

Unit-I

INTRODUCTION: *TV transmitter and receivers, synchronization. Television Pictures: Geometric form and aspect ratio, image continuity, interlaced scanning, picture resolution, Composite video signal: Horizontal and vertical sync, scanning sequence, Colour signal generation and Encoding: Perception of brightness and colours, additive colour mixing, video signals for colours, luminance signal, colour difference signals, encoding of colour difference signals, formation of chrominance signals, PAL encoder.*

Introduction

Development of Television

Television* means 'to see from a distance'. The desire in man to do so has been there for ages. In the early years of the twentieth century many scientists experimented with the idea of using selenium photosensitive cells for converting light from pictures into electrical signals and transmitting them through wires.

The first demonstration of actual television was given by J.L. Baird in UK and C.F. Jenkins in USA around 1927 by using the technique of mechanical scanning employing rotating discs. However, the real breakthrough occurred with the invention of the cathode ray tube and the success of V.K. Zworykin of the USA in perfecting the first camera tube (the iconoscope) based on the storage principle. By 1930 electromagnetic scanning of both camera and picture tubes and other ancillary circuits such as for beam deflection, video amplification, etc. were developed. Though television broadcast started in 1935, world political developments and the second world war slowed down the progress of television. With the end of the war, television rapidly grew into a popular medium for dispersion of news and mass entertainment.

Television Systems

At the outset, in the absence of any international standards, three monochrome (*i.e.* black and white) systems grew independently. These are the 525 line American, the 625 line European and the 819 line French systems. This naturally prevents direct exchange of programme between countries using different television standards. Later, efforts by the all world committee on radio and television (CCIR) for changing to a common 625 line system by all concerned proved ineffective and thus all the three systems have apparently come to stay. The inability to change over to a common system is mainly due to the high cost of replacing both the transmitting equipment and the millions of receivers already in use. However the UK, where initially a 415 line monochrome system was in use, has changed to the 625 line system with some modification in the channel bandwidth. In India, where television transmission started in 1959, the 625-B monochrome system has been adopted.

The three different standards of black and white television have resulted in the development of three different systems of colour television, respectively compatible with the three monochrome systems. The original colour system was that adopted by the USA in 1953 on the recommendations of its National Television Systems Committee and hence called the NTSC system. The other two colour systems—PAL and SECAM are later modifications of the NTSC system, with minor improvements, to conform to the other two monochrome standards.

The fundamental aim of a television system is to extend the sense of sight beyond its natural limits, along with the sound associated with the scene being televised. Essentially then, a TV system is an extension of the science of radio communication with the additional complexity that besides sound the picture details are also to be transmitted.

In most television systems, as also in the C.C.I.R. 625 line monochrome system adopted by India, the picture signal is amplitude modulated and sound signal frequency modulated before transmission. The carrier frequencies are suitably spaced and the modulated outputs radiated through a common antenna. Thus each broadcasting station can have its own carrier frequency and the receiver can then be tuned to select any desired station. Figure 1.1 shows a simplified block representation of a TV transmitter and receiver.

1.1 PICTURE TRANSMISSION

The picture information is optical in character and may be thought of as an assemblage of a large number of bright and dark areas representing picture details. These elementary areas into which the picture details may be broken up are known as 'picture elements', which when viewed together, represent the visual information of the scene. Thus the problem of picture transmission is fundamentally much more complex, because, at any instant there are almost an infinite number of pieces of information, existing simultaneously, each representing the level of brightness of the scene to be reproduced. In other words the information is a function of two variables, time and space. Ideally then, it would need an infinite number of channels to transmit optical information corresponding to all the picture elements simultaneously. Presently the practical difficulties of transmitting all the information simultaneously and decoding it at the receiving end seem insurmountable and so a method known as scanning is used instead. Here the conversion of optical information to electrical form and its transmission are carried out element by element, one at a time and in a sequential manner to cover the entire scene which is to be televised. Scanning of the elements is done at a very fast rate and this process is repeated a large number of times per second to create an illusion of simultaneous pick-up and transmission of picture details.

A TV camera, the heart of which is a camera tube, is used to convert the optical information into a corresponding electrical signal, the amplitude of which varies in accordance with the variations of brightness. Fig. 1.2 (a) shows very elementary details of one type of camera tube (vidicon) to illustrate this principle. An optical image of the scene to be transmitted is focused by a lens assembly on the rectangular glass face-plate of the camera tube. The inner

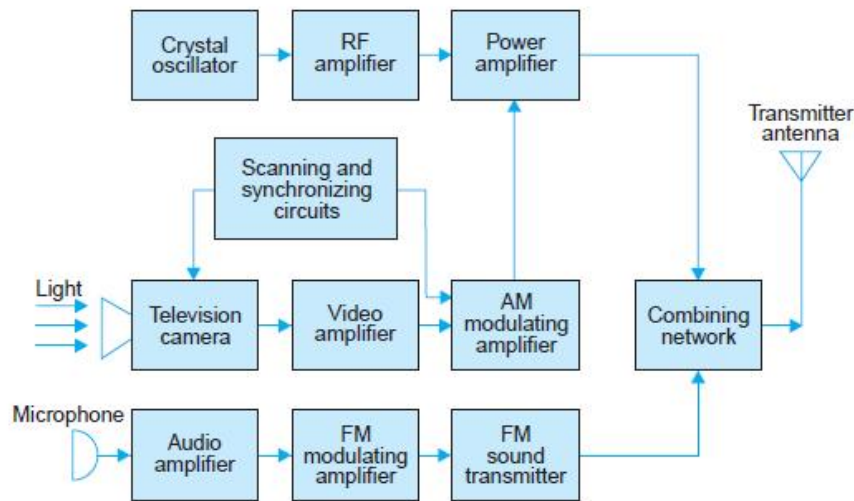


Fig. 1.1 (a) Basic monochrome television transmitter.

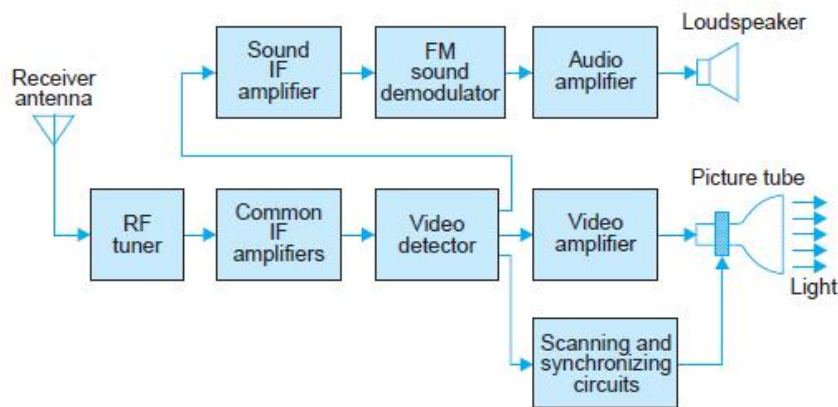


Fig. 1.1 (b) Basic monochrome television receiver.

Fig. 1.1 Simplified block diagram of a monochrome television broadcasting system.

side of the glass face-plate has a transparent conductive coating on which is laid a very thin layer of photoconductive material. The photolayer has a very high resistance when no light falls on it, but decreases depending on the intensity of light falling on it. Thus depending on the light intensity variations in the focused optical image, the conductivity of each element of the photolayer changes accordingly. An electron beam is used to pick-up the picture information now available on the target plate in terms of varying resistance at each point. The beam is formed by an electron gun in the TV camera tube. On its way to the inner side of the glass face-plate it is deflected by a pair of deflecting coils mounted on the glass envelope and kept mutually perpendicular to each other to achieve scanning of the entire target area. Scanning is done in the same way as one reads a written page to cover all the words in one line and all the lines on the page (see Fig. 1.2 (b)). To achieve this the deflecting coils are fed separately from two sweep oscillators which continuously generate saw-tooth waveforms, each operating at a different desired frequency. The magnetic deflection caused by the current in one coil gives horizontal motion to the beam from left to right at a uniform rate and then brings it quickly to

the left side to commence the trace of next line. The other coil is used to deflect the beam from top to bottom at a uniform rate and for its quick retrace back to the top of the plate to start this process all over again. Two simultaneous motions are thus given to the beam, one from left to right across the target plate and the other from top to bottom thereby covering the entire area on which the electrical image of the picture is available. As the beam moves from element to element, it encounters a different resistance across the target-plate, depending on the resistance of the photoconductive coating. The result is a flow of current which varies in magnitude as the elements are scanned. This current passes through a load resistance R_L , connected to the conductive coating on one side and to a dc supply source on the other. Depending on the magnitude of the current a varying voltage appears across the resistance R_L and this corresponds to the optical information of the picture.

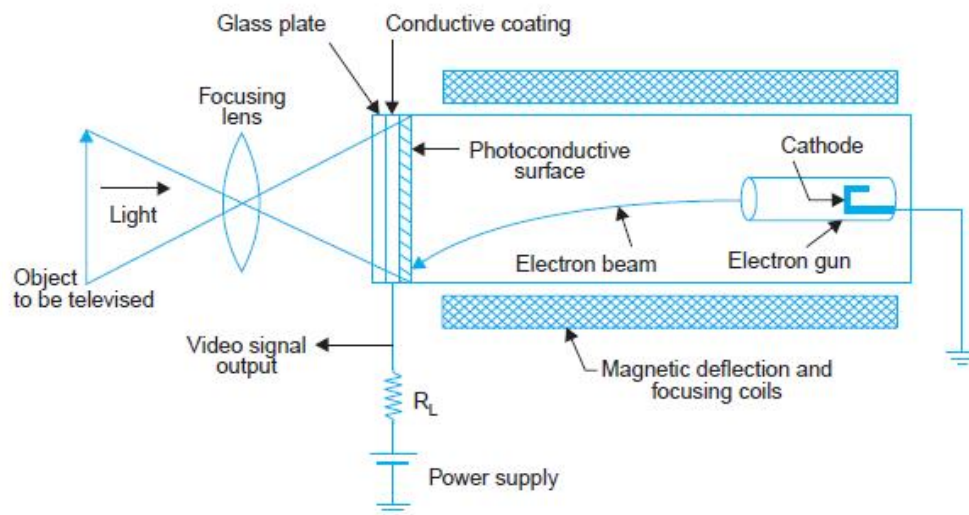


Fig. 1.2 (a) Simplified cross-sectional view of a Vidicon TV camera tube.

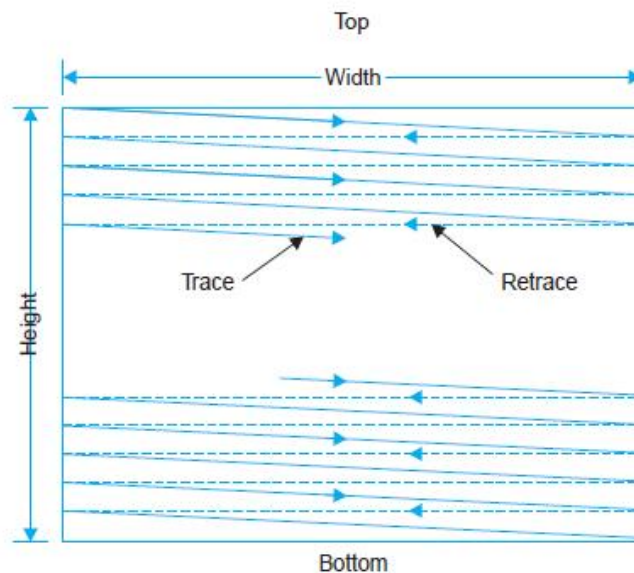


Fig. 1.2 (b) Path of scanning beam in covering picture area.

If the scanning beam moves at such a rate that any portion of the scene content does not have time to move perceptibly in the time required for one complete scan of the image, the resultant electrical signal contains the true information existing in the picture during the time of the scan. The desired information is now in the form of a signal varying with time and scanning may thus be identified as a particular process which permits the conversion of information existing in space and time coordinates into time variations only. The electrical information obtained from the TV camera tube is generally referred to as video signal (video is Latin for 'see'). This signal is amplified and then amplitude modulated with the channel picture carrier frequency. The modulated output is fed to the transmitter antenna for radiation along with the sound signal.

1.3 PICTURE RECEPTION

The receiving antenna intercepts the radiated picture and sound carrier signals and feeds them to the RF tuner (see Fig. 1.1 (b)). The receiver is of the heterodyne type and employs two or three stages of intermediate frequency (IF) amplification. The output from the last IF stage

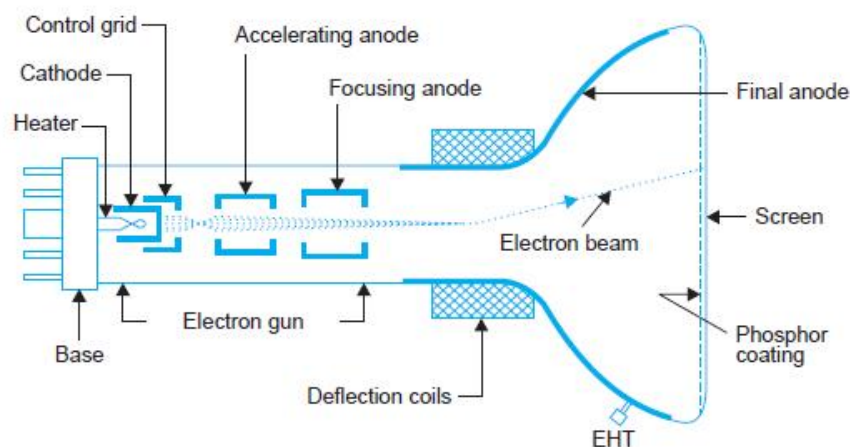


Fig. 1.3 Elements of a picture tube.

is demodulated to recover the video signal. This signal that carries the picture information is amplified and coupled to the picture tube which converts the electrical signal back into picture elements of the same degree of black and white. The picture tube shown in Fig. 1.3 is very similar to the cathode-ray tube used in an oscilloscope. The glass envelope contains an electron-gun structure that produces a beam of electrons aimed at the fluorescent screen. When the electron beam strikes the screen, light is emitted. The beam is deflected by a pair of deflecting coils mounted on the neck of the picture tube in the same way and rate as the beam scans the target in the camera tube. The amplitudes of the currents in the horizontal and vertical deflecting coils are so adjusted that the entire screen, called raster, gets illuminated because of the fast rate of scanning.

The video signal is fed to the grid or cathode of the picture tube. When the varying signal voltage makes the control grid less negative, the beam current is increased, making the spot of light on the screen brighter. More negative grid voltage reduces the brightness. If the grid voltage is negative enough to cut-off the electron beam current at the picture tube there will be no light. This state corresponds to black. Thus the video signal illuminates the fluorescent screen from white to black through various shades of grey depending on its amplitude at any instant. This corresponds to the brightness changes encountered by the electron beam of the camera tube while scanning the picture details element by element. The rate at which the spot of light moves is so fast that the eye is unable to follow it and so a complete picture is seen because of the storage capability of the human eye.

1.5 SYNCHRONIZATION

It is essential that the same coordinates be scanned at any instant both at the camera tube target plate and at the raster of the picture tube, otherwise, the picture details would split and get distorted. To ensure perfect synchronization between the scene being televised and the picture produced on the raster, synchronizing pulses are transmitted during the retrace, *i.e.*, fly-back intervals of horizontal and vertical motions of the camera scanning beam. Thus, in addition to carrying picture detail, the radiated signal at the transmitter also contains synchronizing pulses. These pulses which are distinct for horizontal and vertical motion control, are processed at the receiver and fed to the picture tube sweep circuitry thus ensuring that the receiver picture tube beam is in step with the transmitter camera tube beam.

The basic factors with which the television system must deal for successful transmission and reception of pictures are:

- (a) *Gross Structure*: Geometric form and aspect ratio of the picture.
- (b) *Image Continuity*: Scanning and its sequence.
- (c) *Number of Scanning Lines*: Resolution of picture details.
- (d) *Flicker*: Interlaced scanning.
- (e) *Fine Structure*: Vertical and horizontal resolution.
- (f) *Tonal Gradation*: Picture brightness transfer characteristics of the system.

2.1 GROSS STRUCTURE

The frame adopted in all television systems is rectangular with width/height ratio, *i.e.*, aspect ratio = 4/3. There are many reasons for this choice. In human affairs most of the motion occurs in the horizontal plane and so a larger width is desirable. The eyes can view with more ease and comfort when the width of a picture is more than its height. The usage of rectangular frame in motion pictures with a width/height ratio of 4/3 is another important reason for adopting this shape and aspect ratio. This enables direct television transmission of film programmes without wastage of any film area.

It is not necessary that the size of the picture produced on the receiver screen be same as that being televised but it is essential that the aspect ratio of the two be same, otherwise the scene details would look too thin or too wide. This is achieved by setting the magnitudes of the current in the deflection coils to correct values, both at the TV camera and receiving picture tube. Another important requirement is that the same coordinates should be scanned at any instant both by the camera tube beam and the picture tube beam in the receiver. Synchronizing pulses are transmitted along with the picture information to achieve exact congruence between transmitter and receiver scanning systems.

2.2 IMAGE CONTINUITY

While televising picture elements of the frame by means of the scanning process, it is necessary to present the picture to the eye in such a way that an illusion of continuity is created and any

motion in the scene appears on the picture tube screen as a smooth and continuous change. To achieve this, advantage is taken of 'persistence of vision' or storage characteristics of the human eye. This arises from the fact that the sensation produced when nerves of the eye's retina are stimulated by incident light does not cease immediately after the light is removed but persists for about 1/16th of a second. Thus if the scanning rate per second is made greater than sixteen, or the number of pictures shown per second is more than sixteen, the eye is able to integrate the changing levels of brightness in the scene. So when the picture elements are scanned rapidly enough, they appear to the eye as a complete picture unit, with none of the individual elements visible separately.

In present day motion pictures twenty-four still pictures of the scene are taken per second and later projected on the screen at the same rate. Each picture or frame is projected individually as a still picture, but they are shown one after the other in rapid succession to produce the illusion of continuous motion of the scene being shown. A shutter in the projector rotates in front of the light source and allows the film to be projected on the screen when the film frame is still, but blanks out any light from the screen during the time when the next film frame is being moved into position. As a result, a rapid succession of still-film frames is seen on the screen. With all light removed during the change from one frame to the next, the eye sees a rapid sequence of still pictures that provides the illusion of continuous motion.

Scanning. A similar process is carried out in the television system. The scene is scanned rapidly both in the horizontal and vertical directions simultaneously to provide sufficient number of complete pictures or frames per second to give the illusion of continuous motion. Instead of the 24 as in commercial motion picture practice, the frame repetition rate is 25 per second in most television systems.

Horizontal scanning. Fig. 2.1 (a) shows the trace and retrace of several horizontal lines. The linear rise of current in the horizontal deflection coils (Fig. 2.1 (b)) deflects the beam across the screen with a continuous, uniform motion for the trace from left to right. At the peak of the rise, the sawtooth wave reverses direction and decreases rapidly to its initial value. This fast reversal produces the retrace or flyback. The start of the horizontal trace is at the left

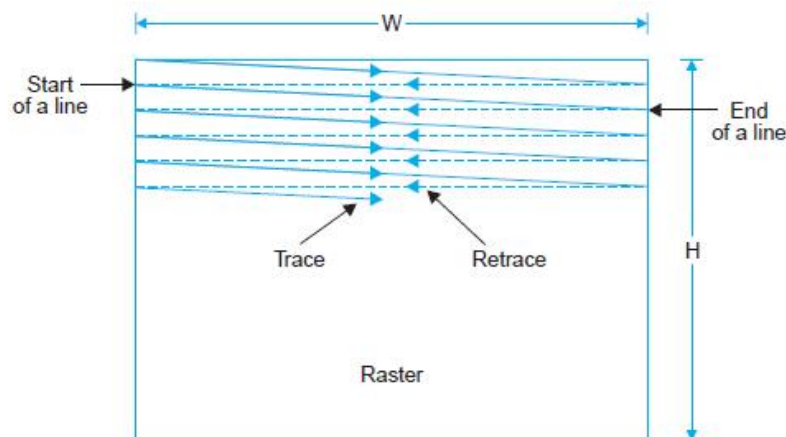


Fig. 2.1 (a) Path of scanning beam in covering picture area (Raster).

edge of raster. The finish is at the right edge, where the flyback produces retrace back to the left edge.

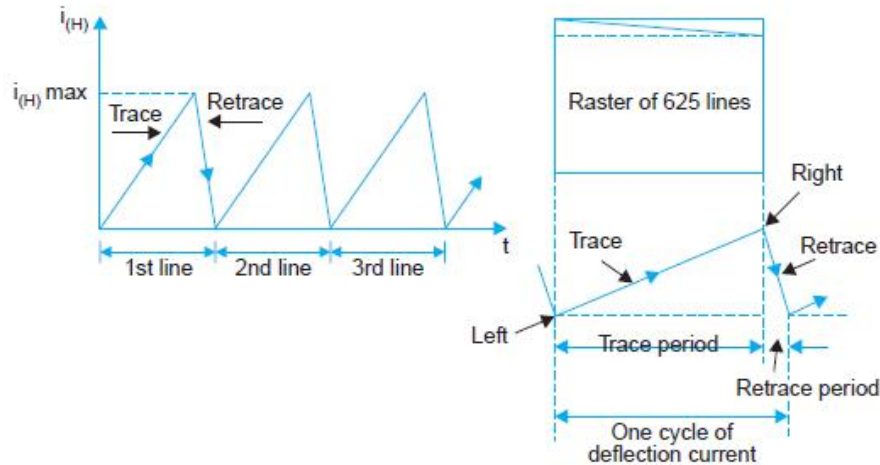


Fig. 2.1 (b) Waveform of current in the horizontal deflection coils producing linear (constant velocity) scanning in the horizontal direction.

Note, that 'up' on the sawtooth wave corresponds to horizontal deflection to the right. The heavy lines in Fig. 2.1 (a) indicate the useful scanning time and the dashed lines correspond to the retrace time.

Vertical scanning. The sawtooth current in the vertical deflection coils (see Fig. 2.2) moves the electron beam from top to bottom of the raster at a uniform speed while the electron beam is being deflected horizontally. Thus the beam produces complete horizontal lines one below the other while moving from top to bottom.

As shown in Fig. 2.2 (c), the trace part of the sawtooth wave for vertical scanning deflects the beam to the bottom of the raster. Then the rapid vertical retrace returns the beam to the top. Note that the maximum amplitude of the vertical sweep current brings the beam to the bottom of the raster. As shown in Fig. 2.2 (b) during vertical retrace the horizontal scanning continues and several lines get scanned during this period. Because of motion in the scene being televised, the information or brightness at the top of the target plate or picture tube screen normally changes by the time the beam returns to the top to recommence the whole process. This information is picked up during the next scanning cycle and the whole process is repeated 25 times to cause an illusion of continuity. The actual scanning sequence is however a little more complex than that just described and is explained in a later section of this chapter. It must however be noted, that both during horizontal retrace and vertical retrace intervals the scanning beams at the camera tube and picture tube are blanked and no picture information is either picked up or reproduced. Instead, on a time division basis, these short retrace intervals are utilized for transmitting distinct narrow pulses to keep the sweep oscillators of the picture tube deflection circuits of the receiver in synchronism with those of the camera at the transmitter. This ensures exact correspondence in scanning at the two ends and results in distortionless reproduction of the picture details.

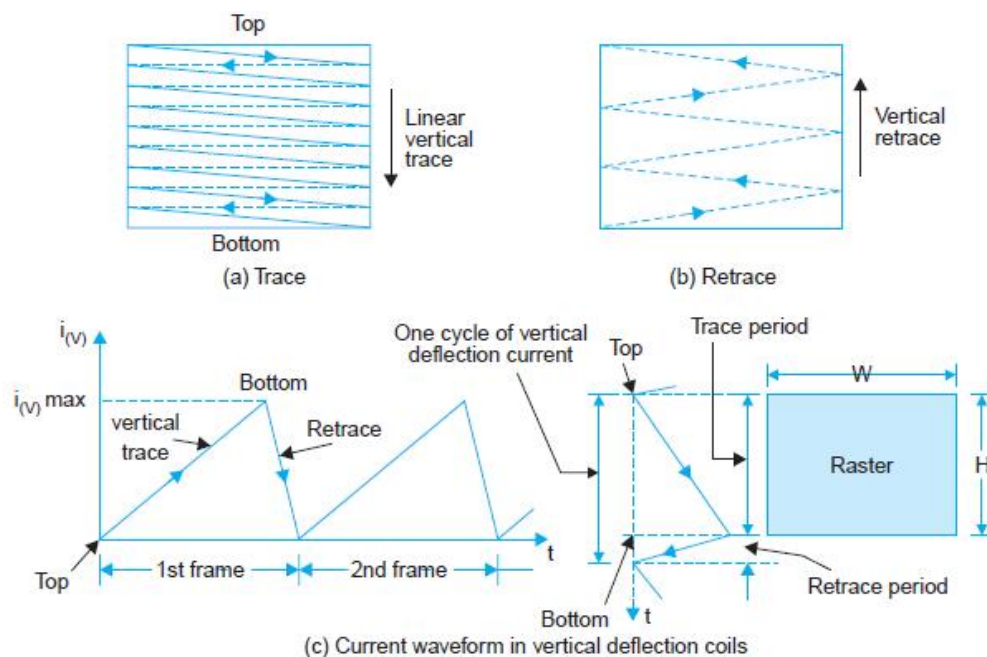


Fig. 2.2 Vertical deflection and deflection current waveform.

2.3 NUMBER OF SCANNING LINES

Most scenes have brightness gradations in the vertical direction. The ability of the scanning beam to allow reproduction of electrical signals according to these variations and the capability of the human eye to resolve these distinctly, while viewing the reproduced picture, depends on the total number of lines employed for scanning.

It is possible to arrive at some estimates of the number of lines necessary by considering the bar pattern shown in Fig. 2.3 (a), where alternate lines are black and white. If the thickness of the scanning beam is equal to the width of each white and black bar, and the number of scanning lines is chosen equal to the number of bars, the electrical information corresponding to the brightness of each bar will be correctly reproduced during the scanning process. Obviously the greater the number of lines into which the picture is divided in the vertical plane, the better will be the resolution. However, the total number of lines that need be employed is limited by the resolving capability of the human eye at the minimum viewing distance.

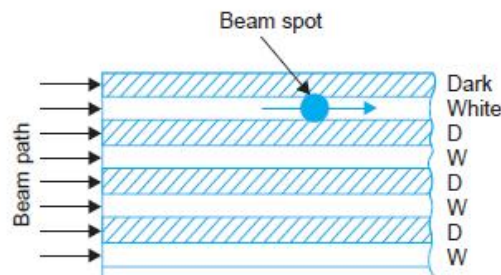


Fig. 2.3 (a) Scanning spot perfectly aligned with black and white lines.

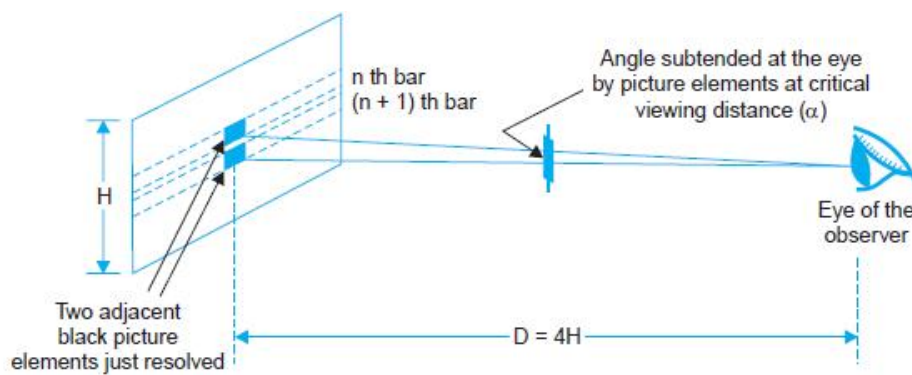


Fig. 2.3 (b) Critical viewing distance as determined by the ability of the eye to resolve two separate picture elements.

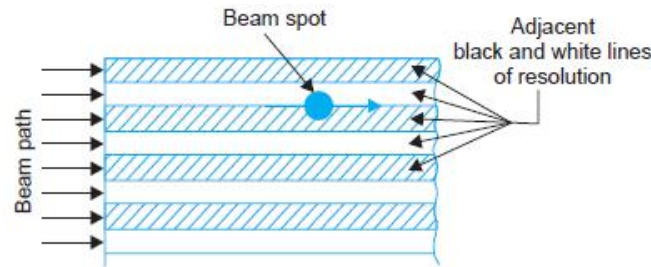


Fig. 2.3 (c) Scanning beam focused on the junction of black and white lines.

The maximum number of alternate light and dark elements (lines) which can be resolved by the eye is given by

$$N_v = \frac{1}{\alpha \rho}$$

where N_v = total number of lines (elements) to be resolved in the vertical direction, α = minimum resolving angle of the eye expressed in radians, and $\rho = D/H$ = viewing-distance/picture height.

For the eye this resolution is determined by the structure of the retina, and the brightness level of the picture. it has been determined experimently that with reasonable brightness variations and a minimum viewing distance of four times the picture height ($D/H = 4$), the angle that any two adjacent elements must subtend at the eye for distinct resolution is approximately one minute ($1/60$ degree). This is illustrated in Fig. 2.3 (b). Substituting these values of α and ρ we get

$$N_v = \frac{1}{(\pi / 180 \times 1 / 60) \times 4} \approx 860$$

Thus if the total number of scanning lines is chosen close to 860 and the scanning beam as illustrated in Fig. 2.3 (a) just passes over each bar (line) separately while scanning all the lines from top to bottom of the picture frame, a distinct pick up of the picture information results and this is the best that can be expected from the system. This perhaps explains the use of 819 lines in the original French TV system.

In practice however, the picture elements are not arranged as equally spaced segments but have random distribution of black, grey and white depending on the nature of the picture details or the scene under consideration. Statistical analysis and subjective tests carried out to determine the average number of effective lines suggest that about 70 per cent of the total lines or segments get separately scanned in the vertical direction and the remaining 30 per cent get merged with other elements due to the beam spot falling equally on two consecutive lines. This is illustrated in Fig. 2.3 (c). Thus the effective number of lines distinctly resolved, i.e., $N_r = N_v \times k$, where k is the resolution factor whose value lies between 0.65 to 0.75. Assuming the value of $k = 0.7$ we get, $N_r = N_v \times k = 860 \times 0.7 = 602$.

However, there are other factors which also influence the choice of total number of lines in a TV system. Tests conducted with many observers have shown that though the eye can detect the effective sharpness provided by about 800 scanning lines, but the improvement is not very significant with line numbers greater than 500 while viewing pictures having motion. Also the channel bandwidth increases with increase in number of lines and this not only adds to the cost of the system but also reduces the number of television channels that can be provided in a given VHF or UHF transmission band. Thus as a compromise between quality and cost, the total number of lines inclusive of those lost during vertical retrace has been chosen to be 625 in the 625-B monochrome TV system. In the 525 line American system, the total number of lines has been fixed at 525 because of a somewhat higher scanning rate employed in this system.

2.4 FLICKER

Although the rate of 24 pictures per second in motion pictures and that of scanning 25 frames per second in television pictures is enough to cause an illusion of continuity, they are not rapid enough to allow the brightness of one picture or frame to blend smoothly into the next through the time when the screen is blanked between successive frames. This results in a definite flicker of light that is very annoying to the observer when the screen is made alternately bright and dark.

This problem is solved in motion pictures by showing each picture twice, so that 48 views of the scene are shown per second although there are still the same 24 picture frames per second. As a result of the increased blanking rate, flicker is eliminated.

Interlaced scanning. In television pictures an effective rate of 50 vertical scans per second is utilized to reduce flicker. This is accomplished by increasing the downward rate of travel of the scanning electron beam, so that every alternate line gets scanned instead of every successive line. Then, when the beam reaches the bottom of the picture frame, it quickly returns to the top to scan those lines that were missed in the previous scanning. Thus the total number of lines are divided into two groups called 'fields'. Each field is scanned alternately. This method of scanning is known as interlaced scanning and is illustrated in Fig. 2.4. It reduces flicker to an acceptable level since the area of the screen is covered at twice the rate. This is like reading alternate lines of a page from top to bottom once and then going back to read the remaining lines down to the bottom.

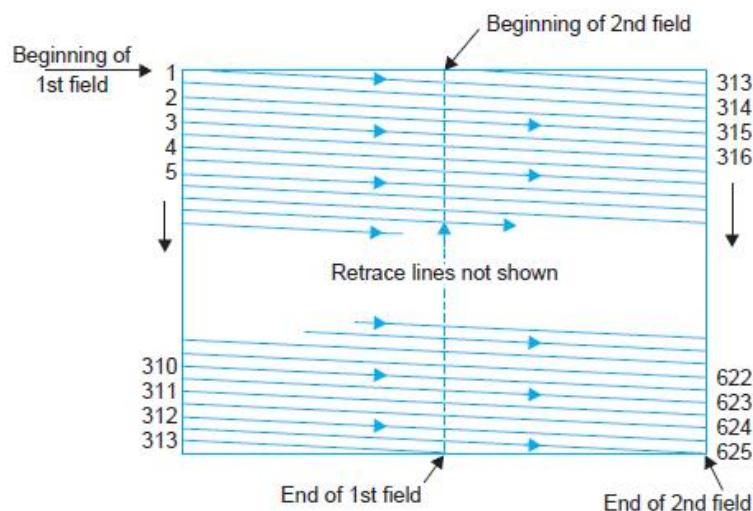


Fig. 2.4 Principle of interlaced scanning. Note that the vertical retrace time has been assumed to be zero.

In the 625 line monochrome system, for successful interlaced scanning, the 625 lines of each frame or picture are divided into sets of 312.5 lines and each set is scanned alternately to cover the entire picture area. To achieve this the horizontal sweep oscillator is made to work at a frequency of 15625 Hz ($312.5 \times 50 = 15625$) to scan the same number of lines per frame ($15625/25 = 625$ lines), but the vertical sweep circuit is run at a frequency of 50 instead of 25 Hz. Note that since the beam is now deflected from top to bottom in half the time and the horizontal oscillator is still operating at 15625 Hz, only half the total lines, i.e., 312.5 ($625/2 = 312.5$) get scanned during each vertical sweep. Since the first field ends in a half line and the second field commences at middle of the line on the top of the target plate or screen (see Fig. 2.4), the beam is able to scan the remaining 312.5 alternate lines during its downward journey. In all then, the beam scans 625 lines ($312.5 \times 2 = 625$) per frame at the same rate of 15625 lines ($312.5 \times 50 = 15625$) per second. Therefore, with interlaced scanning the flicker effect is eliminated without increasing the speed of scanning, which in turn does not need any increase in the channel bandwidth.

It may be noted that the frame repetition rate of 25 (rather than 24 as used in motion pictures) was chosen to make the field frequency equal to the power line frequency of 50 Hz. This helps in reducing the undesired effects of hum due to pickup from the mains, because then such effects in the picture stay still, instead of drifting up or down on the screen. In the American TV system, a field frequency of 60 was adopted because the supply frequency is 60 Hz in USA. This brings the total number of lines scanned per second ($(525/2) \times 60 = 15750$) lines to practically the same as in the 625 line system.

Scanning periods. The waveshapes of both horizontal and vertical sweep currents are shown in Fig. 2.5. As shown there the retrace times involved (both horizontal and vertical) are due to physical limitations of practical scanning systems and are not utilized for transmitting or receiving any video signal. The nominal duration of the horizontal line as shown in Fig. 2.5 (a) is $64 \mu\text{s}$ ($10^6/15625 = 64 \mu\text{s}$), out of which the active line period is $52 \mu\text{s}$ and the remaining $12 \mu\text{s}$

is the line blanking period. The beam returns during this short interval to the extreme left side of the frame to start tracing the next line.

Similarly with the field frequency set at 50 Hz, the nominal duration of the vertical trace (see Fig. 2.5(b)) is 20 ms ($1/50 = 20$ ms). Out of this period of 20 ms, 18.720 ms are spent in bringing the beam from top to bottom and the remaining 1.280 ms is taken by the beam to return back to the top to commence the next cycle. Since the horizontal and vertical sweep oscillators operate continuously to achieve the fast sequence of interlaced scanning, 20 horizontal

lines $\left(\frac{1280 \mu\text{s}}{64 \mu\text{s}} = 20 \text{ lines} \right)$ get traced during each vertical retrace interval. Thus 40 scanning lines are lost per frame, as blanked lines during the retrace interval of two fields. This leaves the active number of lines, N_a , for scanning the picture details equal to $625 - 40 = 585$, instead of the 625 lines actually scanned per frame.

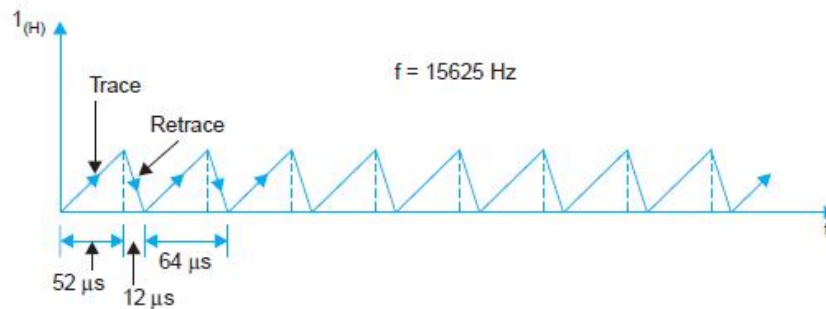


Fig. 2.5 (a) Horizontal deflection current.

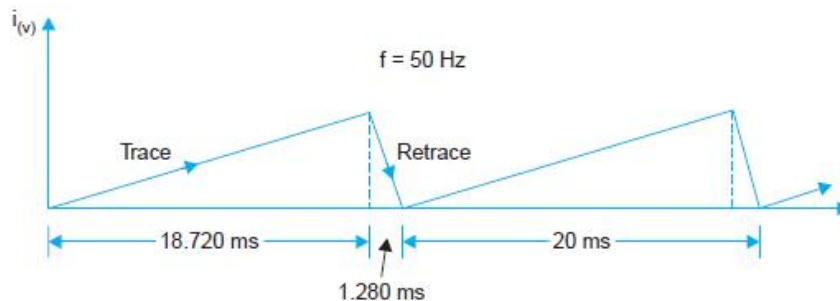


Fig. 2.5 (b) Vertical deflection current.

Scanning sequence. The complete geometry of the standard interlaced scanning pattern is illustrated in Fig. 2.6. Note that the lines are numbered in the sequence in which these are actually scanned. During the first vertical trace actually 292.5 lines are scanned. The beam starts at A, and sweeps across the frame with uniform velocity to cover all the picture elements in one horizontal line. At the end of this trace the beam then retraces rapidly to the left side of the frame as shown by the dashed line in the illustration to begin the next horizontal line. Note that the horizontal lines slope downwards in the direction of scanning because the vertical deflecting current simultaneously produces a vertical scanning motion, which is very slow

compared with horizontal scanning. The slope of the horizontal trace from left to right is greater than during retrace from right to left. The reason is that the faster retrace does not allow the beam so much time to be deflected vertically. After line one, the beam is at the left side ready to scan line 3, omitting the second line. However, as mentioned earlier it is convenient to number the lines as they are scanned and so the next scanned line skipping one line, is numbered two and not three. This process continues till the last line gets scanned half when the vertical motion reaches the bottom of the raster or frame. As explained earlier skipping of lines is accomplished by doubling the vertical scanning frequency from the frame or picture repetition rate of 25 to the field frequency of 50 Hz. With the field frequency of 50 Hz the height of the raster is so set that 292.5 lines get scanned as the beam travels from top to bottom and reaches

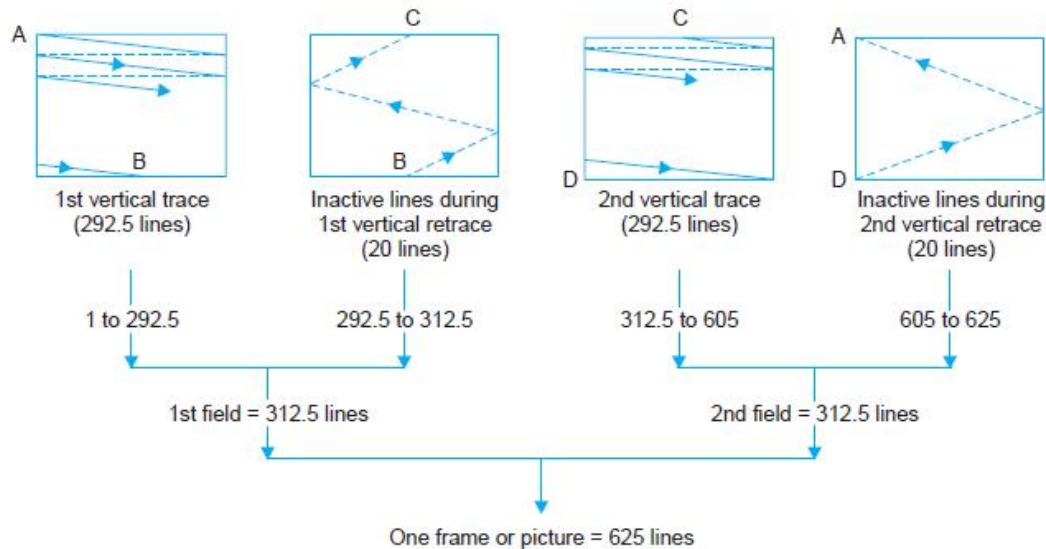


Fig. 2.6 Odd line interlaced scanning procedure.

point B. Now the retrace starts and takes a period equal to 20 horizontal line periods to reach the top marked C. These 20 lines are known as inactive lines, as the scanning beam is cut-off during this period. Thus the second field starts at the middle of the raster and the first line scanned is the 2nd half of line number 313. The scanning of second field, starting at the middle of the raster automatically enables the beam to scan the alternative lines left unscanned during the first field. The vertical scanning motion otherwise is exactly the same as in the previous field giving all the horizontal lines the same slope downwards in the direction of scanning. As a result 292.5 lines again get scanned and the beam reaches the bottom of the frame when it has completed full scanning of line number 605. The inactive vertical retrace again begins and brings the beam back to the top at point A in a period during which 20 blanked horizontal lines (605 to 625) get scanned. Back at point A, the scanning beam has just completed two fields or one frame and is ready to start the third field covering the same area (no. of lines) as scanned during the first field. This process (of scanning fields) is continued at a fast rate of 50 times a second, which not only creates an illusion of continuity but also solves the problem of flicker satisfactorily.

Composite Video Signal

Composite video signal consists of a camera signal corresponding to the desired picture information, blanking pulses to make the retrace invisible, and synchronizing pulses to synchronize the transmitter and receiver scanning. A horizontal synchronizing (sync) pulse is needed at the end of each active line period whereas a vertical sync pulse is required after each field is scanned. The amplitude of both horizontal and vertical sync pulses is kept the same to obtain higher efficiency of picture signal transmission but their duration (width) is chosen to be different for separating them at the receiver. Since sync pulses are needed consecutively and not simultaneously with the picture signal, these are sent on a time division basis and thus form a part of the composite video signal.

3.1 VIDEO SIGNAL DIMENSIONS

Figure 3.1 shows the composite video signal details of three different lines each corresponding to a different brightness level of the scene. As illustrated there, the video signal is constrained to vary between certain amplitude limits. The level of the video signal when the picture detail being transmitted corresponds to the maximum whiteness to be handled, is referred to as peak-white level. This is fixed at 10 to 12.5 percent of the maximum value of the signal while the black level corresponds to approximately 72 percent. The sync pulses are added at 75 percent level called the blanking level. The difference between the black level and blanking level is known as the 'Pedestal'. However, in actual practice, these two levels, being very close, tend to merge with each other as shown in the figure. Thus the picture information may vary between 10 percent to about 75 percent of the composite video signal depending on the relative brightness of the picture at any instant. The darker the picture the higher will be the voltage within those limits.

Note that the lowest 10 percent of the voltage range (whiter than white range) is not used to minimize noise effects. This also ensures enough margin for excessive bright spots to be accommodated without causing amplitude distortion at the modulator.

At the receiver the picture tube is biased to ensure that a received video voltage corresponding to about 10 percent modulation yields complete whiteness at that particular point on the screen, and an analogous arrangement is made for the black level. Besides this, the television receivers are provided with 'brightness' and 'contrast' controls to enable the viewer to make final adjustments as he thinks fit.

D.C. component of the video signal. In addition to continuous amplitude variations for individual picture elements, the video signal has an average value or dc component

corresponding to the average brightness of the scene. In the absence of dc component the receiver cannot follow changes in brightness, as the ac camera signal, say for grey picture elements on a black background will then be the same as a signal for white area on a grey background. In Fig. 3.1, dc components of the signal for three lines have been identified, each representing a different level of average brightness in the scene. It may be noted that the break shown in the illustration after each line signal is to emphasize that dc component of the video signal is the average value for complete frames rather than lines since the background information of the picture indicates the brightness of the scene. Thus Fig. 3.1 illustrates the concept of change in the average brightness of the scene with the help of three lines in separate frames because the average brightness can change only from frame to frame and not from line to line.

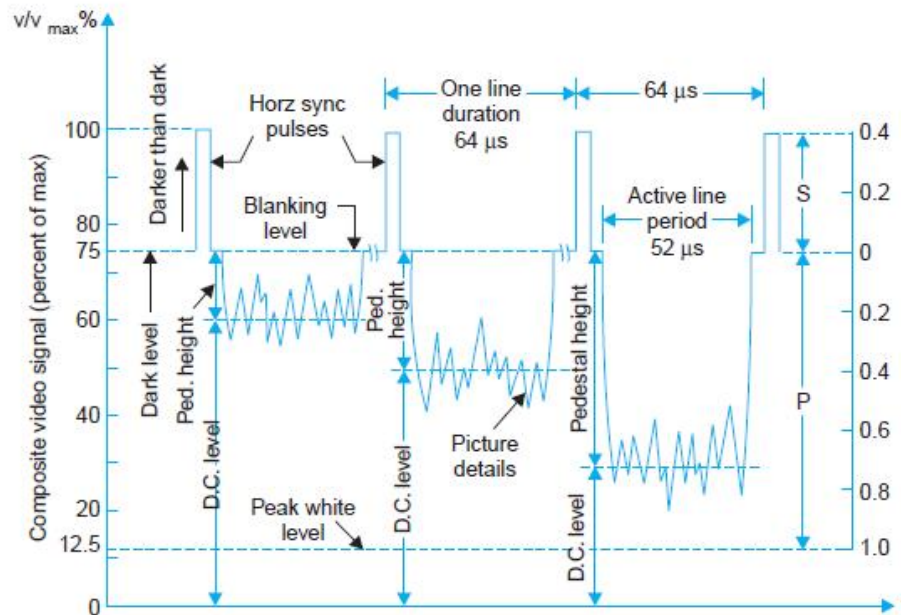


Fig. 3.1 Arbitrary picture signal details of three scanning lines with different average brightness levels. Note that picture to sync ratio $P/S = 10/4$.

Pedestal height. As noted in Fig. 3.1 the pedestal height is the distance between the pedestal level and the average value (dc level) axis of the video signal. This indicates average brightness since it measures how much the average value differs from the black level. Even when the signal loses its dc value when passed through a capacitor-coupled circuit the distance between the pedestal and the dc level stays the same and thus it is convenient to use the pedestal level as the reference level to indicate average brightness of the scene.

Setting the pedestal level. The output signal from the TV camera is of very small amplitude and is passed through several stages of ac coupled high gain amplifiers before being coupled to a control amplifier. Here sync pulses and blanking pulses are added and then clipped at the correct level to form the pedestals. Since the pedestal height determines the average brightness of the scene, any smaller value than the correct one will make the scene darker while a larger pedestal height will result in higher average brightness. The video control operator who observes the scene at the studio sets the level for the desired brightness in the reproduced picture which

he is viewing on a monitor receiver. This is known as dc insertion because this amounts to adding a dc component to the ac signal. Once the dc insertion has been accomplished the pedestal level becomes the black reference and the pedestal height indicates correct relative brightness for the reproduced picture. However, the dc level inserted in the control amplifier is usually lost in succeeding stages because of capacitive coupling, but still the correct dc component can be reinserted when necessary because the pedestal height remains the same.

The blanking pulses. The composite video signal contains blanking pulses to make the retrace lines invisible by raising the signal amplitude slightly above the black level (75 per cent) during the time the scanning circuits produce retraces. As illustrated in Fig. 3.2, the composite video signal contains horizontal and vertical blanking pulses to blank the corresponding retrace intervals. The repetition rate of horizontal blanking pulses is therefore equal to the line scanning frequency of 15625 Hz. Similarly the frequency of the vertical blanking pulses is equal to the field-scanning frequency of 50 Hz. It may be noted that though the level of the blanking pulses is distinctly above the picture signal information, these are not used as sync pulses. The reason is that any occasional signal corresponding to any extreme black portion in the picture may rise above the blanking level and might conceivably interfere with the synchronization of the scanning generators. Therefore, the sync pulses, specially designed for triggering the sweep oscillators are placed in the upper 25 per cent (75 per cent to 100 per cent of the carrier amplitude) of the video signal, and are transmitted along with the picture signal.

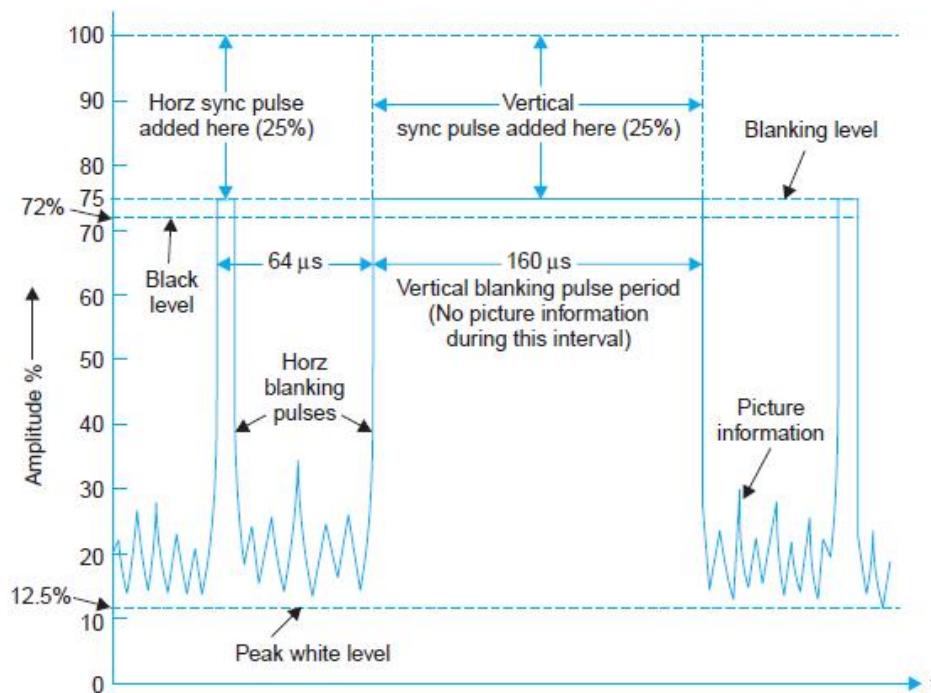


Fig. 3.2 Horizontal and vertical blanking pulses in video signal. Sync pulses are added above the blanking level and occupy upper 25% of the composite video signal amplitude.

Sync pulse and video signal amplitude ratio. The overall arrangement of combining the picture signal and sync pulses may be thought of as a kind of voltage division multiplexing where about 65 per cent of the carrier amplitude is occupied by the video signal and the upper

25 per cent by the sync pulses. Thus, as shown in Fig. 3.1, the final radiated signal has a picture to sync signal ratio (P/S) equal to 10/4. This ratio has been found most satisfactory because if the picture signal amplitude is increased at the expense of sync pulses, then when the signal to noise ratio of the received signal falls, a point is reached when the sync pulse amplitude becomes insufficient to keep the picture locked even though the picture voltage is still of adequate amplitude to yield an acceptable picture. On the other hand if sync pulse height is increased at the expense of the picture detail, then under similar conditions the raster remains locked but the picture content is of too low an amplitude to set up a worthwhile picture. A ratio of $P/S = 10/4$, or thereabout, results in a situation such that when the signal to noise ratio reaches a certain low level, the sync amplitude becomes insufficient, *i.e.*, the sync fails at the same time as the picture ceases to be of entertainment value. This represents the most efficient use of the television system.

3.2 HORIZONTAL SYNC DETAILS

The horizontal blanking period and sync pulse details are illustrated in Fig. 3.3. The interval between horizontal scanning lines is indicated by H . As explained earlier, out of a total line

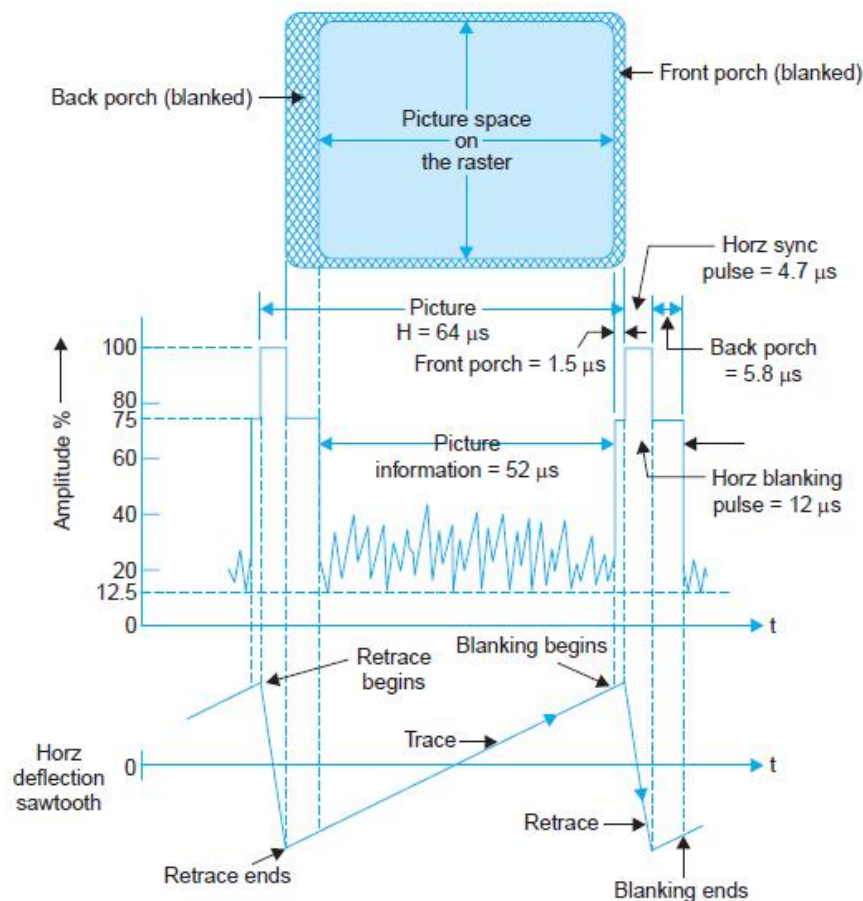


Fig. 3.3 Horz line and sync details compared to horizontal deflection sawtooth and picture space on the raster

period of 64 μs , the line blanking period is 12 μs . During this interval a line synchronizing pulse is inserted. The pulses corresponding to the differentiated leading edges of the sync pulses are actually used to synchronize the horizontal scanning oscillator. This is the reason why in Fig. 3.3 and other figures to follow, all time intervals are shown between sync pulse leading edges.

The line blanking period is divided into three sections. These are the 'front porch', the 'line sync' pulse and the 'back porch'. The time intervals allowed to each part are summarized below and their location and effect on the raster is illustrated in Fig. 3.3.

Details of Horizontal Scanning

<i>Period</i>	<i>Time (μs)</i>
Total line (<i>H</i>)	64
Horz blanking	$12 \pm .3$
Horz sync pulse	4.7 ± 0.2
Front porch	$1.5 \pm .3$
Back porch	$5.8 \pm .3$
Visible line time	52

Front porch. This is a brief cushioning period of 1.5 μs inserted between the end of the picture detail for that line and the leading edge of the line sync pulse. This interval allows the receiver video circuit to settle down from whatever picture voltage level exists at the end of the picture line to the blanking level before the sync pulse occurs. Thus sync circuits at the receiver are isolated from the influence of end of the line picture details. The most stringent demand is made on the video circuits when peak white detail occurs at the end of a line. Despite the existence of the front porch when the line ends in an extreme white detail, and the signal amplitude touches almost zero level, the video voltage level fails to decay to the blanking level before the leading-edge of the line sync pulse occurs. This results in late triggering of the time base circuit thus upsetting the 'horz' line sync circuit. As a result the spot (beam) is late in arriving at the left of the screen and picture information on the next line is displaced to the left. This effect is known as 'pulling-on-whites'.

Line sync pulse. After the front porch of blanking, horizontal retrace is produced when the sync pulse starts. The flyback is definitely blanked out because the sync level is blacker than black. Line sync pulses are separated at the receiver and utilized to keep the receiver line time base in precise synchronism with the distant transmitter. The nominal time duration for the line sync pulses is 4.7 μs . During this period the beam on the raster almost completes its back stroke (retrace) and arrives at the extreme left end of the raster.

Back porch. This period of 5.8 μs at the blanking level allows plenty of time for line flyback to be completed. It also permits time for the horizontal time-base circuit to reverse direction of current for the initiation of the scanning of next line. Infact, the relative timings are so set that small black bars (see Fig. 3.3) are formed at both the ends of the raster in the horizontal plane. These blanked bars at the sides have no effect on the picture details reproduced during the active line period.

The back porch* also provides the necessary amplitude equal to the blanking level (reference level) and enables to preserve the dc content of the picture information at the transmitter. At the receiver this level which is independent of the picture details is utilized in the AGC (automatic gain control) circuits to develop true AGC voltage proportional to the signal strength picked up at the antenna.

3.3 VERTICAL SYNC DETAILS

The vertical sync pulse train added after each field is somewhat complex in nature. The reason for this stems from the fact that it has to meet several exacting requirements. Therefore, in order to fully appreciate the various constituents of the pulse train, the vertical sync details are explored step by step while explaining the need for its various components.

The basic vertical sync added at the end of both even and odd fields is shown in Fig. 3.4. Its width has to be kept much larger than the horizontal sync pulse, in order to derive a suitable field sync pulse at the receiver to trigger the field sweep oscillator.

The standards specify that the vertical sync period should be 2.5 to 3 times the horizontal line period. If the width is less than this, it becomes difficult to distinguish between horizontal and vertical pulses at the receiver.

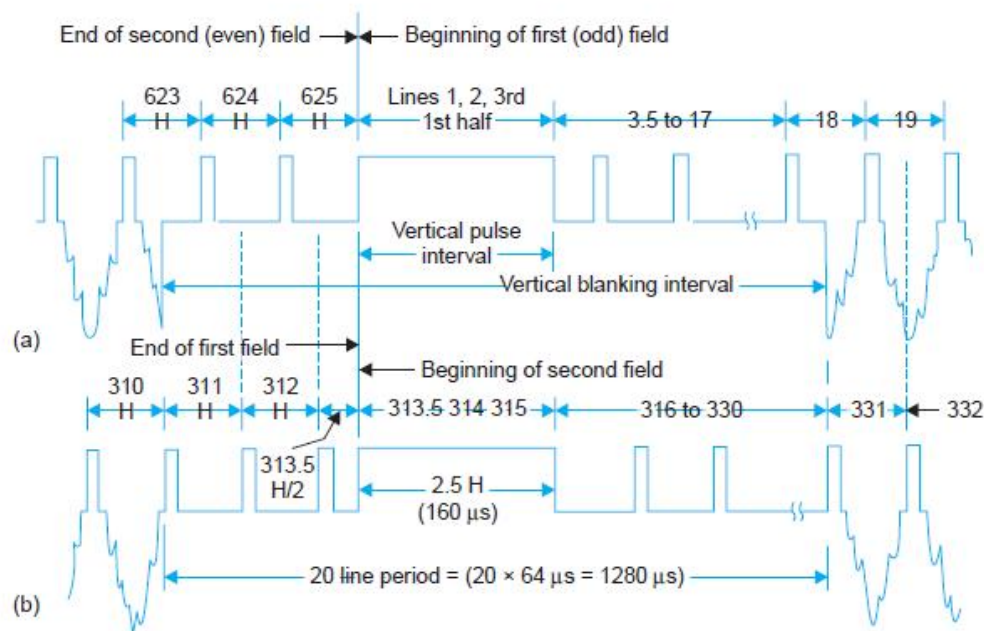


Fig. 3.4 Composite video waveforms showing horizontal and basic vertical sync pulses at the end of (a) second (even) field, (b) first (odd) field. Note, the widths of horizontal blanking intervals and sync pulses are exaggerated.

*In colour TV transmission a short sample (8 to 10 cycles) of the colour subcarrier oscillator output is sent to the receiver for proper detection of colour signal sidebands. This is known as colour burst and is located at the back porch of the horizontal blanking pedestal.

If the width is greater than this, the transmitter must operate at peak power for an unnecessarily long interval of time. In the 625 line system 2.5 line period ($2.5 \times 64 = 160 \mu\text{s}$) has been allotted for the vertical sync pulses. Thus a vertical sync pulse commences at the end of 1st half of 313th line (end of first field) and terminates at the end of 315th line. Similarly after an exact interval of 20 ms (one field period) the next sync pulse occupies line numbers—1st, 2nd and 1st half of third, just after the second field is over. Note that the beginning of these pulses has been aligned in the figure to signify that these must occur after the end of vertical stroke of the beam in each field, *i.e.*, after each $1/50$ th of a second. This alignment of vertical sync pulses, one at the end of a half-line period and the other after a full line period (see Fig. 3.4), results in a relative misalignment of the horizontal sync pulses and they do not appear one above the other but occur at half-line intervals with respect to each other. However, a detailed examination of the pulse trains in the two fields would show that horizontal sync pulses continue to occur exactly at $64 \mu\text{s}$ intervals (except during the vertical sync pulse periods) throughout the scanning period from frame to frame and the apparent shift of $32 \mu\text{s}$ is only due to the alignment of vertical sync instances in the figure.

As already mentioned the horizontal sync information is extracted from the sync pulse train by differentiation, *i.e.*, by passing the pulse train through a high-pass filter. Indeed pulses corresponding to the differentiated leading edges of sync pulses are used to synchronise the horizontal scanning oscillator. The process of deriving these pulses is illustrated in Fig. 3.5. Furthermore, receivers often use monostable multivibrators to generate horizontal scan, and so a pulse is required to initiate each and every cycle of the horizontal oscillator in the receiver.

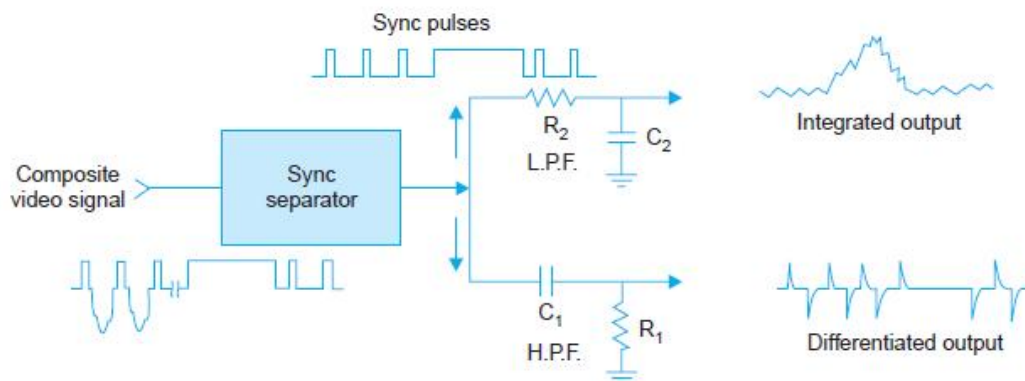


Fig. 3.5 Sync pulse separation and generation of vertical and horizontal sync pulses.

This brings out the first and most obvious shortcoming of the waveforms shown in Fig. 3.4. The horizontal sync pulses are available both during the active and blanked line periods but there are no sync pulses (leading edges) available during the 2.5 line vertical sync period. Thus the horizontal sweep oscillator that operates at 15625 Hz , would tend to step out of synchronism during each vertical sync period. The situation after an odd field is even worse. As shown in Fig. 3.4, the vertical blanking period at the end of an odd field begins midway through a horizontal line. Consequently, looking further along this waveform, we see that the leading edge of the vertical sync pulse comes at the wrong time to provide synchronization for the horizontal oscillator. Therefore, it becomes necessary to cut slots in the vertical sync pulse at half-line-intervals to provide horizontal sync pulses at the correct instances both after even and odd fields. The technique is to take the video signal amplitude back to the blanking level

4.7 μs before the line pulses are needed. The waveform is then returned back to the maximum level at the moment the line sweep circuit needs synchronization. Thus five narrow slots of 4.7 μs width get formed in each vertical sync pulse at intervals of 32 μs . The trailing but rising edges of these pulses are actually used to trigger the horizontal oscillator. The resulting waveforms together with line numbers and the differentiated output of both the field trains is illustrated in Fig. 3.6. This insertion of short pulses is known as notching or serration of the broad field pulses.

Note that though the vertical pulse has been broken to yield horizontal sync pulses, the effect on the vertical pulse is substantially unchanged. It still remains above the blanking voltage level all of the time it is acting. The pulse width is still much wider than the horizontal pulse width and thus can be easily separated at the receiver. Returning to Fig. 3.6 it is seen that each horizontal sync pulse yields a positive spiked output from its leading edge and a negative spiked pulse from its trailing edge. Time-constant of the differentiating circuit is so chosen, that by the time a trailing edge arrives, the pulse due to the leading edge has just about decayed. The negative-going triggering pulses may be removed with a diode since only the positive going pulses are effective in locking the horizontal oscillator.

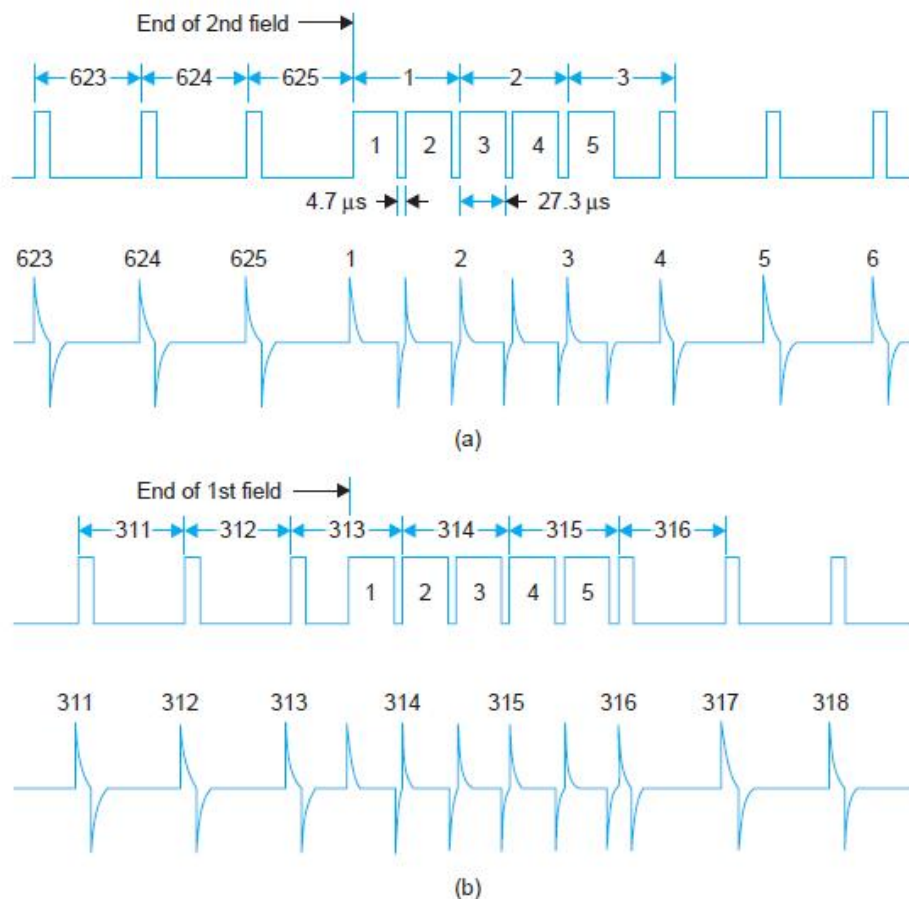


Fig. 3.6 Differentiating waveforms (a) pulses at the end of even (2nd) field and the corresponding output of the differentiator (H.P.F.) (b) pulses at the end of odd (1st) field and the corresponding output of the differentiator (H.P.F.) Note, the differentiated pulses

However, the pulses actually utilized are the ones that occur sequentially at $64\ \mu\text{s}$ intervals. Such pulses are marked with line numbers for both the fields. Note that during the intervals of serrated vertical pulse trains, alternate vertical spikes are utilized. The pulses not used in one field are the ones utilized during the second field. This happens because of the half-line difference at the commencement of each field and the fact that notched vertical sync pulses occur at intervals of $32\ \mu\text{s}$ and not $64\ \mu\text{s}$ as required by the horizontal sweep oscillator. The pulses that come at a time when they cannot trigger the oscillator are ignored. Thus the requirement of keeping the horizontal sweep circuit locked despite insertion of vertical sync pulses is realized.

Now we turn to the second shortcoming of the waveform of Fig. 3.4. First it must be mentioned that synchronization of the vertical sweep oscillator in the receiver is obtained from vertical sync pulses by integration. This is illustrated in Fig. 3.5 where the time-constant R_2C_2 is chosen to be large compared to the duration of horizontal pulses but not with respect to width of the vertical sync pulses. The integrating circuit may equally be looked upon as a low-pass filter, with a cut-off frequency such that the horizontal sync pulses produce very little output, while the vertical pulses have a frequency that falls in the pass-band of the filter. The voltage built across the capacitor of the low-pass filter (integrating circuit) corresponding to the sync pulse trains of both the fields is shown in Fig. 3.7. Note that each horizontal pulse causes a slight rise in voltage across the capacitor but this is reduced to zero by the time the next pulse arrives. This is so, because the charging period for the capacitor is only $4.7\ \mu\text{s}$ and the voltage at the input to the integrator remains at zero for the rest of the period of $59.3\ \mu\text{s}$. Hence there is no residual voltage across the vertical filter (L.P. filter) due to horizontal sync-pulses. Once the broad serrated vertical pulse arrives the voltage across the output of the filter starts increasing. However, the built up voltage differs for each field. The reason is not difficult to find. At the beginning of the first field (odd field) the last horz sync pulse corresponding to the beginning of 625th line is separated from the 1st vertical pulse by full one line and any voltage developed across the filter will have enough time to return to zero before the arrival of the first vertical pulse, and thus the filter output voltage builds up from zero in response to the five successive broad vertical sync pulses. The voltage builds up because the capacitor has more time to charge and only $4.7\ \mu\text{s}$ to discharge. The situation, however, is not the same for the beginning of the 2nd (even) field. Here the last horizontal pulse corresponding to the beginning of 313th line is separated from the first vertical pulse by only half-a-line. The voltage developed across the vertical filter will thus not have enough time to reach zero before the arrival of the first vertical pulse, which means that the voltage build-up does not start from zero, as in the case of the 1st field. The residual voltage on account of the half line discrepancy gets added to the voltage developed on account of the broad vertical pulses and thus the voltage developed across the output filter is some what higher at each instant as compared to the voltage developed at the beginning of the first-field. This is shown in dotted chain line in Fig. 3.7.

The vertical oscillator trigger potential level marked as trigger level in the diagram (Fig. 3.7) intersects the two filter output profiles at different points which indicates that in the case of second field the oscillator will get triggered a fraction of a second too soon as compared

25.5 LUMINANCE, HUE AND SATURATION

Any colour has three characteristics to specify its visual information. These are (i) luminance, (ii) hue or tint, and (iii) saturation. These are defined as follows:

(i) Luminance or Brightness

This is the amount of light intensity as perceived by the eye regardless of the colour. In black and white pictures, better lighted parts have more luminance than the dark areas. Different colours also have shades of luminance in the sense that though equally illuminated appear more or less bright as indicated by the relative brightness response curve of Fig. 25.2. Thus on a monochrome TV screen, dark red colour will appear as black, yellow as white and a light blue colour as grey.

(ii) Hue

This is the predominant spectral colour of the received light. Thus the colour of any object is distinguished by its hue or tint. The green leaves have green hue and red tomatoes have red hue. Different hues result from different wavelengths of spectral radiation and are perceived as such by the sets of cones in the retina.

(iii) Saturation

This is the spectral purity of the colour light. Since single hue colours occur rarely alone, this indicates the amounts of other colours present. Thus saturation may be taken as an indication of how little the colour is diluted by white. A fully saturated colour has no white. As an example, vivid green is fully saturated and when diluted by white it becomes light green. The hue and saturation of a colour put together is known as chrominance. Note that it does not contain the brightness information. Chrominance is also called chroma.

Colour Signal Generation

At any instant during the scanning process the transmitted signal must indicate the proportions, of red, green and blue lights which are present in the element being scanned. Besides this, to fulfil the requirements of compatibility, the luminance signal which represents the brightness of the elements being scanned must also be generated and transmitted along with the colour signals. Figure 25.5 illustrates the method of generating these signals. The camera output voltages are labelled as V_R , V_G and V_B but generally the prefix V is omitted and only the symbols R , G , and B are used to represent these voltages. With the specified source of white light the three cameras are adjusted to give equal output voltage.

25.3 COLOUR PERCEPTION

All objects that we observe are focused sharply by the lens system of the eye on its retina. The retina which is located at the back side of the eye has light sensitive organs which measure the visual sensations. The retina is connected with the optic nerve which conducts the light stimuli as sensed by the organs to the optical centre of the brain.

According to the theory formulated by Helmholtz the light sensitive organs are of two types—rods and cones. The rods provide brightness sensation and thus perceive objects only in various shades of grey from black to white. The cones that are sensitive to colour are broadly in three different groups. One set of cones detects the presence of blue colour in the object focused on the retina, the second set perceives red colour and the third is sensitive to the green range. Each set of cones, may be thought of as being ‘tuned’ to only a small band of frequencies and so absorb energy from a definite range of electromagnetic radiation to convey the sensation of corresponding colour or range of colour. The combined relative luminosity curve showing relative sensation of brightness produced by individual spectral colours radiated at a constant energy level is shown in Fig. 25.2. It will be seen from the plot that the sensitivity of the human eye is greatest for green light, decreasing towards both the red and blue ends of the spectrum. In fact the maximum is located at about 550 nm, a yellow green, where the spectral energy maximum of sunlight is also located.

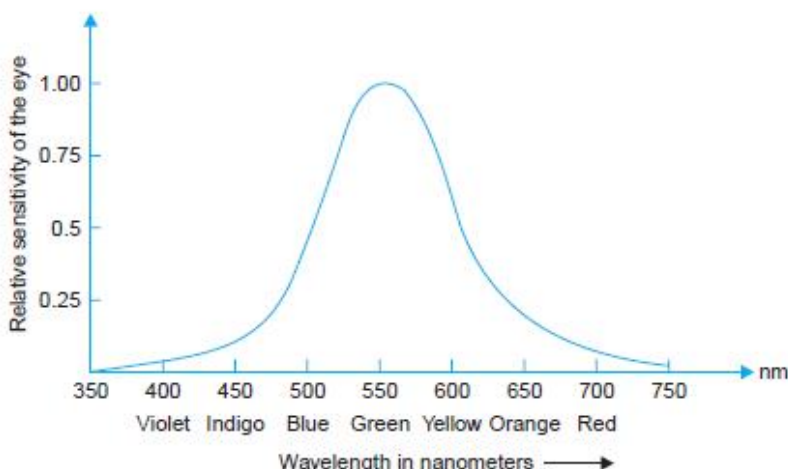


Fig. 25.2. Approximate relative response of the eye to different colours.

Mixing of Colours

Mixing of colours can take place in two ways—subtractive mixing and additive mixing. In subtractive mixing, reflecting properties of pigments are used, which absorb all wavelengths but for their characteristic colour wavelengths. When pigments of two or more colours are mixed, they reflect wavelengths which are common to both. Since the pigments are not quite saturated (pure in colour) they reflect a fairly wide band of wavelengths. This type of mixing takes place in painting and colour printing.

In additive mixing which forms the basis of colour television, light from two or more colours obtained either from independent sources or through filters can create a combined sensation of a different colour. Thus different colours are created by mixing pure colours and not by subtracting parts from white.

The additive mixing of three primary colours—red, green and blue in adjustable intensities can create most of the colours encountered in everyday life. The impression of white light can also be created by choosing suitable intensities of these colours.

Red, green and blue are called primary colours. These are used as basic colours in television. By pairwise additive mixing of the primary colours the following complementary colours are produced:

Red + Green = Yellow

Red + Blue = Magenta (purplish red shade)

Blue + Green = Cyan (greenish blue shade)

Colour plate 1 depicts the location of primary and complementary colours on the colour circle.

If a complementary is added in appropriate proportion to the primary which it itself does not contain, white is produced. This is illustrated in Fig. 25.3 (a) where each circle corresponds to one primary colour. Colour plate 2 shows the effect of colour mixing. Similarly Fig. 25.3 (b), illustrates the process of subtractive mixing. Note that as additive mixing of the three primary colours produces white, their subtractive mixing results in black.

*Research has shown that the actual neural process of colour perception is substantially different from the tricolour process. However, all colour reproduction processes in television or printing use variations of this process and is found satisfactory.

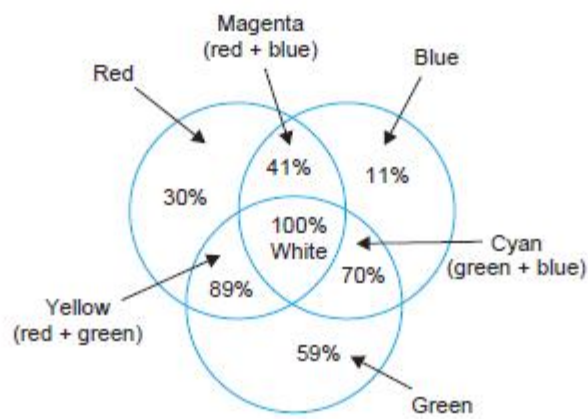


Fig. 25.3 (a). Additive colour mixing. The diagram shows the effect of projecting green, red and blue beams on a white screen in such a way that they overlap.

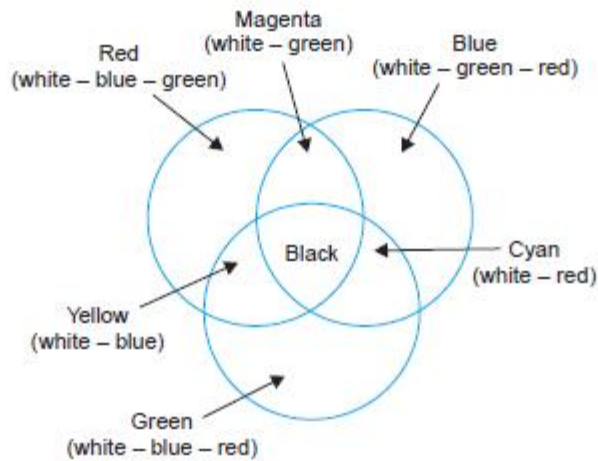


Fig. 25.3 (b). Subtractive colour mixing. The diagram shows the effect of mixing colour pigments under white light.

25.7 THE LUMINANCE SIGNAL

To generate the monochrome or brightness signal that represents the luminance of the scene, the three camera outputs are added through a resistance matrix (see Fig. 25.5) in the proportion of 0.3, 0.59 and 0.11 of R , G and B respectively. This is because with white light which contains the three primary colours in the above ratio, the camera outputs were adjusted to give equal voltages. The signal voltage that develops across the common resistance R_C represents the brightness of the scene and is referred to as 'Y' signal. Therefore,

$$Y = 0.3 R + 0.59 G + 0.11 B$$

Colour Voltage Amplitudes

Figure 25.6 (a) illustrates the nature of output from the three cameras when a horizontal line across a picture having vertical bars of red, green and blue colours is scanned. Note that at any one instant only one camera delivers output voltage corresponding to the colour being scanned.

In Fig. 25.6 (b) different values of red colour voltage are illustrated. Here the red pink and pale pink which are different shades of red have decreasing values of colour intensity. Therefore the corresponding output voltages have decreasing amplitudes. Thus we can say that R , G or B voltage indicates information of the specific colour while their relative amplitudes depend on the level of saturation of that colour.

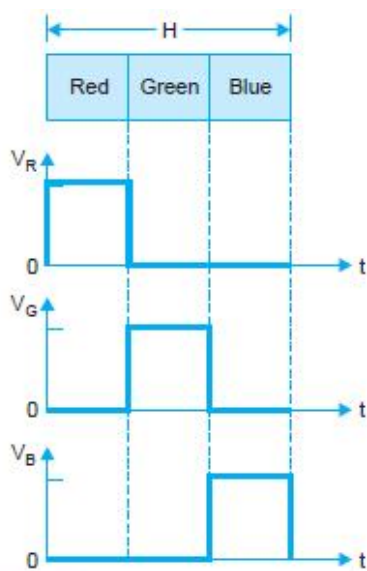


Fig. 25.6 (a). Camera video output voltages for red green and blue colour bars. 'H' indicates one horizontal scanning line.

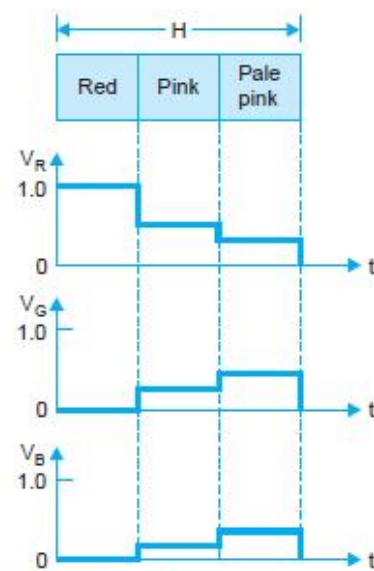


Fig. 25.6 (b). Decreasing amplitudes of the red camera output indicates effect of colour desaturation.

Next consider the scanning across a picture that has yellow and white bars besides the three pure colour bars. The voltages of the three camera outputs are drawn below the colour bar pattern in Fig. 25.7. Notice the values shown for yellow, as an example of a complementary colour. Since yellow includes red and green, video voltage is produced for both these primary colours. Since there is no blue in yellow, the blue camera output voltage is at zero for the yellow bar. The white bar at the right includes all the three primary colours and so all the three cameras develop output voltage when this bar is scanned.

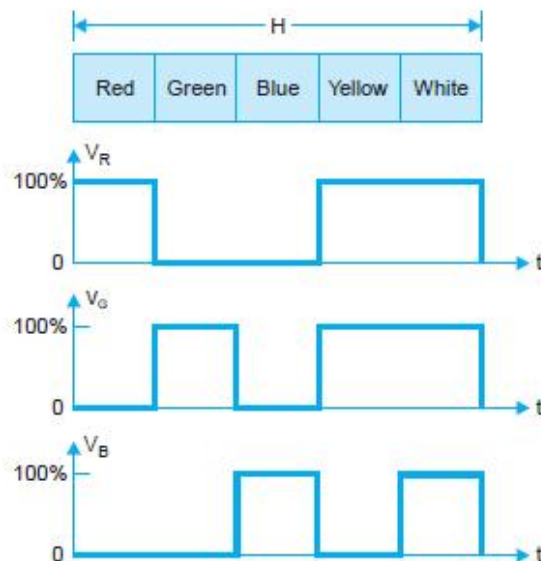


Fig. 25.7. Red, green and blue camera video output voltages for the bar pattern shown above.

'Y' Signal Amplitude

As already stated the 'Y' signal contains brightness variations of the picture information, and is formed by adding the three camera outputs in the ratio, $Y = 0.3 R + 0.59 G + 0.11 B$.

These percentages correspond to the relative brightness of the three primary colours. Therefore a scene reproduced in black and white by the 'Y' signal looks the same as when it is televised in monochrome. Figure 25.8 illustrates how the 'Y' signal voltage is formed from the specified proportions of R , G , and B voltages for the colour bar pattern. The addition, as already explained is carried out (see Fig. 25.5) by the resistance matrix. Note that the 'Y' signal for white has the maximum amplitude (1.0 or 100%) because it includes R , G and B .

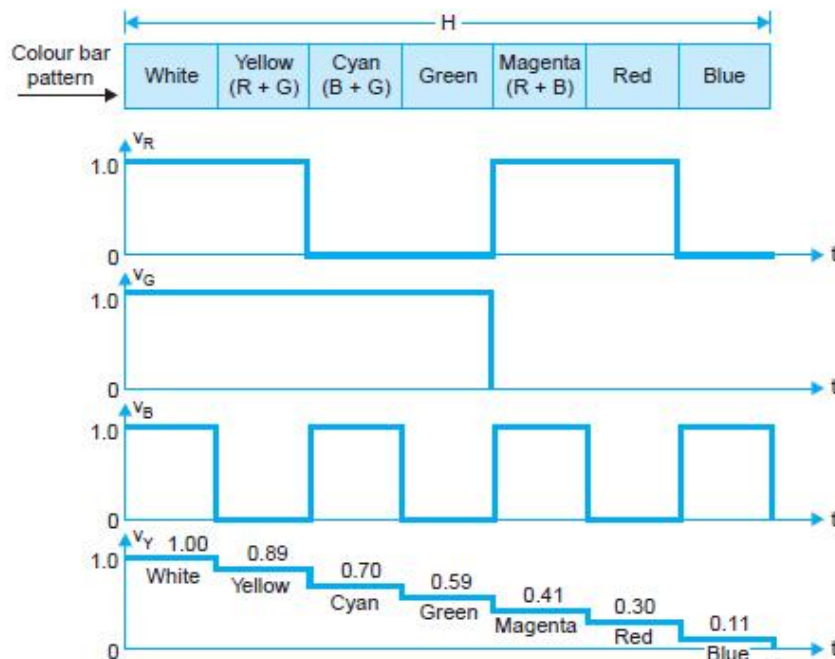


Fig. 25.8. Formation of the luminance (Y) video signal with the resistance matrix from colour camera outputs. Note that yellow appears 89% ($.3R + .59G$) bright as compared to 100% for white. Similarly cyan, green, magenta, red and blue appear 70%, 59%, 41%, 30% and 11% bright respectively as compared to assumed 100% brightness for white.

For the other bars the magnitude of Y decreases or changes in accordance with the colour or colours that form the bars (see colour plate 5). All the voltage values can be calculated as illustrated by the writeup below Fig. 25.8. If only this 'Y' signal is used to reproduce the pattern, it will appear as monochrome bars shading-off from white at the left to grey in the centre and black at the right. These values correspond to the staircase pattern of Y voltage shown in the figure. Note the progressive decrease in voltage for the relative brightness of the various colour bars.

25.8 VALUES OF LUMINANCE (Y) AND COLOUR DIFFERENCE SIGNALS ON COLOURS

When televising colour scenes even when voltages R , G and B are not equal, the 'Y' signal still represents monochrome equivalent of the colour because the proportions 0.3, 0.59 and 0.11 taken of R , G and B respectively still represent the contribution which red, green and blue lights make to the luminance. This aspect can be illustrated by considering some specific colours.

Desaturated Purple

Consider a desaturated purple colour, which is a shade of magenta. Since the hue is magenta (purple) it implies that it is a mixture of red and blue. Two word desaturated indicates that some white light is also there. The white light content will develop all the three i.e., R , G and B voltages, the magnitudes of which will depend on the intensity of desaturation of the colour. Thus R and B voltages will dominate and both must be of greater amplitude than G . As an illustration let $R = 0.7$, $G = 0.2$ and $B = 0.6$ volts. The white content is represented by equal quantities of the three primaries and the actual amount must be indicated by the smallest voltage of the three, that is, by the magnitude of G .

Thus white is due to 0.2 R , 0.2 G and 0.2 B . The remaining, 0.5 R and 0.4 B together represent the magenta hue.

(i) The luminance signal $Y = 0.3 R + 0.59 G + 0.11 B$. Substituting the values of R , G , and B we get $Y = 0.3 (0.7) + 0.59 (0.2) + 0.11(0.6) = 0.394$ (volts).

(ii) The colour difference signals are:

$$(R - Y) = 0.7 - 0.394 = + 0.306 \text{ (volts)}$$

$$(B - Y) = 0.6 - 0.394 = + 0.206 \text{ (volts)}$$

(iii) *Reception at the colour receiver*—At the receiver after demodulation, the signals, Y , $(B - Y)$ and $(R - Y)$, become available. Then by a process of matrixing the voltages B and R are obtained as:

$$R = (R - Y) + Y = 0.306 + 0.394 = 0.7 \text{ V}$$

$$B = (B - Y) + Y = 0.206 + 0.394 = 0.6 \text{ V}$$

(iv) $(G - Y)$ matrix—The missing signal $(G - Y)$ that is not transmitted can be recovered by using a suitable matrix based on the explanation given below:

$$Y = 0.3 R + 0.59G + 0.11B$$

$$\text{also } (0.3 + 0.59 + 0.11)Y = 0.3R + 0.59G + 0.11B$$

Rearranging the above expression we get:

$$0.59(G - Y) = -0.3 (R - Y) - 0.11 (B - Y)$$

$$\therefore (G - Y) = \frac{-0.3}{0.59} (R - Y) - \frac{0.11}{0.59} (B - Y) = -0.51(R - Y) - 0.186 (B - Y)$$

Substituting the values of $(R - Y)$ and $(B - Y)$

$$(G - Y) = - (0.51 \times 0.306) - 0.186(0.206) = -0.15606 - 0.038216 = -0.194$$

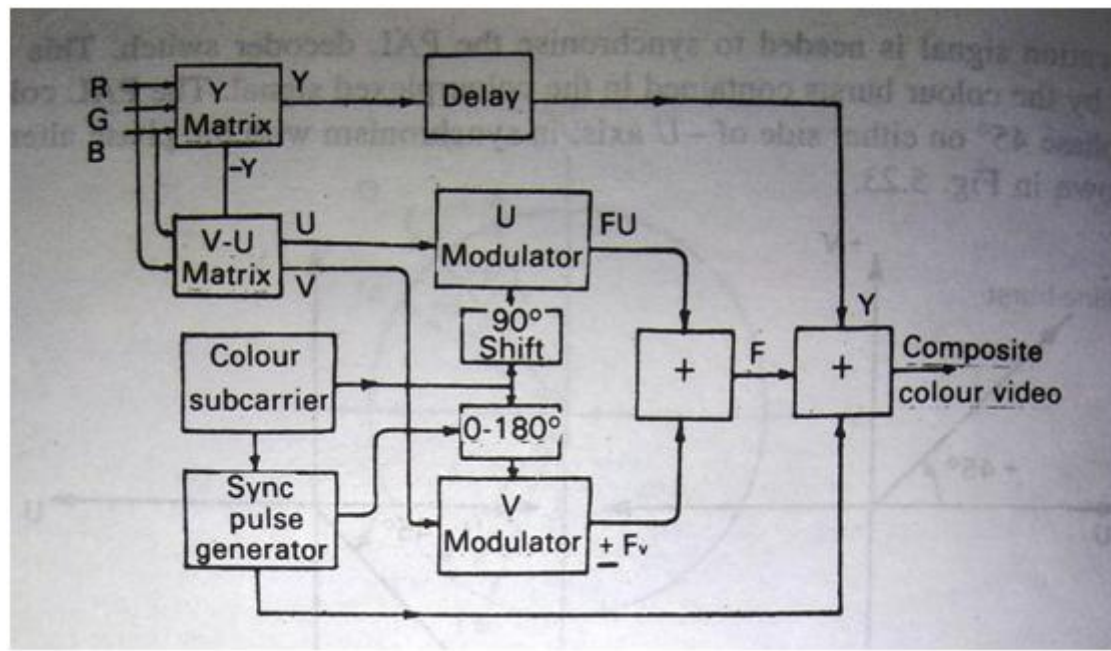
$\therefore G = (G - Y) + Y = -0.194 + 0.394 = 0.2$, and this checks with the given value.

(v) *Reception on a monochrome receiver*—Since the value of luminance signal $Y = 0.394$ V, and the peak white corresponds to 1 volt (100%) the magenta will show up as a fairly dull grey in a black and white picture. This is as would be expected for this colour.

PAL Encoder:

Introduction:

- The block diagram of PAL encoder is shown in figure, it uses the gamma corrected RGB signals from the camera tube as input and produces the composite colour video signal at its output.
 - The gamma corrected RGB signals are applied to the Y matrix, which is a resistive network. It will attenuate RGB signals in adequate proportions to produce the luminance signal Y and its inverted version ($-Y$).
 - The Y signal is applied to the delay line while $-Y$ signal is applied to the (V-U) matrix.
 - The (V-U) matrix is a resistive network which combines the R, B and $-Y$ signals in appropriate proportion to produce the chrominance signal V and U. The relation between V and U and RGB signals can be expressed using the following equations:



- At the output of (V-U) matrix we get U and V signals as shown in figure, the 90 degree phase shifted colour subcarrier(CSC) and the U signal are applied to the U modulator. The U and V signals are band limited to 1-2 MHz. The U modulator output is denoted by a F_U .
- The CSC is also applied to the PAL switch controlled by the sync pulse generator to obtain phase shift of zero degree and 180 degree on alternate lines. This CSC is modulated by V signal to produce signal $\pm F_V$ at the output of the V modulator.
- The F_U and $\pm F_V$ signals are then added together to obtain the F signal, which is further added to the delay compensated luminance Y and the sync and blanking pulses from the sync pulse generator to produce the composite colour video signal.

