Type characters follow the control character (thus, they are the second character of two) and identify the packet type. They have a value of 01_F to $0F_H$.

Checksum: Checksum characters always follow the "end of packet" control character. Thus, they are the second character of two and have a value of 00_F to $7F_H$.

Informational: These characters may be ASCII or non-ASCII data. They are transmitted in pairs up to and including 32 characters. A NUL character (00_H) is used to ensure pairs of characters are always sent.

Control Characters

Table 8.34 lists the control codes. The *current class* describes a program currently being transmitted. The *future class* describes a program to be transmitted later. It contains the same information and formats as the current class. The *channel class* describes non-program-specific information about the channel. The *miscellaneous class* describes miscellaneous information. The *public class* transmits data or messages of a public service nature. The *undefined class* is used in proprietary systems for whatever that system wishes.

Type Characters (Current, Future Class)

Program Identification Number (01_H)

This packet uses four characters to specify the program start time and date relative to Coordinated Universal Time (UTC). The format is shown in Table 8.35.

Minutes have a range of 0–59. Hours have a range of 0–23. Dates have a range of 1–31. Months have a range of 1–12. "T" indicates if a program is routinely tape delayed for the Mountain and Pacific time zones. The "D," "L," and "Z" bits are ignored by the decoder.

Program Length (02_H)

This packet has 2, 4, or 6 characters and indicates the scheduled length of the program and elapsed time for the program. The format is shown in Table 8.36.

Minutes and seconds have a range of 0–59. Hours have a range of 0–63.

Program Name (03_H)

This packet contains 2–32 ASCII characters that specify the title of the program.

Program Type (04_H)

This packet contains 2–32 characters that specify the type of program. Each character is assigned a keyword, as shown in Table 8.37.

Control Code	Function	Class
01_H 02_H	start continue	current
03_H 04_H	start continue	future
05_H 06_H	start continue	channel
07_H 08_H	start continue	miscellaneous
09_H $0A_H$	start continue	public service
$0B_H$ $0C_H$	start continue	reserved
$0D_H$ $0E_H$	start continue	undefined
$0F_H$	end	all

Table 8.34. EIA-608 Control Codes.

D6	D5	D4	D3	D2	D1	D0	Character
1	m5	m4	m3	m2	m1	m0	minute
1	D	h4	h3	h2	h1	h0	hour
1	L	d4	d3	d2	d1	d0	date
1	Z	T	m3	m2	m1	m0	month

Table 8.35. EIA-608 Program Identification Number Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	m5	m4	m3	m2	m1	m0	length, minute
1	h5	h4	h3	h2	h1	h0	length, hour
1	m5	m4	m3	m2	m1	m0	elapsed time, minute
1	h5	h4	h3	h2	h1	h0	elapsed time, hour
1	s5	s4	s3	s2	s1	s0	elapsed time, second
0	0	0	0	0	0	0	null character

Table 8.36. EIA-608 Program Length Format.

Code (hex)	Keyword	Code (hex)	Keyword	Code (hex)	Keyword
20	education	30	business	40	fantasy
21	entertainment	31	classical	41	farm
22	movie	32	college	42	fashion
23	news	33	combat	43	fiction
24	religious	34	comedy	44	food
25	sports	35	commentary	45	football
26	other	36	concert	46	foreign
27	action	37	consumer	47	fund raiser
28	advertisement	38	contemporary	48	game/quiz
29	animated	39	crime	49	garden
2A	anthology	3A	dance	4A	golf
2B	automobile	3B	documentary	4B	government
2C	awards	3C	drama	4C	health
2D	baseball	3D	elementary	4D	high school
2E	basketball	3E	erotica	4E	history
2F	bulletin	3F	exercise	4F	hobby
50	hockey	60	music	70	romance
51	home	61	mystery	71	science
52	horror	62	national	72	series
53	information	63	nature	73	service
54	instruction	64	police	74	shopping
55	international	65	politics	75	soap opera
56	interview	66	premiere	76	special
57	language	67	prerecorded	77	suspense
58	legal	68	product	78	talk
59	live	69	professional	79	technical
5A	local	6A	public	7A	tennis
5B	math	6B	racing	7B	travel
5C	medical	6C	reading	7C	variety
5D	meeting	6D	repair	7D	video
5E	military	6E	repeat	7E	weather
5F	miniseries	6F	review	7F	western

Table 8.37. EIA-608 Program Types.

Program Rating (05_H)
This packet, commonly referred to regarding the "v" chip, contains the information shown in Table 8.38 to indicate the program rating.

V indicates if violence is present. S indicates if sexual situations are present. L indicates if adult language is present. D indicates if sexually suggestive dialog is present.

Program Audio Services (06_H)
This packet contains two characters as shown in Table 8.39 to indicate the program audio services available.

Program Caption Services (07_H)
This packet contains 2–8 characters as shown in Table 8.40 to indicate the program caption services available. L2–L0 are coded as shown in Table 8.39.

Copy Generation Management System (08_H)
This CGMS-A (Copy Generation Management System—Analog) packet contains 2 characters as shown in Table 8.41.

In the case where either B3 or B4 is a "0", there is no Analog Protection System (B1 and B2 are "0"). B0 is the analog source bit.

Program Aspect Ratio (09_H)
This packet contains two or four characters as shown in Table 8.42 to indicate the aspect ratio of the program.

S0–S5 specify the first line containing active picture information. The value of S0–S5 is calculated by subtracting 22 from the first line containing active picture information. The valid range for the first line containing active picture information is 22–85.

E0–E5 specify the last line containing active picture information. The last line containing active video is calculated by subtracting the value of E0–E5 from 262. The valid range for the last line containing active picture information is 199–262.

When this packet contains all zeros for both characters, or the packet is not detected, an aspect ratio of 4:3 is assumed.

The Q0 bit specifies whether the video is squeezed ("1") or normal ("0"). Squeezed video (anamorphic) is the result of compressing a 16:9 aspect ratio picture into a 4:3 aspect ratio picture without cropping side panels.

The aspect ratio is calculated as follows:

$$320 / (E - S) : 1$$

Program Description (10_H–17_H)
This packet contains 1–8 packet rows, with each packet row containing 0–32 ASCII characters. A packet row corresponds to a line of text on the display.

Each packet is used in numerical sequence, and if a packet contains no ASCII characters, a blank line will be displayed.

Type Characters (Channel Class)

Network Name (01_H)
This packet uses 2–32 ASCII characters to specify the network name.

Network Call Letters (02_H)
This packet uses four or six ASCII characters to specify the call letters of the channel. When six characters are used, they reflect the over-the-air channel number (2–69) assigned by the FCC. Single-digit channel numbers are preceded by a zero or a null character.

Channel Tape Delay (03_H)
This packet uses two characters to specify the number of hours and minutes the local station typically delays network programs. The format of this packet is shown in Table 8.43.

D6	D5	D4	D3	D2	D1	D0	Character
1	D / a2	a1	a0	r2	r1	r0	MPAA movie rating
1	V	S	L / a3	g2	g1	g0	TV rating

r2–r0: Movie Rating

000	not applicable
001	G
010	PG
011	PG-13
100	R
101	NC-17
110	X
111	not rated

g2–g0: USA TV Rating

000	not rated
001	TV-Y
010	TV-Y7
011	TV-G
100	TV-PG
101	TV-14
110	TV-MA
111	not rated

a3–a0:

xxx0	MPAA movie rating
LD01	USA TV rating
0011	Canadian English TV rating
0111	Canadian French TV rating
1011	reserved
1111	reserved

g2–g0: Canadian English TV Rating

000	exempt
001	C
010	C8 +
011	G
100	PG
101	14 +
110	18 +
111	reserved

g2–g0: Canadian French TV Rating

000	exempt
001	G
010	8 ans +
011	13 ans +
100	16 ans +
101	18 ans +
110	reserved
111	reserved

Table 8.38. EIA-608 and EIA-744 Program Rating Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	L2	L1	L0	T2	T1	T0	main audio program
1	L2	L1	L0	S2	S1	S0	second audio program (SAP)

L2–L0:

000	unknown
001	english
010	spanish
011	french
100	german
101	italian
110	other
111	none

T2–T0:

000	unknown
001	mono
010	simulated stereo
011	true stereo
100	stereo surround
101	data service
110	other
111	none

S2–S0:

000	unknown
001	mono
010	video descriptions
011	non-program audio
100	special effects
101	data service
110	other
111	none

Table 8.39. EIA-608 Program Audio Services Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	L2	L1	L0	F	C	T	service code

FCT:		
	000	line 21, data channel 1 captioning
	001	line 21, data channel 1 text
	010	line 21, data channel 2 captioning
	011	line 21, data channel 2 text
	100	line 284, data channel 1 captioning
	101	line 284, data channel 1 text
	110	line 284, data channel 2 captioning
	111	line 284, data channel 2 text

Table 8.40. EIA-608 Program Caption Services Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	0	B4	B3	B2	B1	B0	CGMS
0	0	0	0	0	0	0	null

B4–B3 CGMS–A Services:

00	copying permitted without restriction
01	condition not to be used
10	one generation copy allowed
11	no copying permitted

B2–B1 Analog Protection Services:

00	no pseudo-sync pulse
01	pseudo-sync pulse on; color striping off
10	pseudo-sync pulse on; 2-line color striping on
11	pseudo-sync pulse on; 4-line color striping on

Table 8.41. EIA-608 and EIA IS–702 CGMS–A Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	S5	S4	S3	S2	S1	S0	start
1	E5	E4	E3	E2	E1	E0	end
1	–	–	–	–	–	Q0	other
0	0	0	0	0	0	0	null

Table 8.42. EIA-608 Program Aspect Ratio Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	m5	m4	m3	m2	m1	m0	minute
1	–	h4	h3	h2	h1	h0	hour

Table 8.43. EIA-608 Channel Tape Delay Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	m5	m4	m3	m2	m1	m0	minute
1	D	h4	h3	h2	h1	h0	hour
1	L	d4	d3	d2	d1	d0	date
1	Z	T	m3	m2	m1	m0	month
1	–	–	–	D2	D1	D0	day
1	Y5	Y4	Y3	Y2	Y1	Y0	year

Table 8.44. EIA-608 Time of Day Format.

Minutes have a range of 0–59. Hours have a range of 0–23. This delay applies to all programs on the channel that have the "T" bit set in their Program ID packet (Table 8.35).

Type Characters (Miscellaneous Class)

Time of Day (01_H)
This packet uses six characters to specify the current time of day, month, and date relative to Coordinated Universal Time (UTC). The format is shown in Table 8.44.

Minutes have a range of 0–59. Hours have a range of 0–23. Dates have a range of 1–31. Months have a range of 1–12. Days have a range of 1 (Sunday) to 7 (Saturday). Years have a range of 0–63 (added to 1990).

"T" indicates if a program is routinely tape delayed for the Mountain and Pacific time zones. "D" indicates whether daylight savings time currently is being observed. "L" indicates whether the local day is February 28th or 29th when it is March 1st UTC. "Z" indicates whether the seconds should be set to zero (to allow calibration without having to transmit the full 6 bits of seconds data).

Impulse Capture ID (02_H)
This packet carries the program start time and length, and can be used to tell a VCR to record this program. The format is shown in Table 8.45.

Start and length minutes have a range of 0–59. Start hours have a range of 0–23; length hours have a range of 0–63. Dates have a range of 1–31. Months have a range of 1–12. "T" indicates if a program is routinely tape delayed for the Mountain and Pacific time zones. The "D," "L." and "Z" bits are ignored by the decoder.

Supplemental Data Location (03_H)
This packet uses 2–32 characters to specify other lines where additional VBI data may be found. Table 8.46 shows the format.

"F" indicates field one ("0") or field two ("1"). N may have a value of 7–31, and indicates a specific line number.

Local Time Zone (04_H)
This packet uses two characters to specify the viewer time zone and whether the locality observes daylight savings time. The format is shown in Table 8.47.

Hours have a range of 0–23. This is the nominal time zone offset, in hours, relative to UTC. "D" is a "1" when the area is using daylight savings time.

Out-of-Band Channel Number (40_H)
This packet uses two characters to specify a channel number to which all subsequent out-of-band packets refer. This is the CATV channel number to which any following out-of-band packets belong to. The format is shown in Table 8.48.

Closed Captioning for Europe

Closed captioning may be also used with PAL videotapes and laserdiscs in Europe, present during the blanked active line-time portion of lines 22 and 335.

The data format, amplitudes, and rise and fall times are the same as for closed captioning in the United States. The timing, as shown in Figure 8.58, is slightly different due to the PAL horizontal timing. Older closed captioning decoders designed for use only with NTSC systems may not work due to these timing differences.

D6	D5	D4	D3	D2	D1	D0	Character
1	m5	m4	m3	m2	m1	m0	start, minute
1	D	h4	h3	h2	h1	h0	start, hour
1	L	d4	d3	d2	d1	d0	start, date
1	Z	T	m3	m2	m1	m0	start, month
1	m5	m4	m3	m2	m1	m0	length, minute
1	h5	h4	h3	h2	h1	h0	length, hour

Table 8.45. EIA-608 Impulse Capture ID Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	F	N4	N3	N2	N1	N0	location

Table 8.46. EIA-608 Supplemental Data Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	D	h4	h3	h2	h1	h0	hour
0	0	0	0	0	0	0	null

Table 8.47. EIA-608 Local Time Zone Format.

D6	D5	D4	D3	D2	D1	D0	Character
1	c5	c4	c3	c2	c1	c0	channel low
1	c11	c10	c9	c8	c7	c6	channel high

Table 8.48. EIA-608 Out-of-Band Channel Number Format.

Widescreen Signalling

To facilitate the handling of various aspect ratios of program material received by TVs, a widescreen signalling (WSS) system has been developed. This standard allows a WSS-enhanced 16:9 TV to display programs in their correct aspect ratio.

625-Line PAL and SECAM Systems

625-line PAL and SECAM systems are based on ITU-R BT.1119 and ETSI EN 300294. For YPbPr and S-video interfaces, WSS is present on the Y signal. For analog RGB interfaces, WSS is present on all three signals.

The Analog Copy Generation Management System (CGMS-A) is also supported by the WSS signal.

Data Timing

The first part of line 23 is used to transmit the WSS information, as shown in Figure 8.59.

The clock frequency is 5 MHz (±100 Hz). The signal waveform should be a sine-squared pulse, with a half-amplitude duration of 200 ±10 ns. The signal amplitude is 500 mV ±5%.

The NRZ data bits are processed by a bi-phase code modulator, such that one data period equals 6 elements at 5 MHz.

Data Content

The WSS consists of a run-in code, a start code, and 14 bits of data, as shown in Table 8.49.

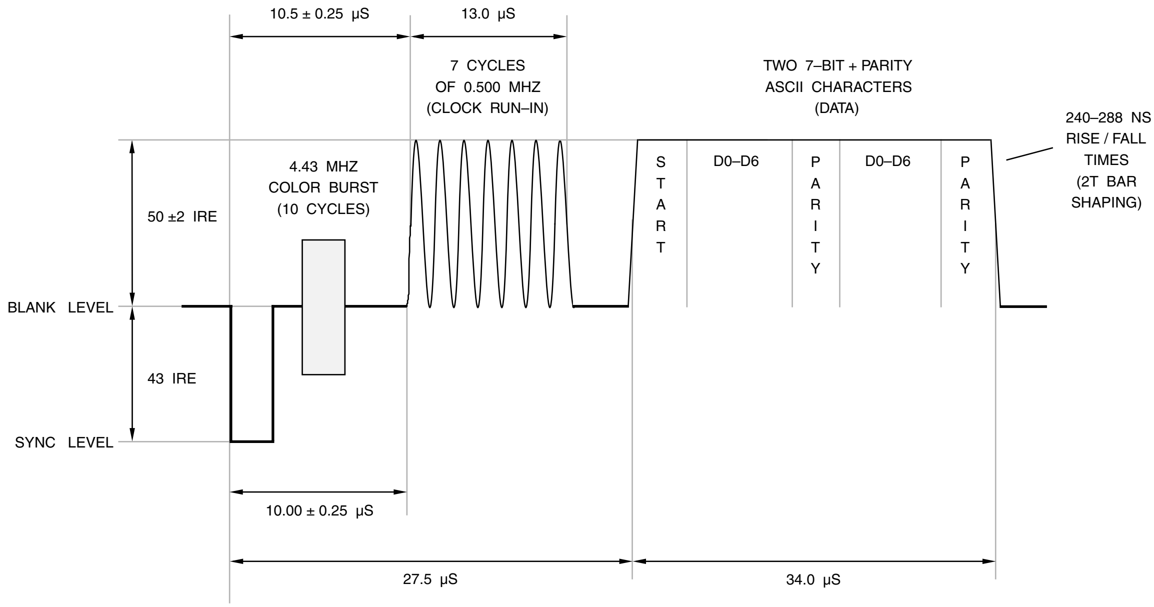

Figure 8.58. (B, D, G, H, I) PAL Line 22 and Line 335 Closed Captioning Timing.

Run-In
The run-in consists of 29 elements at 5 MHz of a specific sequence, shown in Table 8.49.

Start Code
The start code consists of 24 elements at 5 MHz of a specific sequence, shown in Table 8.49.

Group A Data
The group A data consists of 4 data bits that specify the aspect ratio. Each data bit generates 6 elements at 5 MHz. Data bit b0 is the LSB.

Table 8.50 lists the data bit assignments and usage. The number of active lines listed in Table 8.50 are for the exact aspect ratio (a = 1.33, 1.56, or 1.78).

The aspect ratio label indicates a range of possible aspect ratios (a) and number of active lines:

4:3	$a \le 1.46$	527–576
14:9	$1.46 < a \le 1.66$	463–526
16:9	$1.66 < a \le 1.90$	405–462
>16:9	$a > 1.90$	< 405

To allow automatic selection of the display mode, a 16:9 receiver should support the following minimum requirements:

Case 1: The 4:3 aspect ratio picture should be centered on the display, with black bars on the left and right sides.

Case 2: The 14:9 aspect ratio picture should be centered on the display, with black bars on the left and right sides. Alternately, the picture may be displayed using the full display width by using a small (typically 8%) horizontal geometrical error.

Case 3: The 16:9 aspect ratio picture should be displayed using the full width of the display.

Case 4: The >16:9 aspect ratio picture should be displayed as in Case 3 or use the full height of the display by zooming in.

Group B Data
The group B data consists of four data bits that specify enhanced services. Each data bit gen-

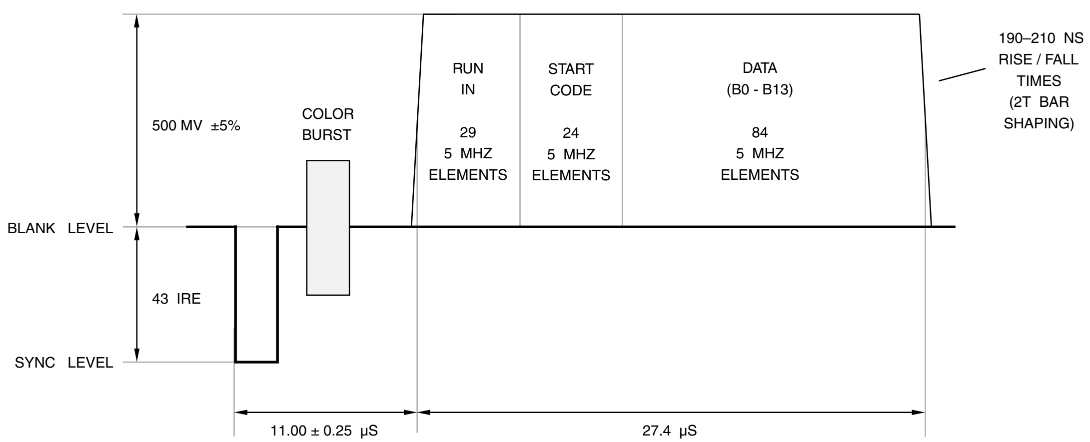

Figure 8.59. PAL Line 23 WSS Timing.

run-in	29 elements at 5 MHz	1 1111 0001 1100 0111 0001 1100 0111 ($1F1C\ 71C7_H$)
start code	24 elements at 5 MHz	0001 1110 0011 1100 0001 1111 ($1E\ 3C1F_H$)
group A (aspect ratio)	24 elements at 5 MHz “0” = 000 111 “1” = 111 000	b0, b1, b2, b3
group B (enhanced services)	24 elements at 5 MHz “0” = 000 111 “1” = 111 000	b4, b5, b6, b7 (b7 = “0” since reserved)
group C (subtitles)	18 elements at 5 MHz “0” = 000 111 “1” = 111 000	b8, b9, b10
group D (reserved)	18 elements at 5 MHz “0” = 000 111 “1” = 111 000	b11, b12, b13

Table 8.49. PAL WSS Information.

b3, b2, b1, b0	Aspect Ratio Label	Format	Position On 4:3 Display	Active Lines	Minimum Requirements
1000	4:3	full format	–	576	case 1
0001	14:9	letterbox	center	504	case 2
0010	14:9	letterbox	top	504	case 2
1011	16:9	letterbox	center	430	case 3
0100	16:9	letterbox	top	430	case 3
1101	> 16:9	letterbox	center	–	case 4
1110	14:9	full format	center	576	–
0111	16:9	full format (anamorphic)	–	576	–

Table 8.50. PAL WSS Group A (Aspect Ratio) Data Bit Assignments and Usage.

erates six elements at 5 MHz. Data bit b4 is the LSB. Bits b5 and b6 are used for PALplus.

b4: mode
- 0 camera mode
- 1 film mode

b5: color encoding
- 0 normal PAL
- 1 Motion Adaptive ColorPlus

b6: helper signals
- 0 not present
- 1 present

Group C Data

The group C data consists of three data bits that specify subtitles. Each data bit generates six elements at 5 MHz. Data bit b8 is the LSB.

b8: teletext subtitles
- 0 no
- 1 yes

b10, b9: open subtitles
- 00 no
- 01 inside active picture
- 10 outside active picture
- 11 reserved

Group D Data

The group D data consists of three data bits that specify surround sound and copy protection. Each data bit generates six elements at 5 MHz. Data bit b11 is the LSB.

b11: surround sound
- 0 no
- 1 yes

b12: copyright
- 0 no copyright asserted or unknown
- 1 copyright asserted

b13: copy protection
- 0 copying not restricted
- 1 copying restricted

525-Line NTSC Systems

EIA-J CPR-1204 and IEC 61880 define a widescreen signalling standard for NTSC systems. For YPbPr and S-video interfaces, WSS is present on the Y signal. For analog RGB interfaces, WSS is present on all three signals.

Data Timing

Lines 20 and 283 are used to transmit the WSS information, as shown in Figure 8.60.

The clock frequency is $F_{SC}/8$ or about 447.443 kHz; F_{SC} is the color subcarrier frequency of 3.579545 MHz. The signal waveform should be a sine-squared pulse, with a half-amplitude duration of 2.235 µs ±50 ns. The signal amplitude is 70 ±10 IRE for a “1”, and 0 ±5 IRE for a “0”.

Data Content

The WSS consists of 2 bits of start code, 14 bits of data, and 6 bits of CRC, as shown in Table 8.51. The CRC used is $X^6 + X + 1$, all preset to “1”.

Start Code

The start code consists of a “1” data bit followed by a “0” data bit, as shown in Table 8.51.

Word 0 Data

Word 0 data consists of 2 data bits:

b1, b0:

00	4:3 aspect ratio	normal
01	16:9 aspect ratio	anamorphic
10	4:3 aspect ratio	letterbox
11	reserved	

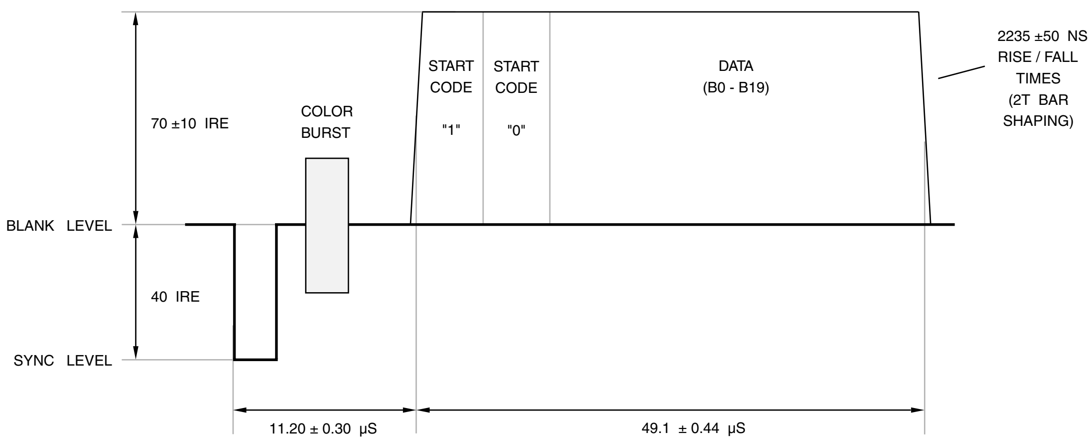

Figure 8.60. NTSC Line 20 and Line 283 WSS Timing.

start code	"1"
start code	"0"
word 0	b0, b1
word 1	b2, b3, b4, b5
word 2	b6, b7, b8, b9, b10, b11, b12, b13
CRC	b14, b15, b16, b17, b18, b19

Table 8.51. NTSC WSS Data Bit Assignments and Usage.

Word 1 Data
Word 1 data consists of 4 data bits:

b5, b4, b3, b2:

0000	copy control information
1111	default

Copy control information is transmitted in Word 2 data when Word 1 data is “0000”. When copy control information is not to be transferred, Word 1 data must be set to the default value “1111”.

Word 2 Data
Word 2 data consists of 14 data bits. When Word 1 data is “0000”, Word 2 data consists of copy control information. Word 2 copy control data must be transferred at the rate of two or more frames per two seconds.

Bits b6 and b7 specify the copy generation management system in an analog signal (CGMS-A). CGMS-A consists of two bits of digital information:

b7, b6:

00	copying permitted
01	one copy permitted
10	reserved
11	no copying permitted

Bits b8 and b9 specify the operation of the the Macrovision copy protection signals added to the analog NTSC video signal:

b9, b8:

00	PSP off
01	PSP on, 2-line split burst on
10	PSP on, split burst off
11	PSP on, 4-line split burst on

PSP is the Macrovision pseudo-sync pulse operation.

Split burst operation inverts the normal phase of the first half of the color burst signal on specified scan lines in a normal analog video signal. The color burst of four successive lines of every 21 lines is modified, beginning at lines 24 and 297 (four-line split burst system) or of two successive lines of every 17 lines, beginning at lines 30 and 301 (two-line split burst system). The color burst on all other lines is not modified.

Bit b10 specifies whether the source originated from an analog pre-recorded medium.

b10:

0	not analog pre-recorded medium
1	analog pre-recorded medium

Bits b11, b12, and b13 are reserved and are “000”.

Teletext

Teletext allows the transmission of text, graphics, and data. Data may be transmitted on any line, although the VBI interval is most commonly used. The teletext standards are specified by ETSI ETS 300706, ITU-R BT.653 and EIA–516.

For YPbPr and S-video interfaces, teletext is present on the Y signal. For analog RGB interfaces, teletext is present on all three signals.

There are many systems that use the teletext physical layer to transmit proprietary information. The advantage is that teletext has already been approved in many countries for broadcast, so certification for a new transmission technique is not required.

The data rate for teletext is much higher than that used for closed captioning, approaching up to 7 Mbps in some cases. Therefore, ghost cancellation is needed to reliably recover the transmitted data.

There are seven teletext systems, as shown in Table 8.52. EIA–516, also referred to as NABTS (North American Broadcast Teletext Specification), is used in the United States, and is an expansion of the BT.653 525-line system C standard.

System A:

Columbia
France
India

System B:

Australia
Belgium
China
Denmark
Egypt
Finland
Germany
Italy
Jordan
Kuwait
Malaysia
Morocco
Netherlands
New Zealand
Norway
Poland
Singapore
South Africa
Spain
Sweden
Turkey
United Kingdom
Yugoslavia

System C:

Brazil
Canada
United States

System D:

Japan

Figure 8.61 illustrates the teletext data on a scan line. If a line normally contains a color burst signal, it will still be present if teletext data is present. The 16 bits of clock run-in (or clock sync) consists of alternating "1's" and "0's".

Figures 8.62 and 8.63 illustrates the structure of teletext systems B and C, respectively.

System B Teletext Overview

Since teletext System B is the most popular teletext format, a basic overview is presented here.

A teletext service typically consists of pages, with each page corresponding to a screen of information. The pages are transmitted one at time, and after all pages have been

Parameter	System A	System B	System C	System D
625-Line Video Systems				
bit rate (Mbps)	6.203125	6.9375	5.734375	5.6427875
data amplitude	67 IRE	66 IRE	70 IRE	70 IRE
data per line	40 bytes	45 bytes	36 bytes	37 bytes
525-Line Video Systems				
bit rate (Mbps)	–	5.727272	5.727272	5.727272
data amplitude	–	70 IRE	70 IRE	70 IRE
data per line	–	37 bytes	36 bytes	37 bytes

Table 8.52. Summary of Teletext Systems and Parameters.

transmitted, the cycle repeats, with a typical cycle time of about 30 seconds. However, the broadcaster may transmit some pages more frequently than others, if desired.

The teletext service is usually based on up to eight magazines (allowing up to eight independent teletext services), with each magazine containing up to 100 pages. Magazine 1 uses page numbers 100–199, magazine 2 uses page numbers 200–299, etc. Each page may also have sub-pages, used to extend the number of pages within a magazine.

Each page contains 24 rows, with up to 40 characters per row. A character may be a letter, number, symbol, or simple graphic. There are also control codes to select colors and other attributes such as blinking and double height.

In addition to teletext information, the teletext protocol may be used to transmit other information, such as subtitling, program delivery control (PDC), and private data.

Subtitling

Subtitling is similar to the closed captioning used in the United States. "Open" subtitles are the insertion of text directly into the picture prior to transmission. "Closed" subtitles are transmitted separately from the picture. The transmission of closed subtitles in the UK use teletext page 888. In the case where multiple languages are transmitted using teletext, separate pages are used for each language.

Program Delivery Control (PDC)

Program Delivery Control (defined by ETSI ETS 300231 and ITU-R BT.809) is a system that controls VCR recording using teletext information. The VCR can be programmed to look for and record various types of programs or a specific program. Programs are recorded even if the transmission time changes for any reason.

There are two methods of transmitting PDC information via teletext: methods A and B.

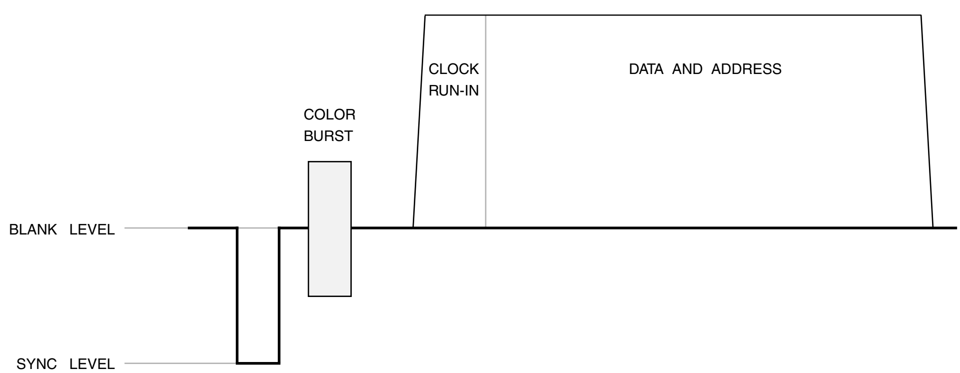

Figure 8.61. Teletext Line Format.

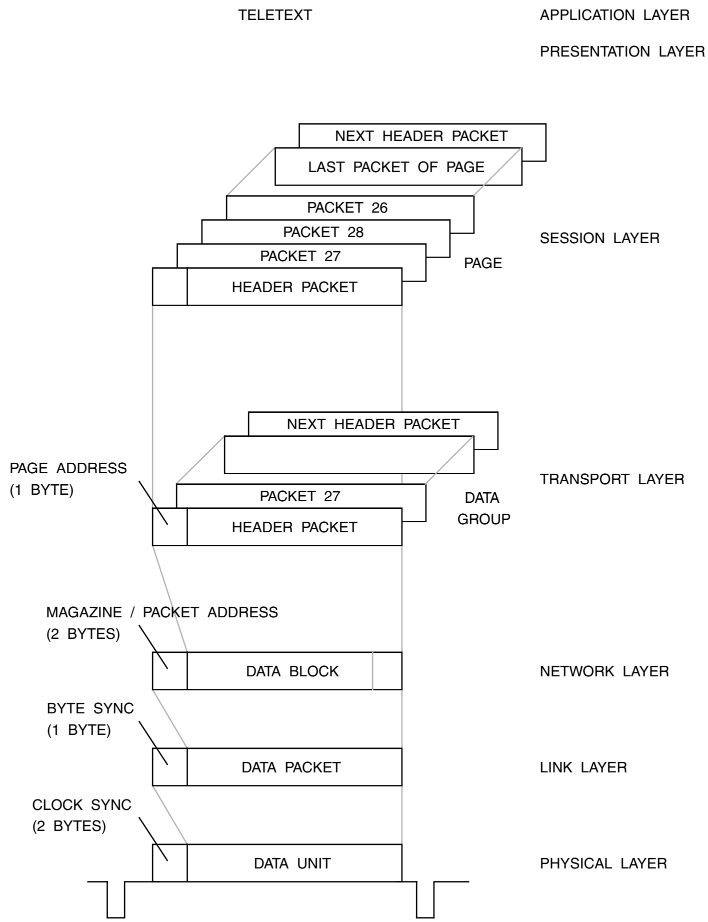

Figure 8.62. Teletext System B Structure.

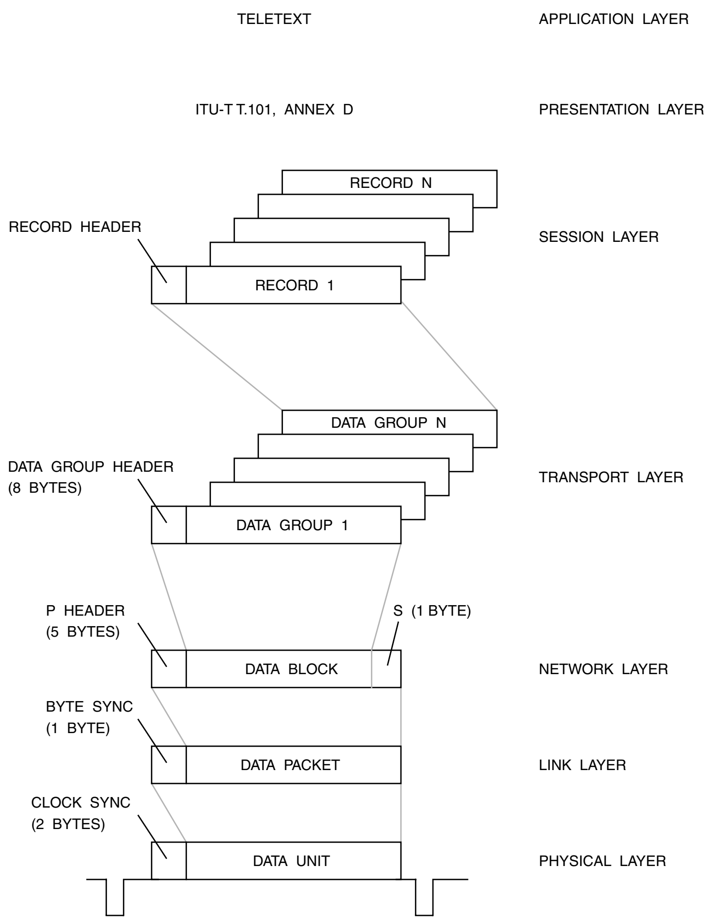

Figure 8.63. Teletext System C Structure.

Method A places the data on a viewable teletext page, and is usually transmitted on scan line 16. This method is also known as the Video Programming System (VPS).

Method B places the data on a hidden packet (packet 26) in the teletext signal. This packet 26 data contains the data on each program, including channel, program data, and start time.

Data Broadcasting

Data broadcasting may be used to transmit information to private receivers. Typical applications include real-time financial information, airport flight schedules for hotels and travel agents, passenger information for railroads, software upgrades, etc.

Packets 0–23

A typical teletext page uses 24 packets, numbered 0–23, that correspond to the 24 rows on a displayed page. Packet 24 can add a status row at the bottom for user prompting. For each packet, three bits specify the magazine address (1–8), and five bits specify the row address (0–23). The magazine and row address bits are Hamming error protected to permit single-bit errors to be corrected.

To save bandwidth, the whole address isn't sent with all packets. Only packet 0 (also called the header packet) has all the address information such as row, page, and magazine address data. Packets 1–28 contain information that is part of the page identified by the most recent packet 0 of the same magazine.

The transmission of a page starts with a header packet. Subsequent packets with the same magazine address provide additional data for that page. These packets may be transmitted in any order, and interleaved with packets from other magazines. A page is considered complete when the next header packet for that magazine is received.

The general format for packet 0 is:

clock run-in	2 bytes
framing code	1 byte
magazine and row address	2 bytes
page number	2 bytes
subcode	4 bytes
control codes	2 bytes
display data	32 bytes

The general format for packets 1–23 is:

clock run-in	2 bytes
framing code	1 byte
magazine and row address	2 bytes
display data	40 bytes

Packet 24

This packet defines an additional row for user prompting. Teletext decoders may use the data in packet 27 to react to prompts in the packet 24 display row.

Packet 25

This packet defines a replacement header line. If present, the 40 bytes of data are displayed instead of the channel, page, time, and date from packet 8.30.

Packet 26

Packet 26 consists of:

clock run-in	2 bytes
framing code	1 byte
magazine and row address	2 bytes
designation code	1 byte

13 3-byte data groups, each consisting of
- 7 data bits
- 6 address bits
- 5 mode bits
- 6 Hamming bits

There are 15 variations of packet 26, defined by the designation code. Each of the 13 data groups specify a specific display location and data relating to that location.

This packet is also used to extend the addressable range of the basic character set in order to support other languages, such as Arabic, Spanish, Hungarian, Chinese, etc.

For PDC, packet 26 contains data for each program, identifying the channel, program date, start time, and the cursor position of the program information on the page. When the user selects a program, the cursor position is linked to the appropriate packet 26 preselection data. This data is then used to program the VCR. When the program is transmitted, the program information is transmitted using packet 8.30 format 2. A match between the preselection data and the packet 8.30 data turns the VCR record mode on.

Packet 27

Packet 27 tells the teletext decoder how to respond to user selections for packet 24. There may be up to four packet 27s (packets 27/0 through 27/3), allowing up to 24 links. It consists of:

clock run-in	2 bytes
framing code	1 byte
magazine and row address	2 bytes
designation code	1 byte
link 1 (red)	6 bytes
link 2 (green)	6 bytes
link 3 (yellow)	6 bytes
link 4 (cyan)	6 bytes
link 5 (next page)	6 bytes
link 6 (index)	6 bytes
link control data	1 byte
page check digit	2 bytes

Each link consists of:
- 7 data bits
- 6 address bits
- 5 mode bits
- 6 hamming bits

This packet contains information linking the current page to six page numbers (links). The four colored links correspond to the four colored Fastext page request keys on the remote. Typically, these four keys correspond to four colored menu selections at the bottom of the display using packet 24. Selection of one of the colored page request keys results in the selection of the corresponding linked page.

The fifth link is used for specifying a page the user might want to see after the current page, such as the next page in a sequence.

The sixth link corresponds to the Fastext index key on the remote, and specifies the page address to go to when the index is selected.

Packets 28 and 29

These are used to define level 2 and level 3 pages to support higher resolution graphics, additional colors, alternate character sets, etc. They are similar in structure to packet 26.

Packet 8.30 Format 1

Packet 8.30 (magazine 8, packet 30) isn't associated with any page, but is sent once per second. This packet is also known as the Television Service Data Packet, or TSDP. It contains data that notifies the teletext decoder about the transmission in general and the time.

clock run-in	2 bytes
framing code	1 byte
magazine and row address	2 bytes
designation code	1 byte
initial teletext page	6 bytes
network ID	2 bytes

time offset from UTC	1 byte
date (Modified Julian Day)	3 bytes
UTC time	3 bytes
TV program label	4 bytes
status display	20 bytes

The *Designation Code* indicates whether the transmission is during the VBI or full-field.

Initial Teletext Page tells the decoder which page should be captured and stored on power-up. This is usually an index or menu page.

The *Network Identification* code identifies the transmitting network.

The *TV Program Label* indicates the program label for the current program.

Status Display is used to display a transmission status message.

Packet 8.30 Format 2

This format is used for PDC recorder control, and is transmitted once per second per stream. It contains a program label indicating the start of each program, usually transmitted about 30 seconds before the start of the program to allow the VCR to detect it and get ready to record.

clock run-in	2 bytes
framing code	1 byte
magazine and row address	2 bytes
designation code	1 byte
initial teletext page	6 bytes
label channel ID	1 byte
program control status	1 byte
country and network ID	2 bytes
program ID label	5 bytes
country and network ID	2 bytes
program type	2 bytes
status display	20 bytes

The content is the same as for Format 1, except for the 13 bytes of information before the status display information.

Label channel ID (LCI) identifies each of up to four PDC streams that may be transmitted simultaneously.

The *Program Control Status* (PCS) indicates real-time status information, such as the type of analog sound transmission.

The *Country and Network ID* (CNI) is split into two groups. The first part specifies the country and the second part specifies the network.

Program ID Label (PIL) specifies the month, day, and local time of the start of the program.

Program Type (PTY) is a code that indicates an intended audience or a particular series. Examples are "adult", "children", "music", "drama", etc.

Packet 31

Packet 31 is used for the transmission of data to private receivers. It consists of:

clock run-in	2 bytes
framing code	1 byte
data channel group	1 byte
message bits	1 byte
format type	1 byte
address length	1 byte
address	0–6 bytes
repeat indicator	0–1 byte
continuity indicator	0–1 byte
data length	0–1 byte
user data	28–36 bytes
CRC	2 bytes

ATVEF Interactive Content

ATVEF (Advanced Television Enhancement Forum) is a standard for creating and delivering enhanced and interactive programs. The enhanced content can be delivered over a variety of mediums—including analog and digital television broadcasts—using terrestrial, cable, and satellite networks.

In defining how to create enhanced content, the ATVEF specification defines the minimum functionality required by ATVEF-compliant receivers. To minimize the creation of new specifications, the ATVEF uses existing Internet technologies such as HTML and Javascript. Two additional benefits of doing this are that there are already millions of pages of potential content, and the ability to use existing web-authoring tools.

The ATVEF 1.0 Content Specification mandates that receivers support, as a minimum, HTML 4.0, Javascript 1.1, and Cascading Style Sheets. Supporting additional capabilities, such as Java and VRML, are optional. This ensures content is available to the maximum number of viewers.

For increased capability, a new "tv:" attribute is added to the HTML. This attribute enables the insertion of the television program into the content, and may be used in a HTML document anywhere that a regular image may be placed. Creating an enhanced content page that displays the current television channel anywhere on the display is as easy as inserting an image in a HTML document.

The specification also defines how the receiver obtains the content and how it is informed that enhancements are available. The latter task is accomplished with triggers.

Triggers

Triggers alert receivers to content enhancements, and contain information about the enhancements. Among other things, triggers contain a Universal Resource Locator (URL) that defines the location of the enhanced content. Content may reside locally—such as when delivered over the network and cached to a local hard drive—or it may reside on the Internet or another network.

Triggers may also contain a human-readable description of the content. For example, it may contain the description "Press ORDER to order this product", which can be displayed for the viewer. Triggers also may contain expiration information, indicating how long the enhancement should be offered to the viewer.

Lastly, triggers may contain scripts that trigger the execution of Javascript within the associated HTML page, to support synchronization of the enhanced content with the video signal and updating of dynamic screen data.

Transports

Besides defining how content is displayed, and how the receiver is notified of new content, the specification also defines how content is delivered. Because a receiver may not have an Internet connection, the specification describes two models for delivering content. These two models are called transports, and the two transports are referred to as Transport Type A and Transport Type B.

If the receiver has a back-channel (or return path) to the Internet, Transport Type A will broadcast the trigger and the content will be pulled over the Internet.

If the receiver does not have an Internet connection, Transport Type B provides for delivery of both triggers and content via the broadcast medium. Announcements are sent over the network to associate triggers with content streams. An announcement describes the content, and may include information regarding bandwidth, storage requirements, and language.

Delivery Protocols

For traditional bi-directional Internet communication, the Hypertext Transfer Protocol (HTTP) defines how data is transferred at the application level. For uni-directional broadcasts where a two-way connection is not available, ATVEF also defines a uni-directional application-level protocol for data delivery: Uni-directional Hypertext Transfer Protocol (UHTTP).

Like HTTP, UHTTP uses traditional URL naming schemes to reference content. Content can reference enhancement pages using the standard "http:" and "ftp:" naming schemes. However, ATVEF also adds the "lid:," or local identifier URL, naming scheme. This allows reference to content that exists locally (such as on the receiver's hard drive) as opposed to on the Internet or other network.

Bindings

How data is delivered over a specific network is called binding. The ATVEF has defined bindings for IP multicast and NTSC. The binding to IP is referred to as "reference binding".

ATVEF Over NTSC

Transport Type A triggers are broadcast on data channel 2 of the EIA-608 captioning signal.

Transport Type B binding also includes a mechanism for delivering IP over the vertical blanking interval (VBI), otherwise knows as IP over VBI (IP/VBI). At the lowest level, the television signal transports NABTS (North American Basic Teletext Standard) packets during the VBI. These NABTS packets are recovered to form a sequential data stream (encapsulated in a SLIP-like protocol) that is unframed to produce IP packets.

"Raw" VBI Data

"Raw", or oversampled, VBI data is simply digitized VBI data. It is typically oversampled using a 2× video sample clock, such as 27 MHz. Two applications for "raw" VBI data are PCs (for software decoding of VBI data) and settop boxes (to pass the VBI data on to the NTSC/PAL encoder).

VBI data may be present on any scan line, except during the serration and equalization intervals.

One requirement for oversampled VBI data is that the "active line time" be a constant, independent of the horizontal timing of the BLANK* control signal. Thus, all the VBI data is assured to be captured regardless of the output resolution of the active video data.

A separate control signal, called VBIVALID*, may be used to indicate when VBI data is present on the digital video interface. This simplifies the design of graphics chips, NTSC/PAL encoders, and ASICs that are required to separate the VBI data from the digital video data.

"Sliced" VBI Data

"Sliced", or binary, VBI data is useful in MPEG video systems, such as settop boxes, DVD, digital VCRs, and TVs. It may also be used in PC applications to reduce PCI bandwidth.

VBI data may be present on any scan line, except during the serration and equalization intervals.

A separate control signal, called VBIVALID*, may be used to indicate when VBI data is present on the digital video interface. This simplifies the design of graphics chips, NTSC/PAL encoders, and ASICs that are required to separate the VBI data from the digital video data.

NTSC/PAL Decoder Considerations

For sliced VBI data capture, hysteresis must be used to prevent VBI decoders from rapidly turning on and off due to noise and transmission errors. In addition, the VBI decoders must also compensate for DC offsets, amplitude variations, ghosting, and timing variations.

For closed captioning, the caption VBI decoder monitors the appropriate scan lines looking for the clock run-in and start bits used by captioning. If found, it locks on to the clock run-in, the caption data is sampled, converted to binary data, and the 16 bits of data are transferred to registers to be output via the host processor or video interface. If the clock run-in and start bits are not found, it is assumed the scan line contains video data, unless other VBI data is detected.

For WSS, the WSS VBI decoder monitors the appropriate scan lines looking for the run-in and start codes used by WSS. If found, it locks on to the run-in code, the WSS data is sampled, converted to binary data, and the 14 or 20 bits of data are transferred to registers to be output via the host processor or video interface. If the clock run-in and start codes are not found, it is assumed the scan line contains video data, unless other VBI data is detected.

For teletext, the teletext VBI decoder monitors each scan line looking for the 16-bit clock run-in code used by teletext. If found, it locks on to the clock run-in code, the teletext data is sampled, converted to binary data, and the data is then transferred to registers to be output via the teletext or video interface. Conventional host serial interfaces, such as I^2C, cannot handle the high bit rates of teletext. Thus, a 2-pin serial teletext interface is commonly used. If the 16-bit clock run-in code is not found, it is assumed the scan line contains video data, unless other VBI data is detected.

Ghost Cancellation

Ghost cancellation is required due to the high data rate of some services, such as teletext. Ghosting greater than 100 ns and –12 dB corrupts teletext data. Ghosting greater than –3 dB is difficult to remove cost-effectively in hardware or software, while ghosting less than –12 dB need not be removed. Ghost cancellation for VBI data is not as complex as ghost cancellation for active video.

Unfortunately, the GCR (ghost cancellation reference) signal is not commonly used in many countries. Thus, a ghost cancellation algorithm must determine the amount of ghosting using other available signals, such as the serration and equalization pulses.

NTSC Ghost Cancellation

The NTSC GCR signal is specified in ATSC A/49 and ITU-R BT.1124. If present, it occupies lines 19 and 282. The GCR permits the detection of ghosting from –3 to +45 µs, and follows an 8-field sequence.

PAL Ghost Cancellation

The PAL GCR signal is also specified in BT.1124 and ETSI ETS 300732. If present, it occupies line 318. The GCR permits the detection of ghosting from –3 to +45 µs, and follows a 4-frame sequence.

References

1. Advanced Television Enhancement Forum, *Enhanced Content Specification,* 1999.
2. ANSI/SMPTE 12M–1999, *Television, Audio and Film—Time and Control Code.*
3. ANSI/SMPTE 170M–1999, *Television—Composite Analog Video Signal—NTSC for Studio Applications.*
4. ANSI/SMPTE 262M–1995, *Television, Audio and Film—Binary Groups of Time and Control Codes—Storage and Transmission of Data.*
5. ANSI/SMPTE 309M–1999, *Television—Transmission of Date and Time Zone Information in Binary Groups of Time and Control Code.*
6. ATSC A/49, 13 May 1993, *Ghost Cancelling Reference Signal for NTSC.*
7. *BBC Technical Requirements for Digital Television Services*, Version 1.0, February 3, 1999, BBC Broadcast.
8. EIA-189-A, July 1976, *Encoded Color Bar Signal.*
9. EIA–516, May 1988, *North American Basic Teletext Specification (NABTS).*
10. EIA–608, September 1994, *Recommended Practice for Line 21 Data Service.*
11. EIA–744–A, December 1998, *Transport of Content Advisory Information Using Extended Data Service (XDS).*
12. EIA/IS–702, July 1997, *Copy Generation Management System (Analog).*
13. EIA-J CPR–1204–1, 1998, *Specifications and Transfer Method of Video Aspect Ratio Identification Signal (II).*
14. ETSI EN 300163, *Television Systems: NICAM 728: Transmission of Two Channel Digital Sound with Terrestrial Television Systems B, G, H, I, K1, and L*, March 1998.
15. ETSI EN 300294, *Television Systems: 625-line Television Widescreen Signalling (WSS)*, April 1998.
16. ETSI ETS 300231, *Television Systems: Specification of the Domestic Video Programme Delivery Control System (PDC)*, April 1998.
17. ETSI ETS 300706, *Enhanced Teletext Specification*, May 1997.
18. ETSI ETS 300708, *Television Systems: Data Transmission within Teletext*, March 1997.
19. ETSI ETS 300731, *Television Systems: Enhanced 625-Line Phased Alternate Line (PAL) Television: PALplus*, March 1997.
20. ETSI ETS 300732, *Television Systems: Enhanced 625-Line PAL/SECAM Television; Ghost Cancellation Reference (GCR) Signals*, January 1997.
21. Faroudja, Yves Charles, *NTSC and Beyond, IEEE Transactions on Consumer Electronics*, Vol. 34, No. 1, February 1988.
22. IEC 61880, 1998–1, *Video Systems (525/60)—Video and Accompanied Data Using the Vertical Blanking Interval—Analog Interface.*
23. ITU-R BS.707–3, 1998, *Transmission of Multisound in Terrestrial Television Systems PAL B, G, H, and I and SECAM D, K, K1, and L.*
24. ITU-R BT.470–6, 1998, *Conventional Television Systems.*

25. ITU-R BT.471–1, 1986, *Nomenclature and Description of Colour Bar Signals.*
26. ITU-R BT.472–3, 1990, *Video Frequency Characteristics of a Television System to Be Used for the International Exchange of Programmes Between Countries that Have Adopted 625-Line Colour or Monochrome Systems.*
27. ITU-R BT.473–5, 1990, *Insertion of Test Signals in the Field-Blanking Interval of Monochrome and Colour Television Signals.*
28. ITU-R BT.569–2, 1986, *Definition of Parameters for Simplified Automatic Measurement of Television Insertion Test Signals.*
29. ITU-R BT.653–3, 1998, *Teletext Systems.*
30. ITU-R BT.809, 1992, *Programme Delivery Control (PDC) System for Video Recording*.
31. ITU-R BT.1118, 1994, *Enhanced Compatible Widescreen Television Based on Conventional Television Systems*.
32. ITU-R BT.1119–2, 1998, *Wide-Screen Signalling for Broadcasting*.
33. ITU-R BT.1124, 1994, *Reference Signals for Ghost Cancelling in Analogue Television Systems*.
34. ITU-R BT.1197–1, 1998, *Enhanced Wide-Screen PAL TV Transmission System (the PALplus System)*.
35. ITU-R BT.1298, 1997, *Enhanced Wide-Screen NTSC TV Transmission System*.
36. *Multichannel Television Sound*, BTSC System Recommended Practices, EIA Television Systems Bulletin No. 5, July 1985, Electronic Industries Association.
37. *NTSC Video Measurements*, Tektronix, Inc., 1997.
38. SMPTE RP164–1996, *Location of Vertical Interval Time Code*.
39. SMPTE RP186–1995, *Video Index Information Coding for 525- and 625-Line Television Systems*.
40. SMPTE RP201–1999, *Encoding Film Transfer Information Using Vertical Interval Time Code.*
41. *Specification of Television Standards for 625-Line System-I Transmissions*, 1971, Independent Television Authority (ITA) and British Broadcasting Corporation (BBC).
42. *Television Measurements, NTSC Systems*, Tektronix, Inc., 1998.
43. *Television Measurements, PAL Systems*, Tektronix, Inc., 1990.