UNIT 10 VIDEO COMMUNICATION

Structure

10.1 INTRODUCTION

Television (TV) has become one of the most inevitable parts of our lives these days. It is used for many purposes–for entertainment, for imparting education, for sharing news and information. Since the time John Logie Baird in the early twentieth century invented the first TV, the technology has advanced so much that even the principle of signal generation and transmission/reception process is getting revolutionised.

The use of TV is not just restricted to receiving signals from the senders and displaying them at our homes, there are many other applications. The TV set can be used as a monitor for a computer; it can be used as a display device in closed circuit TV system (CCTVs) used for surveillances or displays in big auditoriums; sometimes video games can be attached to TV sets; the video cassettes, CD or DVD players can be connected to a TV set for replaying recorded video clippings. However, we will restrict our present discussion to the transmit-receive systems only.

The earlier TV transmission was in monochrome (black and white) mode, which represented the image in the shades of grey. Later on, colour television emerged which reproduces all the colours in the image by a combination of the three basic colours viz. Red, Green and Blue (RGB). You must have noticed that these colours are different from the basic colours you have learnt about in the optics classes (Red, Yellow and Blue). You will learn in this unit, how different colours are derived from the RGB combination.

Conventional television receivers used a modification of the cathode-ray tube (CRT) which you must have used in the oscilloscope in your physics laboratory. These sets are quite bulky and fragile due to their glass vacuum dome. With advances in materials and devices the TV screens are being replaced by liquid crystal display (LCD) and plasma display screens. All these advances have miniaturised the TV sets and are becoming popular, though the present costs of such devices are still on the higher side.

You know that the television signals are much bulkier than the audio signals since each frame of the video image is transmitted in the form of pixel information serially. To transmit and store such information in compact fashion, some data compression techniques are used. There is lot of research going on in compression of images signals without losing the information content.

In this unit we will be covering all these aspects of video communication. The television signal transmission and reception has to be carried out according to certain set standards, so that the signals are compatible across the TV sets from various manufacturers. In Sec.10.2 you will learn about popular TV standards. In Sec.10.3 we discuss the TV transmission system which includes a camera and the allied electronics to modulate the signals and prepare them for transmission. In Sec.10.4 we discuss various types of TV receivers used in black-white and colour modes. The advanced technique of digital television with new types of displays like LCD and plasma is elaborated in Sec.10.5. In the same section a typical video compression format is also discussed.

Objectives

After studying this unit you should be able to:

- list various TV standards;
- understand the generation of colours using RGB scheme;
- describe the working of tube type and CCD camera;
- justify the need of synchronisation;
- describe the working of colour and monochrome TV receivers;
- explain the construction of plasma and LCD screens; and
- describe typical compression techniques used in video signal handling.

10.2 TELEVISION SYSTEMS AND STANDARDS

A large amount of information has to be broadcast by a television transmitter and there is a need for uniform standards for TV transmission and reception. However, till now no agreement has been reached for the adoption of worldwide standards, and thus several different systems exist, necessitating standards conversion for many international television transmissions.

Although we find some agreement in certain respects, there are five essentially different television systems in use around the world. The two main ones are the American (Federal Communications Commissions (FCC) system for monochrome and National Television Standards Committee (NTSC) system for colour), and the European (Comité Consultatif International de Radio (CCIR) system for monochrome and Phase Alternation by Line (PAL) system for colour) systems.
France and a part of Belgium use their own system, SECAM (sequential technique and memory storage), for colour. The USSR and Eastern Europe use a system for monochrome that is almost identical to CCIR, but they use SECAM for colour. With its greater line frequency, the French system has superior definition, but it requires a bandwidth twice as great as for the major systems.

In India we use CCIR PAL-B system, which is a variant of PAL system differing in respect of audio bandwidth.

The American and European TV systems have the following standards in common:

- Vestigial sideband amplitude modulation for video, with most of the lower sideband removed. This is done to save bandwidth as you will learn in later sections.
- Negative video modulation polarity. In both systems black corresponds to a higher modulation percentage than white.

- 2:1 interlace ratio. Interlacing will be described in details later in this unit.
- 4:3 aspect ratio. This is the ratio of the horizontal to the vertical dimension of the receiver picture (or transmitter camera) tube.

Table 10.1 shows the differences in these two standards.

Table 10.1 Selected Standards of Major Television Systems

Standard	**NTSC**	**PAL**
Number of lines per frame	525	625
Number of pixels per line*	700	833
Number of frames per second	30	25
Field frequency, Hz	60	50
Line frequency, Hz	15,750	15,625
Channel width, MHz	6	7
Video bandwidth, MHz	4.2	5
Colour sub-carrier, MHz	3.58	4.43
Sound system	FM	FM
Maximum sound deviation, kHz	25	50
Inter-carrier frequency, MHz	4.5	5.5

* Resulting into 4:3 aspect ratios.

On our television sets, we obtain various TV channels, which are identified by their number. The channels of TV senders are allotted particular frequency bands. Appendix A gives the list of standard TV channel frequency bands.

SAQ 1

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3 *Min.*

"A frame repetition rate of 25 to 30 is necessary only for broadcast TV". Comment on the statement.

After getting a general idea about the television standards, let us now discuss the process of TV transmission.

10.3 TELEVISION TRANSMISSION

Any television system comprises two sections viz. audio and visual sections. When any scene is shot for television, the visual is picked up by the camera while the audio is caught using microphones. Every TV system has to transmit these audio and visual signals in synchronisation so that they are reproduced faithfully at the receiver end. You are already conversant with the audio signal transducers. In the following subsections we discuss the construction and working of some TV cameras which convert the visual signal into electrical output.

10.3.1 Monochrome Television Camera

Television is so common appliance now that we tend to take it for granted, but the ability into convert a picture into a video signal is a fantastic achievement. An important advantage of TV cameras over film cameras is that you see the picture immediately, instead of waiting for film processing.

Camera pickup devices have come a long way since the early days of mechanical scanning. Presently, the vidicon camera tube is employed in practically all TV applications, including broadcasting, small portable cameras, surveillance cameras, and industrial uses. Digital cameras based on charge coupled devices (CCD) are slowly replacing the tube cameras now.

a. Vidicon

Block diagram of a typical tube camera assembly is shown in Fig. 10.1a.

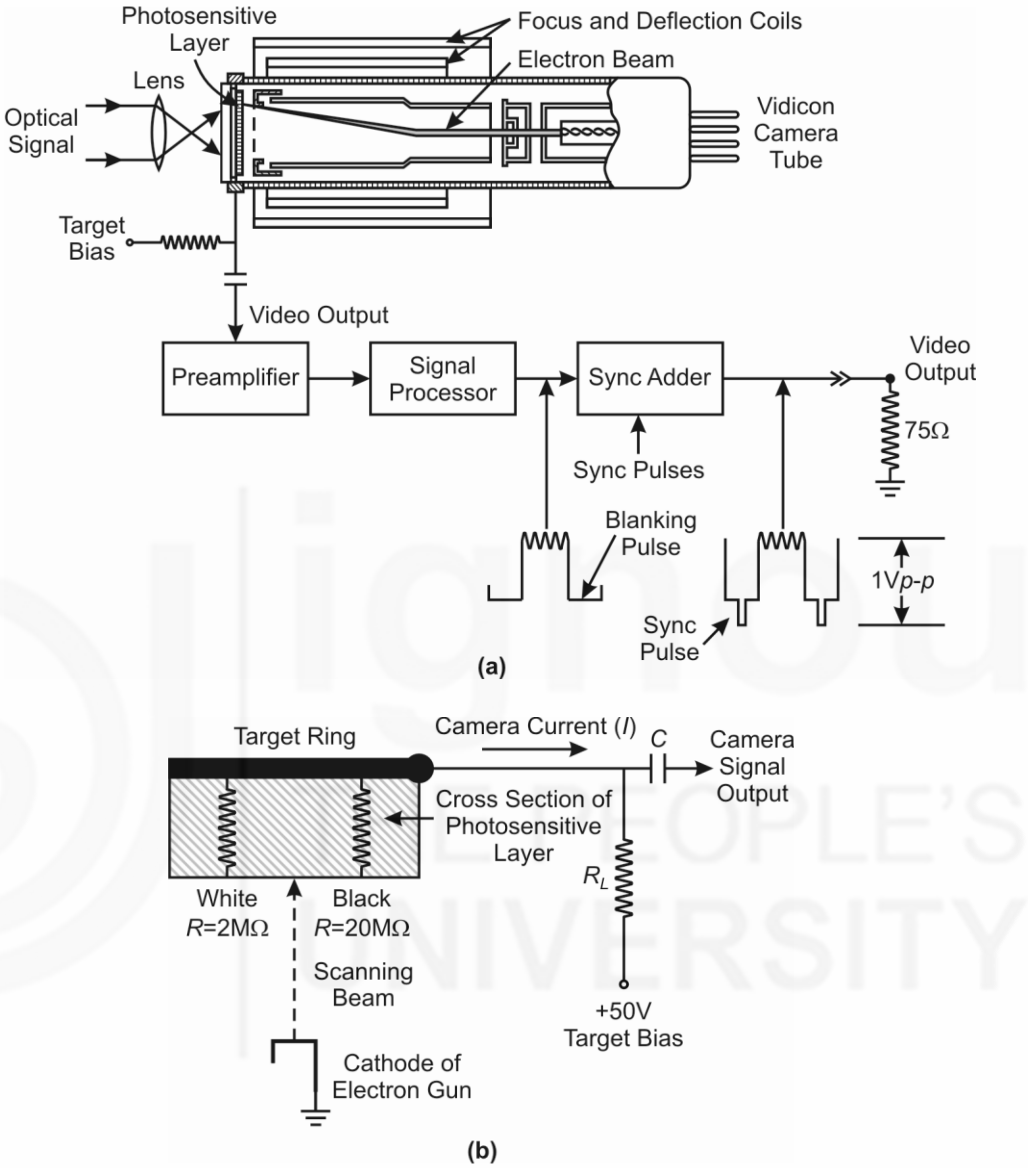

Fig. 10.1: a) Working of camera tube; and b) optical to electrical signal conversion

Working of Camera: In vidicon camera the optical image is focussed on the front glass faceplate. Since the glass is transparent, the light strikes the photosensitive image plate on the inside surface. The optical lens produces an inverted image of the scene on the rectangular areas scanned by the electron beam. An inverted image is reversed right to left and bottom to top. In this way, the lens functions exactly as in a film camera, except that the focal plane in the vidicon photosensitive layer instead of a film surface. In addition to forming the optical image, the lens regulates the light by a mechanical iris built into the lens housing. The iris adjusts the opening, or *aperture*, to determine how much light goes through the lens.

Inside the camera tube, the light image is converted into an electric charge pattern using photosensitive material (typically, a layered structure of tin oxide and antimony sulphide). The amount of charge for each picture element varies directly with the amount of light. This charge pattern is scanned sequentially in time by the electron beam that sweeps over the image plate. Scanning here is done from right to left and from bottom to top. Remember that the image in the camera tube is inverted by the lens.

The function of the electron scanning beam is to discharge each point in the charge pattern of the image. The charge image formed on the photosensitive material does not automatically form the camera current. For this, a low energy, narrow focus electron beam showed in Fig. 10.1b deposits just enough electrons on the target plate to discharge each point to zero potential. This discharge current flows in a series circuit consisting of the target (photosensitive plate), external load resistance R_L, target voltage supply, grounded cathode and the electron beam itself. In this circuit, the target acts as a variable resistance with values ranging between 20 MΩ for no light to 2 MΩ for very strong light. This current is extracted out as camera signal. As the entire charge pattern is scanned, the picture is represented as modulated current signal.

The signal current from the camera tube is extremely small, a few tenths of a microampere. Therefore, the first stage in Fig. 10.1a contains a preamplifier for the low-level camera signal. This stage represents a high-gain, low-noise amplifier, fully shielded to prevent pickup of electrical interference. The preamplifier is located as close as possible to the output terminal of the camera tube.

The electron scanning beam is cut off during the retrace intervals for the horizontal lines and during the vertical retraces. This blanking during retrace is necessary so that the beam can swing back to its starting position without being visible. Retrace is also called *fly-back* because it is much faster than trace. The blanking level establishes a reference for the black level. Following the preamplifier are the blocks of the signal processor and sync adder. The signal processing corrects undesired shading in the picture and provides the desired contrast ratio. Shading is produced because the characteristics of the photosensitive image plate are not perfectly uniform over the entire surface.

Final processing includes clamping of the blanked parts of the video signal to some reference voltage level, followed by insertion of the synchronising pulses. In effect, the blanking level is a pedestal level at which the sync is added. The final result is the composite video signal, including camera signal variations, blanking pulses, and sync pulses. The standard output level is 1 $V_{p\text{-}p}$, across 75Ω. Camera output circuits are designed to drive 75-Ω coaxial cable.

In the camera there are provisions to control the amount of beam current, focusing, and deflection in the camera tube. The beam focus is critical because the size of the moving spot determines the overall resolution, or sharpness, of the resulting picture. You must remember that the TV camera has two focus adjustments. The optical focus brings the light image into sharp focus on the surface of the pickup tube. The electrical focus sharpens the electron beam into a tiny spot on the photosensitive surface being scanned. Otherwise, details are lost as the beam straddles the picture elements.

The electron scanning beam is deflected by coils in an external yoke that fits over the camera tube. The linear scanning current for uniform deflection is provided by ramp or saw-tooth generators for both *H* (horizontal) and *V* (vertical) scanning. They are driven from a master timing source called a *sync generator*.

The vidicon camera discussed so far is a vacuum tube based analog camera, converting the visual signal into analog electrical signal. Here the position of picture cell (pixel) is decided by the position of the continuously rastering beam. In the following we discuss a solid-state device which does not need a vacuum tube for its working and hence is miniature in size and robust in operation. This is the camera using charge coupled devices (CCD).

b. CCD Camera

A Charge-Coupled Device, or CCD, is basically an array of closely-spaced metal-oxide-semiconductor diodes that can store and transfer information using packets of electric charge, or *charge packets*. The substrate of a CCD is a *n*- or *p*-type semiconductor as shown in Fig. 10.2. Over this semiconductor substrate, silicon dioxide is grown as a dielectric or insulating layer. An array of very closely-spaced metal electrodes is then formed over this dielectric layer. In this way, in the CCD the top to bottom layers are metal, oxide and semiconductor (MOS).

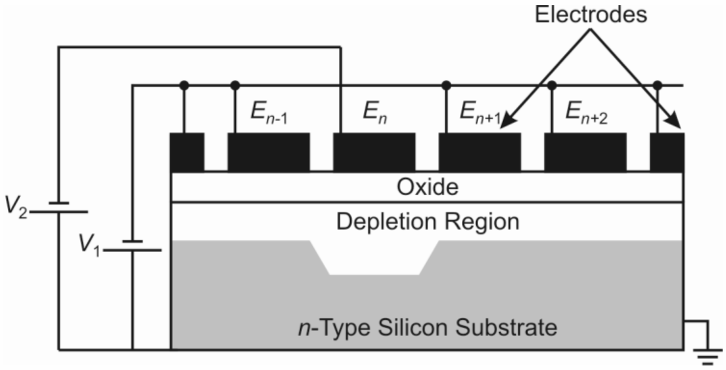

Fig. 10.2: A cross-section of a CCD

In an *n*-type CCD, grounding the substrate and applying a negative voltage $-V_1$ to all the closely-spaced metal electrodes will create a depletion region in the substrate right beneath the oxide layer. This depletion region is devoid of majority carriers (electrons), since these are repelled by the negative voltage applied at the electrodes. On the other hand, some of the minority carriers (holes) present in the substrate will be attracted towards this depletion region.

Applying a significantly more negative voltage $-V_2$ at one of the electrodes, say E_n, while maintaining the other electrodes at $-V_1$ will cause the depletion region beneath E_n to extend more deeply as shown in Fig. 10.2. This deeper depletion region beneath E_n creates a *potential well* across the width of E_n. Placing a charge into the potential well traps it there, since it cannot move outside the well. This is how a CCD stores a charge. This charge could be created by the light falling on these devices and would be proportional to the intensity of light.

The stored charge under the more negative electrode E_n can be laterally transferred to the next adjacent electrode, E_{n+1}. This is done by putting E_{n+1} at the more negative voltage $-V_2$, while allowing E_n to adjust back to $-V_1$. While this is happening, all other electrodes (especially E_{n-1} and E_{n+2}) must be at $-V_1$. As E_n ramps up to $-V_1$, its potential well becomes shallower, and all the trapped charges in it get transferred to the deeper potential well of E_{n+1}. Eventually the charges previously stored by E_n will get transferred in the potential well E_{n+1}.

Moving the charge packets from one electrode to the other in this manner requires at least three electrodes to move one bit of information. In any transfer cycle, one electrode is at $-V_2$, another electrode is ramping up from $-V_2$ to $-V_1$, and the others are at $-V_1$. You must have noticed that the lateral movement of charge packets in a CCD from one electrode to the next is very similar to how digital data moves in a shift register.

Although the CCD was initially invented as a memory device, its extreme sensitivity to light soon made it a popular choice as an image sensor. In an image-sensing CCD chip/(or CCD camera), each MOS diode or capacitor represents one pixel. The charge packets are generated when light excites electrons from the valence band into the conduction band. The light-generated charge packets that carry the image information are stored and transferred from one potential well to another until they are eventually shifted out in an output register.

In a typical CCD camera the pixel (electrode) size may be 10 µm × 10 µm or so.

CCDs containing grids of pixels are used in digital cameras, optical scanners and video cameras as light-sensing devices. They commonly respond to 70% of the incident light (meaning a quantum efficiency of about 70%) making them more efficient than photographic film, which captures only about 2% of the incident light. As a result CCDs were rapidly adopted in astronomy where the signal intensities of star images are very low. One-dimensional CCD array is used in the fax machine.

Once the CCD array is exposed to the image, each pixel acting as a capacitor accumulates charge across it, depending on the intensity of light falling on it. A control circuit causes each capacitor to transfer its contents to its neighbour. The last capacitor in the array dumps its charge into an amplifier that converts the charge into a voltage. By repeating this process, the control circuit converts the entire contents of the array to a varying voltage, which it samples, digitises and stores in memory. Stored images can be transferred to a printer, storage device or video display.

CCDs are typically sensitive to infrared light, which allows infrared photography, night-vision devices, and zero lux (or near zero lux) video-recording/photography.

SAQ 2

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3 Min.

State whether true or false:

a) CCD needs at least five electrodes for moving one bit information.
b) Any point on vidicon camera tube target can be addressed by an individual electrode.
c) Length of a camera tube depends on the area of photosensitive target plate.

The cameras we discussed in this subsection were useful for **monochrome** imaging. Let us now briefly discuss the modifications needed in these cameras to make them work as colour TV cameras.

10.3.2 Colour Television Camera

Almost any colour can be produced by adding red, green, and blue (RGB) in different proportions. The additive effect is obtained by superimposing the individual colours. In the receivers using tricolour picture tube, the red, green and blue information on the screen is integrated by the eye to provide the colour mixtures in the actual scene.

Additive colour mixtures

The idea of adding colour is shown in Fig. 10.3. The three circles in red, green and blue overlap partially. Where the circles are superimposed, the colour shown is the mixture produced by adding the primary colours. At the centre, all three colour circles overlap, resulting in white.

It is clear from the figure that,

- where only green and blue add, the result is a greenish blue mixture called *cyan*. Some people might consider this colour just blue or perhaps turquoise. However, *cyan* is the name to remember for this green-blue mixture.
- when only red and blue are added, the bluish red colour is called *magenta*. This colour is similar to violet or purple, but magenta has more red.

- yellow is an additive colour mixture with approximately equal parts of red and green. More red and less green produce orange.

Similarly, practically all natural colours can be produced as mixtures of red, green, and blue, including the so-called neutral colours, such as white and grey.

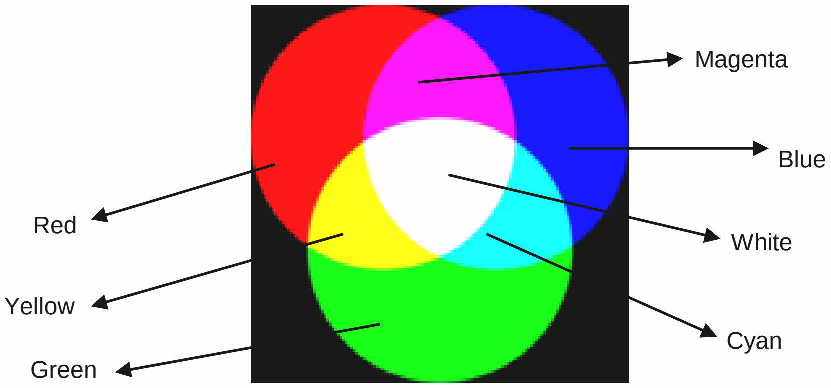

Fig. 10.3: Additive colour scheme for RGB

Primary colours

The primary colours are combined to form different mixture. The only requirement is that no primary can be recreated by mixing the other primaries. Red, green, and blue are the primary colours used in television because they produce a wide range of colour mixtures when they are added together. Therefore, red, green, and blue are additive primaries.

Complementary colours

The colour that produces white light when it is added to a primary is called its *complement*. For instance, yellow, when added to blue, produces white light. Therefore, yellow is the complement of the blue primary. Table 10.2 lists the primary and complementary colours.

Table 10.2: Colours Schemes

Primary Colour	Complementary Colour
Red	Cyan
Green	Magenta
Blue	Yellow

A *subtractive system* is used in colour photography. In this method, mixtures are obtained by subtracting individual primary colours from white light by means of colour filters. Thus cyan, magenta, and yellow are the subtractive primary colours used to filter out red, green and blue, respectively.

a. Triple Tube Camera

The simplest form of a colour camera is really three cameras in one housing. A typical studio camera contains three pickup tubes, one for each primary colour. An optical separator, behind the main lens (called the *taking lens*), breaks incoming light into its red, green, and blue values as seen in Fig. 10.4. Separate preamplifiers and processors handle these R, G, and B signals.

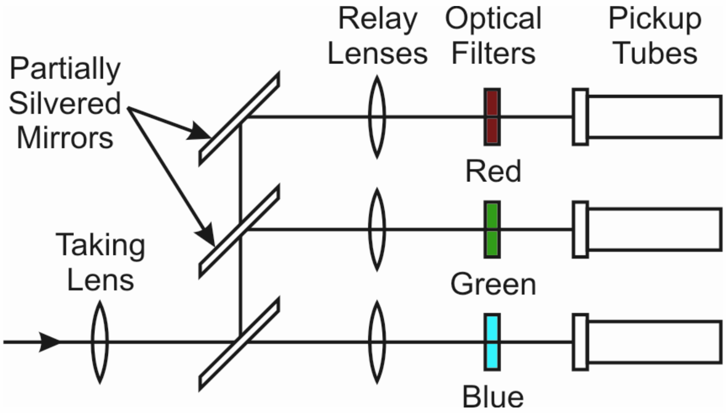

Fig. 10.4: Separator using optical red, green, and blue filters for colour TV camera

The correct percentages of these signals are added, so that the resultant closely resembles the gray scale produced by a black-and-white camera. This resultant signal is called the Y, or *luminance signal*. It is essentially the same as the video signal produced by a monochrome camera.

The percentages taken of each primary signal are adjusted to match the luminance or brightness sensation of human vision. The equation is:

$$Y = 30\% \text{ red} + 59\% \text{ green} + 11\% \text{ blue} \qquad (10.1)$$

These relations for colour additives are decided by each television standard and can vary from system to system.

You know that human vision peaks at the yellow-green wavelengths; therefore, a larger percentage is used for the green primary signal. This equation in fact gives the proportions of the three primary colours in the luminance transmission of an NTSC colour TV transmitter. Remember that it refers to the *proportions, not absolute values*. That is to say, if Y, as given by Eq. 10.1, has an amplitude that corresponds to 12.5 percent modulation of the carrier, the receiver will reproduce white. If the amplitude of the Y video voltage yields 67.5 percent modulation, a black image results. Any value in between gives varying shades of gray.

In order to indicate three primary colours, two more signals must be sent. These clearly cannot be pure colours, since Y is already a mixture. In the NTSC system, the remaining two signals are

$$I = 0.60R - 0.28G - 0.32B; \text{ and} \qquad (10.2)$$

$$Q = 0.21R - 0.52G + 0.31B. \qquad (10.3)$$

I stands for *in phase* and Q for *quadrature phase*; both terms are related to the manner of transmission, as we will discuss shortly. Fig. 10.5 shows how the Y, I and Q signals are generated.

You must be wondering, why this type of odd combination is sent; instead of sending the direct signals corresponding to three colours. The reason for this is similar to the one we discussed in case of stereo sound transmission. The signals sent by colour sender should be compatible with the traditionally used monochrome TV sets, which do not have the capacity to handle colours. Hence a luminance signal is sent which is directly compatible with the black and white television receiver sets.

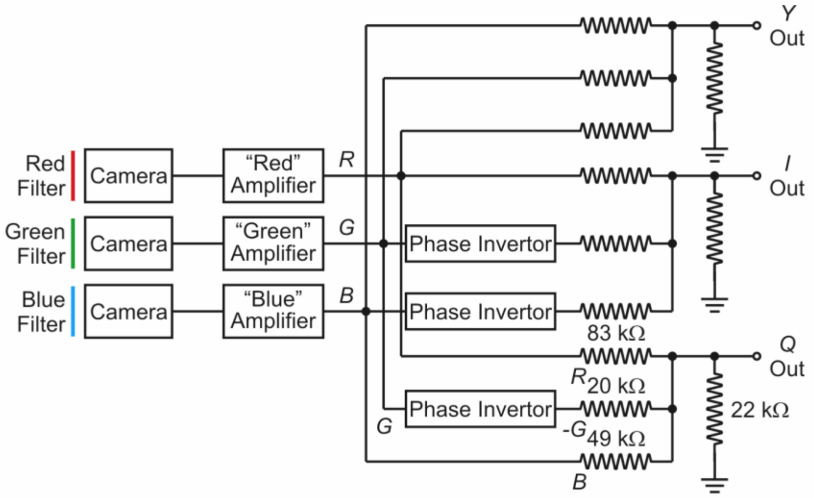

Fig. 10.5: *Y*, *I*, and *Q* generation in TV camera

Fig. 10.6 is a disk showing how the various signals and colours are interrelated. For example, the colour disk shows that if the received *Q* signal is instantaneously zero and *I* is maximum, a saturated reddish-orange will be reporduced at that instant. Had *I* been less than maximum, a paler (i.e., less saturated) colour of the same reddish-orange would have been reporduced. To take another example, consider $I = 0$ and Q = negative maximum; the resulting colour is saturated yellowish-green. Most colours are in fact obtainable from vector addition. Thus various combinations of the *I* and *Q* signals may be transmitted to represent whatever colour is desired.

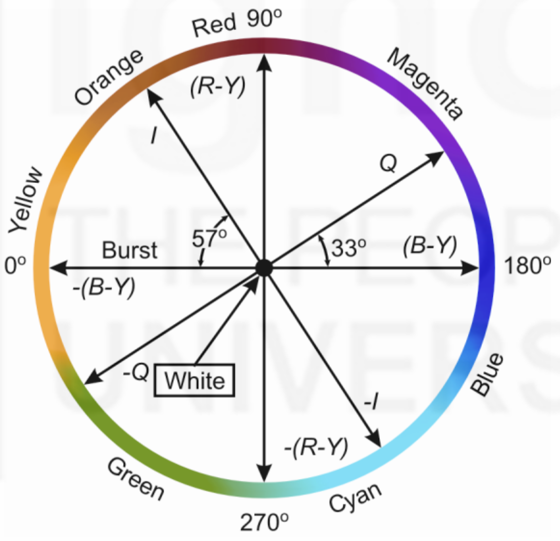

Fig. 10.6: Colour phase relationship

In addition to showing the phase relations of the *I* and *Q* signals of either polarity, the colour disk also indicates three other vectors. The first of these is the *colour burst*, which, as the name suggests, is a short burst of colour subscarrier. It is sent once each horizontal line and is used in the receiver as a phase reference. This is required to ensure that the absolute phase of the *I* and *Q* vectors is correct. For example, if it is not sent and a spurious + 90° phase shift of the colour subscarrier in the receiver occurred, *I* would be mistaken for *Q*, and *Q* for $-I$. The resulting reproduced colours would have the correct phase relationship to each other, but they would be displaying wrong colour. The $(R - Y)$ and $(B - Y)$ vectors are not transmitted but are often used in the receiver, as you will learn in later sections.

The problem with the simple scheme of colour signal capture shown in Fig. 10.4 is excessive light loss. Only one-third of the light passed by the taking lens reaches each pickup tube.

Dichroic mirrors solve the light-loss problem because they pass certain wavelength bands and reflect others. The basic arrangement is shown in Fig. 10.7. The first mirror reflects blue light but passes the remainder. The blue light is totally reflected from a front-silvered mirror into a relay lens, which forms an image of the blue components of the picture onto the target plate of the blue (*B*) pickup tube.

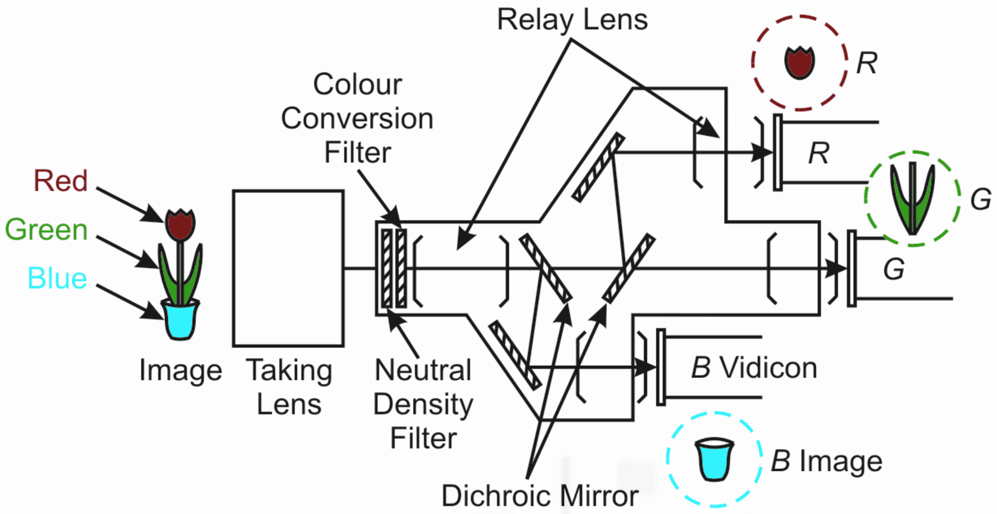

Fig. 10.7: Colour separator using dichroic mirrors

The light that passes through the first dichroic mirror then impinges on a second mirror. Here the red component is reflected, and the remainder passes through. What is left is white minus red and blue, which is essentially green.

These mirrors have extremely thin, accurately controlled transparent layers on one surface. The layer thickness is controlled in manufacture, and at certain wavelengths light reflected from the front and rear surfaces is additive, or in phase, in a given direction. By varying the layer thickness, both the direction and the wavelength can be altered. In this scheme very little of the red-green-blue component is lost.

In multitube cameras, the video image of all three channels must **register**, or **superimpose**, in every respect. This means that the size and centering as well as the deflection linearity must be identical for all three channels. For example, if horizontal deflection in the blue pickup tube were narrower than that in the other two, the picture would show blue outlines at the edges of vertical lines near the sides of the picture.

To register all three pictures, the scan size, centering, and scan linearity are adjusted precisely. Here again, green is taken as the reference. Its scan size, linearity and centering are set first. Then blue and red are made to register with the green.

b. Four-tube cameras

Very small registration errors tend to blur the edges of objects in the picture because the three signals do not occur at exactly the same time. The overall effect is a drop in sharpness, or resolution, that may be detected visually as colour fringing. For this reason, cameras employing four pickup tubes have been developed. In this scheme the black-and-white signals (*Y* signal), is provided by a separate black-and-white pickup tube and does not receive its light from the dichroic beam splitter. Three separate pickup tubes are used to develop the *R*, *G* and *B* signals.

c. Single-tube colour cameras

These cameras also break incoming light into the primary colour components, but they do so in a time sequence. They make use of the time taken for the beam to traverse each tiny area of the target.

The working principle of this method is shown in Fig. 10.8. The camera actually uses two vidicons, one for the *Y* signal and the other for the *R*, *G* and *B* colour signals. The arrangement in Fig. 10.8a shows light from the taking lens split into two paths for the vidicons. The lower vidicon with colour stripes is a single-tube *colour dissector*. The stripes are shown in Fig. 10.8b.

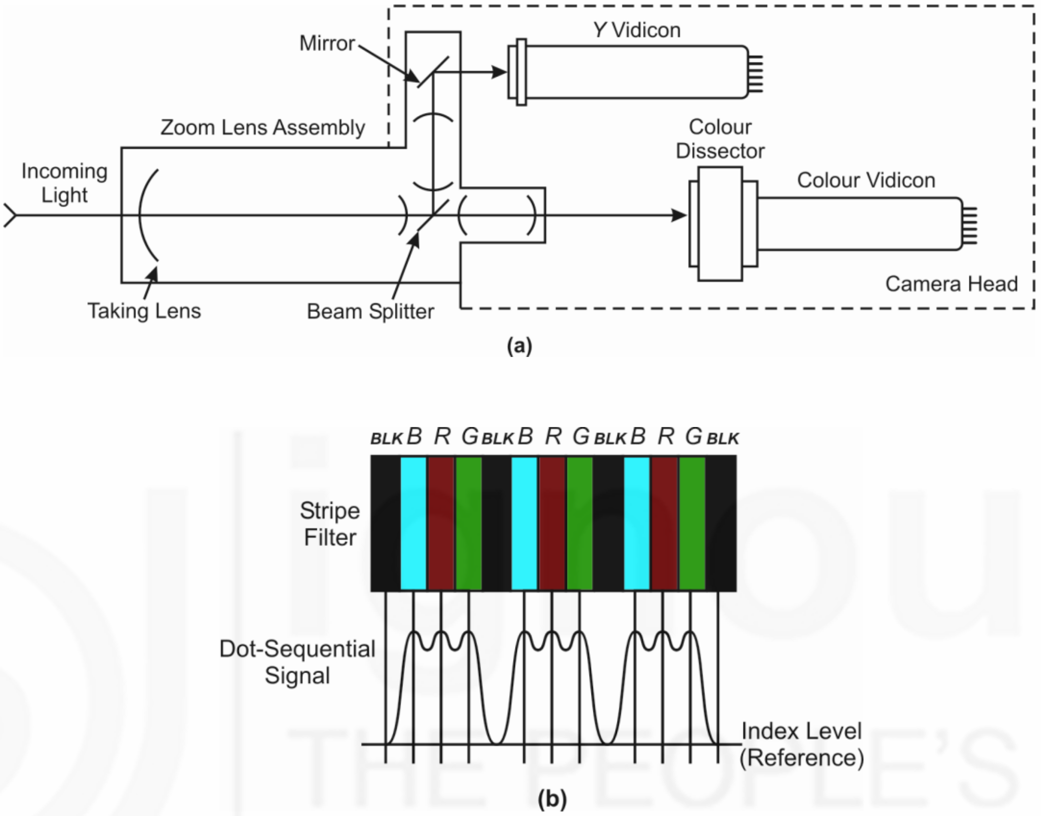

Fig. 10.8: A colour-stripe filter system for single-tube colour camera: a) arrangement with vidicon for *Y* signal and colour dissector for colour vidicon; and b) stripe filter for colour dissector in front of colour vidicon

The tube used for colour separation is equipped with a mask made of groups of vertical colour-stripe filters. Each group consists of a black (opaque) stripe, followed by a blue, red, and green stripe (Fig. 10.8b). A total of about 87 such groups appear from left or right across the target area. The time taken for one visible horizontal scan is about 53.5µs. Therefore, the electron beam scans each stripe group in 53.5 µs/87 = 0.615µs. Dividing this figure by four stripes gives 0.154µs or 154 ns, as the time needed for the beam to move between the centres of consecutive stripes.

The principle of colour separation using masks is simple, but there are practical considerations. First, the beam focus is extremely critical in all single-tube colour dissectors. The spot must be small enough to resolve the light output of the individual stripes. Poor focus shows up first as a loss of colour. In addition, the scanning width is extremely critical because it determines the time needed for the electron beam to move across each stripe. A camera using this system needs elaborate automatic control circuits to maintain a precise scanning width. Also the linearity of the horizontal deflection is critical, because a nonuniform scanning speed results in colour shading from right to left in the picture.

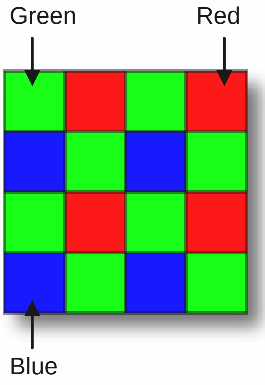

Fig. 10.9: Bayer mask

d. Colour CCD cameras

You know that in a CCD camera, each electrode can be treated as a spearate pixel. Digital colour cameras generally use a Bayer mask over the CCD. Each square of four pixels has one red, one blue, and two green (the human eye is more sensitive to green than either red or blue) filters as shown in Fig. 10.9. As a result, the luminance information is collected at every pixel, but the colour resolution is lower than the luminance resolution.

Better colour separation can be reached by three-CCD devices and a dichroic beam splitter prism, that splits the image into red, green and blue components. Each of the three CCDs is arranged to respond to a particular colour. Some semi-professional digital video camcorders (and all professional camcorders) use this technique.

You must have noticed that the design of CCD camera is just like any other semiconductor CMOS device and hence it can be produced by using the CMOS manufacturing process. Since this is the dominant technology for all chip-making, CMOS image sensors are cheap to make and signal conditioning circuitry can be incorporated into the same device. The latter feature helps in overcoming their greater susceptibility to noise. CMOS sensors also have the advantage of lower power consumption.

SAQ 3

Spend
3 *Min.*

"Colour resolution of the camera is always lesser than its black and white resolution". Comment on this statement.

10.3.3 Transmitter Electronics

Fig. 10.10 shows the block diagram of a typical monochrome TV transmission system with single black and white camera.

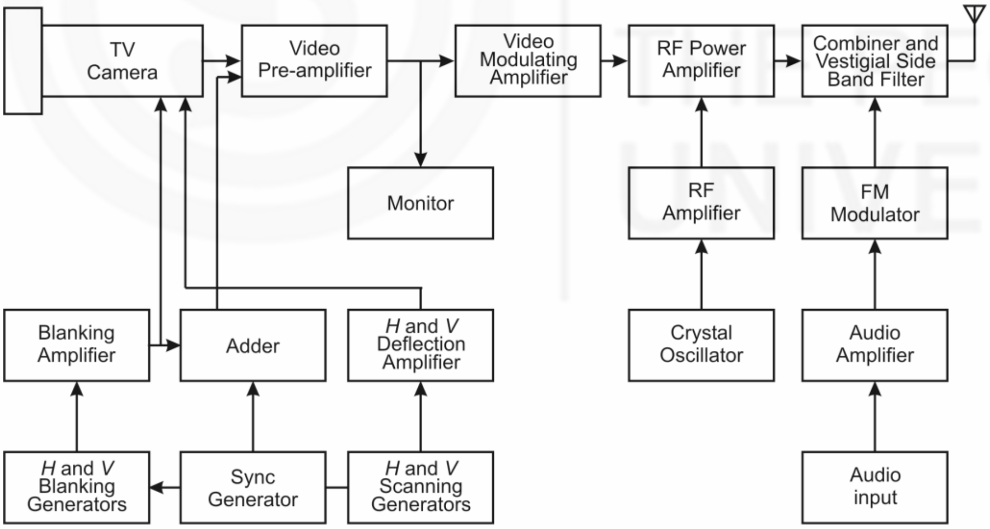

Fig. 10.10: Block diagram of a Monochrome TV transmitter

a. Video stage

The output of the camera is fed to a chain of video amplifiers whose function is to raise the signal level until it is sufficient for modulation. Along the chain of video amplifiers, certain pulses are inserted. These are the vertical and horizontal blanking and synchronising pulses, which are required by receivers to control their scanning processes. The final video amplifier is the power amplifier which amplitude modulates the output RF amplifier. The output stage at the RF stage must be broadband in view of the large bandwidth of the transmitted video modulated signals.

The sound transmitter is a frequency modulated transmitter similar to the one you have learnt about in the last Unit. The only difference is that maximum deviation is limited to 25 kHz, instead of the 75-kHz limit for FM broadcast transmitters.

The output stage is followed by a vestigial sideband filter, about which you will learn in the subsequent sections. This *LC* filter is capable of handling the high power at this point. Its frequency response is critical and carefully shaped.

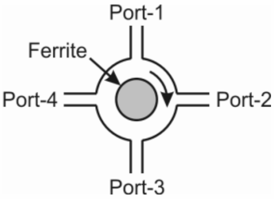

Fig. 10.11: Circulator schematic

Finally, the output of the sound and picture transmitters is fed to the antenna via a coupling network. This is in fact an *LC* equivalent of the circulator. A circulator (Fig. 10.11) is a three or four port device, (as you will learn in unit 11) in which the neighbouring ports are connected in clockwise fashion, i.e. port 1 is connected only to port 2 and not to 3 and 4 etc. Its function is to ensure that although both the picture and sound transmitters are connected to the antenna with a minimum of loss, neither is connected to the other.

b. Scanning

As already discussed in Unit 1, the complete frame of a television picture is typically scanned 30 times per second, in a manner that is very similar to reading a page. The beam in camera or picture tube (in case of receivers) moves at a constant velocity across the screen and when it reaches the end of the screen on the right-hand side, it "whips back" to the left-hand edge of the screen and starts again. Meanwhile, it has descended down the screen, so that the next line traced out is somewhat below the first one. This process continues until the bottom of the screen is reached.

You know that for a typical horizontal scan rate of 30 per second and with 525 lines per frame, the total time taken from the beginning of one line to the instant when the next line begins to be scanned is 63.5 μs. This time obviously includes not only the scan of the picture from left to right but also the rapid return, or *retrace*, from right to left. Clearly, the retrace cannot take an infinitesimally short time, and in fact a period of 10.2 μs (16 percent of the time allocated to scanning one line) is allocated to it. That is to say, the retrace time is 0.16 *H*, and the *active* time is 0.84 *H*, where *H* is equal to 63.5 μs.

The scanning is achieved by using a ramp type (saw tooth) voltage sweep across horizontal deflection plates. In the falling edge of the ramp the beam retraces to the left side of the screen again. It is necessary to hide the retrace. The method of preventing this disturbance is a very simple one. It consists of reducing the scanning beam current to zero, from just before the beginning of the retrace until just after its end. The process is known as **horizontal blanking**. This consists of adding a pulse to the video waveform, at the right time and for the correct period, to ensure that the signal level is raised to that corresponding to black. In TV, negative modulation is used; that is, the voltage corresponding to black is much higher than the voltage that indicates white. The sequence of events is as follows:

1. As the active beam is about to reach the right-hand side of the picture, the blanking voltage is applied.
2. Immediately afterward, the horizontal scanning generator receives a (horizontal) sync pulse, which initiates the retrace.
3. The retrace continues for a period of time that is governed by the time constant of the oscillator generating the scanning waveform but must be less than 0.16 *H*.
4. The retrace ends, and scanning of the next line begins.
5. Immediately afterward, after a total time of 0.16 *H*, the horizontal blanking pulse ends and the picture becomes visible once again.

SAQ 4

Spend
2 Min.

What is the maximum scan time of horizontal line in PAL system?

The **vertical scanning** is similar to horizontal scanning, except for the obvious difference in the direction of movement and the fact that everything happens much more slowly (i.e., 60 rather than 15,750 times per second). However the technique of interlacing discussed below introduces some complications.

When the beam has returned to the left side after horizontal retrace, its vertical position is lowered so that the beam will not repeat a scan of the same line. This is shown in Fig. 10.12. When the beam is at the bottom, vertical retrace returns the beam to the top to start the scanning sequence again.

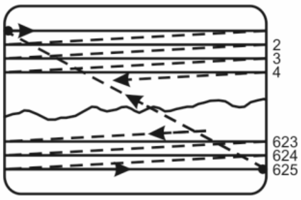

Fig. 10.12: Vertical scanning

You know that the rate of vertical scanning of 25 to 30 pictures per second is sufficient to give continuity of motion to a moving scene due to persistence of vision. However it results in *flicker* of light which is annoying to the viewer. The dark interruption between bright pictures becomes visible as flicker. Hence the solution is to increase the vertical scanning rate. But as the vertical scanning rate is increased, it increases the video bandwidth of channel.

Hence to reduce the flicker and limit the bandwidth of video channel vertical field scanning rate is chosen as 50 Hz (or 60 Hz). Use of mains supply frequency for vertical scanning reduces possible effects like supply ripple in the reproduced picture. The vertical scanning rate is 50 pictures (frames) per second for 625 horizontal lines per picture. It means that horizontal line scan frequency should be 31250 Hz (625×50) and hence the line period is about 32μs. This leads to high bandwidth requirement of 10 MHz. But standard bandwidth of a TV channel is restricted to 6 MHz only.

A method of reducing bandwidth requirement and maintaining effective vertical scan rate of 50 Hz (60 Hz) to reduce flicker, is to employ **Interlaced Scanning** rather than sequential scanning.

In interlaced scanning, the number of lines on the picture is divided into two groups called **fields**. Each field is scanned alternately as shown in Fig. 10.13.

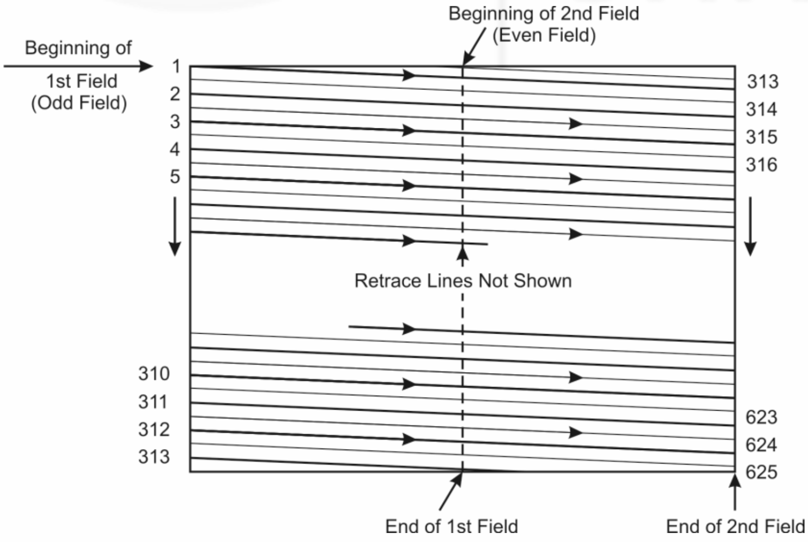

Fig. 10.13: Interlaced scanning

In the interlace technique, 625 lines are divided into two sets of 312 and half lines each. The first set of 312 and half odd number of lines, called first field (or odd field) are first scanned sequentially. Halfway through the 313th line, the spot is returned to the top of the screen and the remaining 312 and half even number lines, called the second field (or even field) are then scanned sequentially between the lines of the first set as shown. This is done by operating the vertical scan at 50 Hz so that the two successive interlaced scans, each at 25 Hz rate, make up.

In all, the beam scans 625 lines (312.5 × 2) per picture, at the same horizontal scanning rate of 15625 lines (312.5 × 50) per second. Thus the flicker effect is eliminated without increasing the speed of horizontal scanning which in turn does not need any increase in the channel bandwidth.

You will notice here that, though the interlacing technique is applied for a satisfactory display of image at the receiver end, the originating signal from the camera also needs to be captured using same format and transmitted. Then with the help of accompanying synchronisation pulses, the image can be reproduced at the receiving end.

c. Blanking and synchronising pulse

Video voltage is limited to certain amplitude limits. Thus, for example, the white level corresponds to 12.5 percent modulation of the carrier, and the black level corresponds to approximately 67.5 percent modulation. Thus, at some point along the video amplifier chain, the voltage may vary between 1.25 and 6.75 V, depending on the relative brightness of the picture at that instant.

When the picture is blanked out, before the vertical or horizontal retrace, a pulse of suitable amplitude and duration is added to the video voltage, at the correct instant of time. Video superimposed on top of this pulse is clipped. The pulses are clamped at typically 7.5V and the result is video with blanking.

As shown in Fig. 10.14 the procedure for inserting synchronising pulses is fundamentally the same as used in blanking pulse insertion. Horizontal and vertical pulses are added appropriately on top of the blanking pulses, and the resulting waveform is again clipped and clamped. It is seen that the tips of horizontal and vertical synchronising pulses reach a level that corresponds to 100 percent modulation of the picture carrier. At the hypothetical video point we may thus have video between 1.25 and 6.75 V, the blanking level at 7.5 V and the sync pulse tips at 10 V.

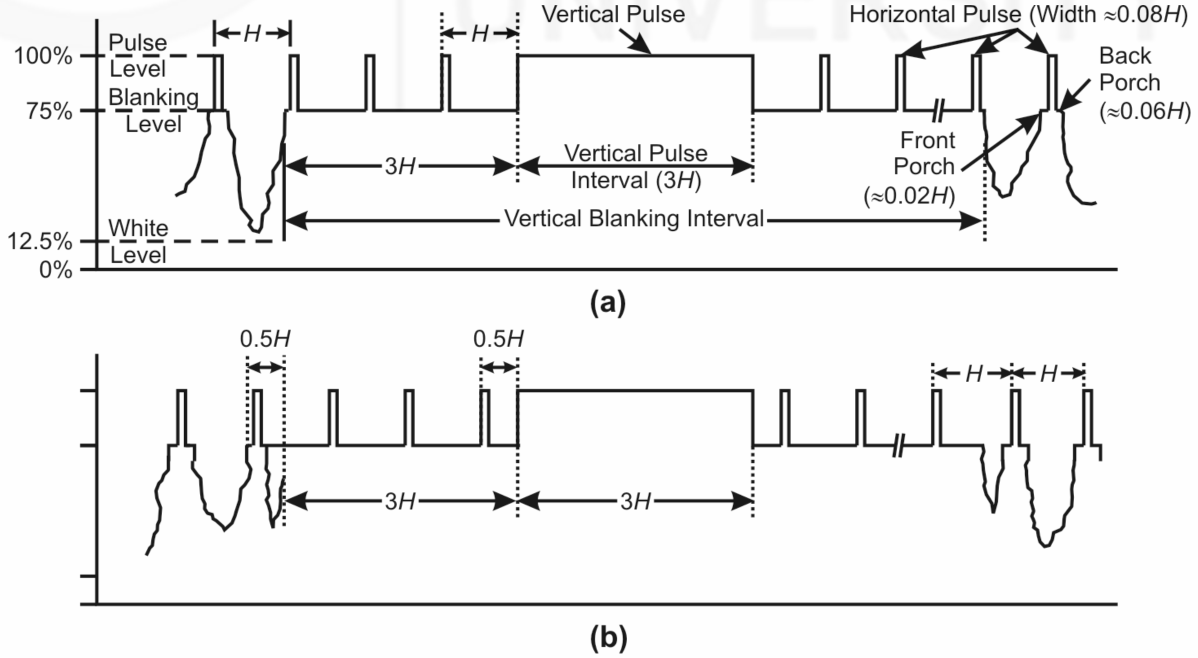

Fig. 10.14: TV video waveform showing horizontal and vertical sync pulses for a) even; and b) odd fields

The video signals generated for even and odd fields are mixed together and after amplitude modulation are transmitted along with the corresponding voice signal in frequency modulated form.

d. Video modulation

The visual signal uses vestigial side band amplitude modulation. In this method, all upper side bands, but only a part (vestige) of lower side band is used. The upper side band has all video modulating frequencies up to 4 MHz. The lower side band however, includes video modulating frequencies for only 0 to 0.75 MHz approximately. The purpose of this is to reduce the frequency band needed for the video modulation in the picture signal. Specifically, a 6-MHz TV broadcast channel is used instead of 8 MHz, or more, that would be needed for a double side band with 4 MHz modulation. Fig. 10.15 shows a frequency map of vestigial sidebands. The frequency scale shown here is absolute.

These 6 MHz frequencies map onto the lowest frequency of every channel band. For example for channel 3, it lies between 60 to 66 MHz.

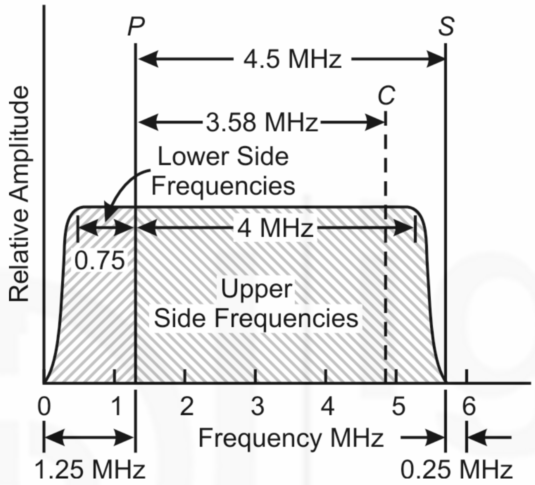

Fig. 10.15: Vestigial sidebands

In this diagram it is clear that the picture and sound signals fit into the 6 MHz channel. The picture carrier is not at the centre of the channel because of vestigial sideband transmission. The spacing for various carrier frequencies are:

1. The picture carrier *P* is 1.25 MHz above the low end of the channel;
2. The sound carrier *S* is 4.5 MHz above the picture carrier (at 5.75 MHz) i.e. *S* is 0.25 MHz below the top-end of the channel; and
3. The colour sub carrier *C* is 3.58 MHz above the picture carrier, as video modulation in the upper sideband.

e. Colour transmission

The block diagram of a colour related section of a TV transmitter is shown in Fig. 10.16. The *Y*, *I* and *Q* output derived from the camera signals are fed to their respective low-pass filters. Though these filters attenuate the unwanted frequencies, they also introduce unwanted phase shifts. Phase-compensating networks (not shown) are inserted after the filters, to produce the correct phase relationships at the balanced modulators.

The output of the colour sub-carrier oscillator is sent in three directions. One of the three outputs is used to synchronise the blanking and sync pulse generators. Their output, in turn, is transmitted as in monochrome TV, and a portion of it is used to synchronise the transmission cameras, as well as to introduce blanking into the transmitted video. The second path for the 3.58-MHz oscillator output is to the colour burst generator, which ensures the correct transmission (and phase preservation) of the colour burst. Finally, the last output from this oscillator is fed to a 57° phase shifter to provide the necessary shift for the *I* signal. A further 90° phase shift is produced, giving a total of 147° for the *Q* signal. Note here the 90° phase difference between the *I* and *Q* signals.

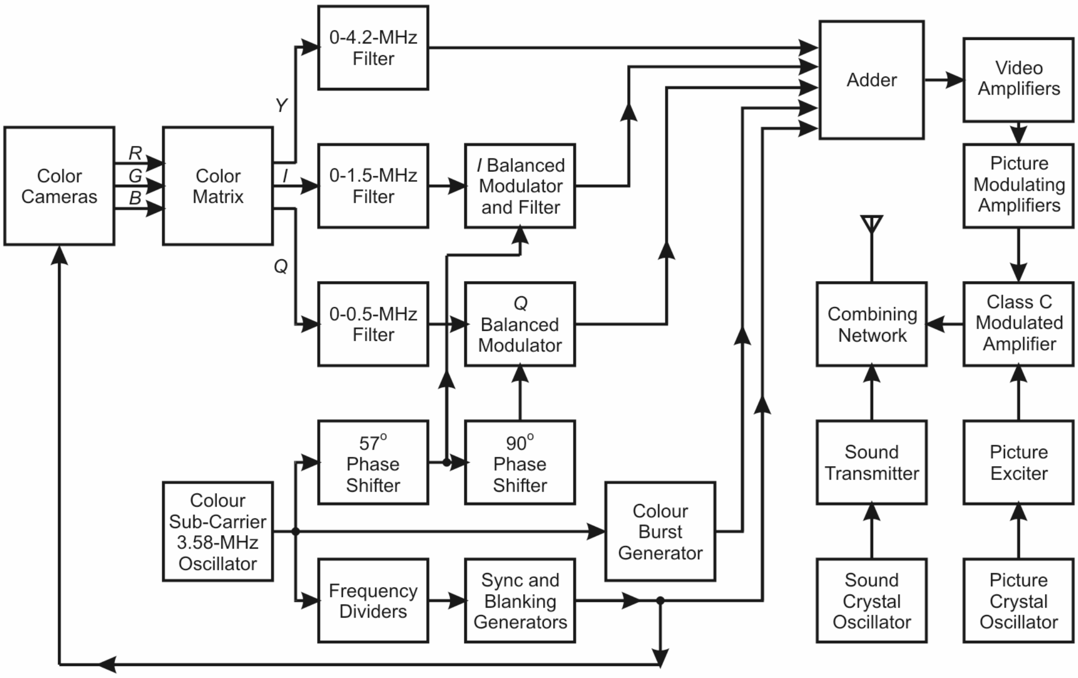

Fig. 10.16: Colour transmission

The *I* balanced modulator produces a double-sideband (suppressed-carrier) signal stretching 1.5 MHz on either side of the 3.58-MHz sub-carrier. The vestigial sideband filter then removes the top 1 MHz from that. The output of the *Q* balanced modulator is a signal occupying the range of 0.5 MHz below and above the suppressed 3.58-MHz sub-carrier. The added 90° phase shift puts this signal in quadrature with the *I* component; hence the name *Q signal*.

All these signals are fed to the adder, whose output therefore contains:

1. The *Y* luminance signal, occupying the band from 0 to 4.2 MHz, and virtually indistinguishable from the video signal in monochrome TV;
2. Synchronising and blanking pulses, identical to those in monochrome TV;
3. About 8 cycles of the 3.579545-MHz colour sub-carrier reference burst superimposed on the front porch of each horizontal sync pulse, with an amplitude of ± 7.5 percent of peak modulation.
4. An *I* chroma signal, occupying the frequency range from 1.5 MHz below to 0.5 MHz above the colour sub-carrier frequency; and
5. A *Q* chroma signal, occupying the frequency range from 0.5 MHz below to 0.5 MHz above the colour sub-carrier frequency with 90° phase shift with reference to *I* signal.

The output of the adder then undergoes the same amplifying and modulating processes as did the video signal at this point in a black-and-white transmitter. The signal is finally combined with the output of an FM sound transmitter, whose carrier frequency is 4.5 MHz above the picture carrier frequency, as in monochrome TV.

SAQ 5

Spend
2 *Min.*

Justify the necessity of blanking circuit in TV.

After discussing the generation and transmission of TV signals, let us now discuss the reception of TV signals.

10.4 TELEVISION RECEIVERS

The TV signals coming from the transmitter via medium contains the visual and audio signals in composite form. Any receiver has to separate these signals and condition them so that they are ready to be seen and heard on the TV set. Let us first discuss the electronic circuits used for processing the input signal.

10.4.1 Monochrome Reception

TV receivers use the superheterodyne principle of operation. In addition, there is extensive pulse circuitry, to ensure that the demodulated video is displayed correctly. A block diagram of a typical TV receiver is shown in Fig. 10.17. At the input stage it has two sorts of tuners for VHF and UHF signals.

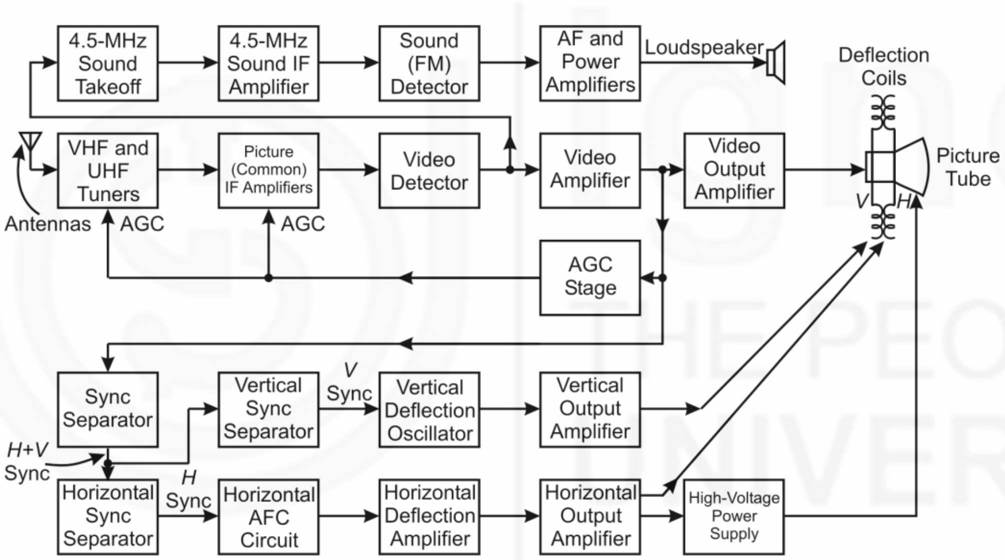

Fig. 10.17: Block diagram to typical monochrome television receiver

a. Tuners

The VHF tuner covers the frequency range from 54 to 216 MHz. The antenna most frequently used for reception of terrestrial transmission is the Yagi-Uda, consisting typically of a reflector, a folded dipole for the five lower channels and 3 to 4 shorter directors for the upper channels as shown in Fig. 10.18a.

The frequency range covered by the UHF tuner is the 470- to 890-MHz band, and here the antenna used is a single log-periodic antenna covering the whole band. This antenna is an array of dipoles fed with alternating phase as shown in Fig. 10.18b.

Old fashion VHF tuners often use a *turret* principle, in which 12 sets of ganged (RF, mixer and local oscillator) coils are mounted in spring-loaded brackets around a central shaft. The tuning knob is connected to this shaft, and channels are changed by means of switching in the appropriate set of coil for the fixed tuning capacitor. This is an example of mechanical tuner. Fine tuning is achieved by a slight variation of the tuning capacitor in the local oscillator. The modern television receivers use PLL (phase-locked loop) circuitry to replace switch-type tuners with electronic tuners. Reliability is much better with these tuners, which have no mechanical parts.

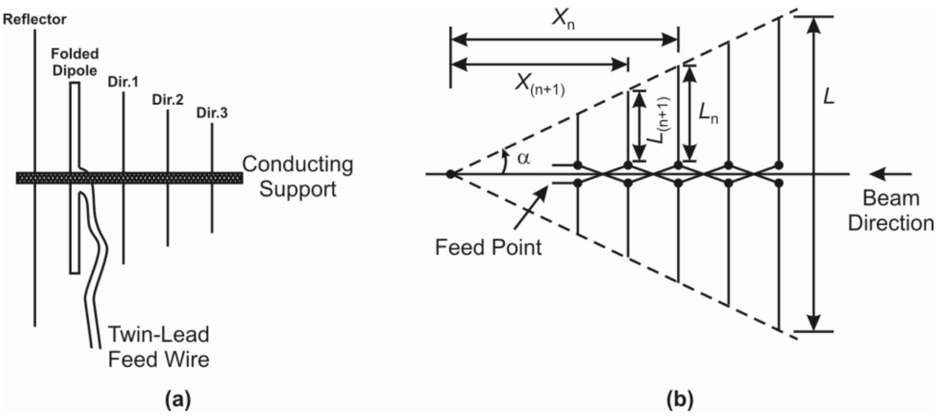

Fig. 10.18: a) Yagi-Uda array; and b) log-periodic antenna

The UHF tuner's active stages are a diode (point-contact or Schottky-barrier) mixer and a bipolar or FET local oscillator. The diode mixer is used here as the first stage to lower the UHF noise figure. Adequate gain can be obtained from the remaining RF circuits. Coaxial transmission lines are used instead of coils in the UHF tuner, and they are tuned by means of variable capacitors. These are continuously variable (and of course ganged) over the whole range, but click stops are sometimes provided for the individual channels.

An alternative means of UHF tuning consists of having varactor diodes to which fixed dc increments are applied to change capacitance, instead of variable capacitors. One of the advantages of this arrangement is that it facilitates remote-control channel changing. The remainder of the circuit is unchanged, but a UHF RF amplifier is normally added. The reason for this is the low Q of varactor, necessitating an additional tuned circuit to sharpen up the RF frequency response.

When any VHF channel is received, the UHF local oscillator is disabled. The significant carriers appearing at the input to the VHF RF amplifier are the picture (P), chroma (C) and sound (S) carriers. Typical value of these signals for (say) channel 5 are P = 77.2 MHz; C = 80.83 MHz; and S = 81.75 MHz (you can refer to the frequency band of channel 5 in Appendix A).

These three are mixed with the output of the local oscillator operating at the standardised frequency of 45.75 MHz, above the picture carrier frequency. The resulting carrier signals fed to the first IF amplifier are thus, P = 45.75 MHz, C = 42.17 MHz and S = 41.25 MHz. The IF pass-band is large enough to accommodate these signals and their accompanying modulating frequencies.

b. Picture IF amplifiers

The picture IF amplifiers are always double-tuned. As in the other receivers, the IF stages provide the majority of the sensitivity and gain before demodulation. Consequently, three or four stages of amplification are normally used. The IF stages provide amplification for the luminance, chrominance and sound information.

c. Video stage

The picture IF amplifier is followed by the video detector and (customarily) two video amplifiers, whose output drives the (cathode of the) picture tube. Before reaching the display device, the signals for sound IF, AGC and sync separation are taken off.

As you must have expected, the contrast and brightness controls are located in the circuitry of the output video amplifier. The **contrast control** is in fact the direct, video equivalent of the volume control in a radio receiver. When contrast is varied, the value of the video output voltage is adjusted, either directly or through a variation in the gain of the video output stage. Note that a typical tube requires about 100V peak to peak of video voltage for good contrast. The **brightness control** varies the grid-cathode dc bias on the picture tube, compensating for the average room brightness.

d. Sound section

As shown in the block diagram of Fig. 10.17, the sound section of a television receiver is identical to the corresponding section of an FM receiver.

e. Synchronising circuits

The task of the synchronising circuits in a television receiver is to process received information in such a way as to ensure that the vertical and horizontal oscillators in the receiver work at the correct frequencies. As shown in Fig. 10.17, this task is broken down into three specific functions, namely:

- to extract sync information from the composite waveform;
- to provide vertical sync pulses (from the transmitted vertical sync pulses); and
- to provide horizontal sync pulses (from the transmitted horizontal, vertical and equalising pulses).

Fig. 10.19 shows the circuitry used for sync separation. The *clipper* portion of the circuit removes the sync information from the composite waveform received.

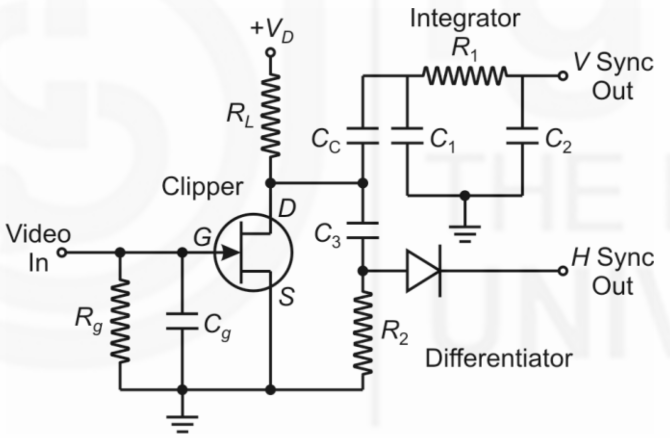

Fig. 10.19: Sync separator circuit

The clipper uses leak-type bias and a low drain supply voltage to perform a function that is similar to an amplitude limiter. The video voltage is applied to an amplifier biased beyond cut off, so that only the tips of the sync pulses cause output current to flow. The output of the sync clipper is split with a portion of it going to the combination of C_3 and R_2. This is a differentiating circuit. Here, a positive pulse is obtained for each sync pulse leading edge, and a negative pulse for each trailing edge. When the input sync waveform has constant amplitude, no output results from the differentiating circuit. The negative pulses are removed by diode D_1, and the positive pulses are used as the horizontal sync signal to trigger the horizontal deflection oscillator in Fig.10.17.

The other portion of the clipper output (separated sync signal) is given to a circuit consisting of C_1, R_1 and C_2, via a coupling capacitor C_C. This forms a standard integrating circuit. Its time constant is long compared with the duration of horizontal pulses but is comparable with respect to the width of the vertical sync pulse. This integrating circuit acts as a low-pass filter, with a cut-off frequency such that the horizontal sync pulses produce very little output, and the vertical pulses have frequency that falls into the pass-band of the filter producing significant output. This signal is used to trigger the vertical deflection oscillator in the Fig. 10.17.

f. Deflection circuits

The deflection circuits in the block diagram of Fig. 10.17 include the vertical oscillator and amplifier for vertical scanning at 50 (60) Hz and a similar horizontal arrangement for scanning at 15625 (15750) Hz. For either scanning, the oscillator provides a deflection voltage at a frequency determined by its time constants and corrected by the appropriate sync pulses. This voltage is used to drive the corresponding output amplifier, which provides a current of the correct waveform, and at the right frequency, for the deflection coils. Magnetic deflection is always used for TV picture tubes and requires a few watts of power for the complete 90° or 110° (measured diagonally) deflection across the tube. Two pairs of deflection coils are used, one pair for each direction, mounted in a *yoke* around the neck of the picture tube, just past the electron gun. You will learn the construction of a picture tube later in this section. Let us now discuss in brief about colour reception.

Spend
3 *Min.*

SAQ 6

What is the role of sync separator in a TV receiver?

10.4.2 Colour Reception

Most of the circuits and functions in monochrome and colour television receivers are common. For example, a colour TV receiver also requires a tuner, picture and sound IF stages, a sound demodulator section, horizontal and vertical deflection currents through a yoke, a picture tube anode high dc voltage, and finally video amplifiers (luminance amplifiers in this case). Now we discuss the sections, which are different and specific for colour reception. These include the picture tube related circuit. Fig. 10.20 shows a diagram of the blocks associated with the colour section of a television receiver.

A tuner of a colour TV receiver almost invariably has as an automatic frequency control (AFC) circuit, as indicated in Fig. 10.20. It is often called **automatic fine tuning** (AFT) and is used to automatically minimise mistuning, particularly at too high frequency. The AFT circuit consists basically of a 45.75-MHz filter, whose output is fed to a phase discriminator. This produces a dc correcting voltage whenever its input frequency differs from 45.75 MHz, and this voltage is applied to a varactor diode in the circuit of the appropriate local oscillator in the tuner. It is normally possible to bypass the AFT circuit, so as to permit manual fine tuning.

The output of the video detector undergoes the same treatment as in monochrome receivers, with a few differences:

- The bandwidth of the video amplifiers is somewhat narrower than in a monochrome receiver. This is to reduce interference between the Y signal, which these amplifiers handle, and the lowest I sidebands of the chroma signal; and
- Use of the delay line. The chroma signal undergoes more phase delay than the luminance signal before reaching the picture tube, and so a phase correction is required. The simplest method of equalising the phase difference is by introducing a delay into the Y channel. This delay is normally just under 1 μs and can be in the form of a predefined length of transmission lines.

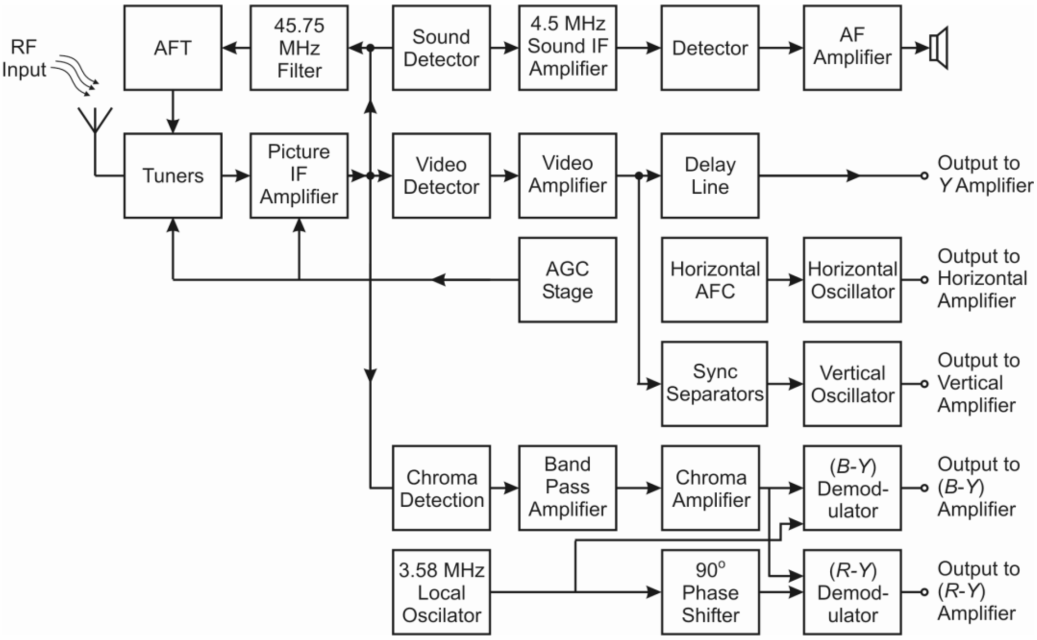

Fig.10.20: Partial block diagram of a colour television receiver showing connections to corresponding points of Fig. 10.17

Colour Circuits

You have learnt that the visual signal of colour transmission is a combination of luminance and colour information. The colour information signal is called **chrominance** or **chroma** (*C*) in short. This is the 3.58 MHz modulated sub-carrier signal and contains the hue and saturation for all the colours. Before modulation and after demodulation the *C* signal contains the information of red, green and blue colour video signals. The bandwidths of various components are:

- *C* signal includes side frequencies above and below 3.58 MHz modulated sub-carrier, mainly 3.08 MHz to 4.08 MHz.
- *R*, *G*, *B* video signals include base band frequencies of 0 to 0.5 MHz.
- $(R-Y)$, $(B-Y)$ and $(G-Y)$ video signals also include 0 to 0.05 MHz base band frequencies. However, these symbols are colour mixtures because each has the components of the $-Y$ signal.

At the receiving end it is not necessary to demodulate all the three colour signals ($R-Y$, $B-Y$ and $G-Y$); it is enough to detect any two signals and the third signal can be reconstructed by a combination of these two signals. For example, from the colour circle in Fig.10.6, it is evident that combination of $-0.5R$ and $-0.2B$ produces G vector. If the same voltage Y is subtracted from all these, the relationship still holds, and we get,

$$(G-Y) = -0.5\,(R-Y) - 0.2\,(B-Y) \qquad (10.4)$$

The picture tube circuitry contains a $(G-Y)$ adder to derive this signal.

From the colour circle of Fig. 10.6, you must have noted that the $(R-Y)$ and $(B-Y)$ signals have 90° phase difference, hence the two demodulators in Fig. 10.20 are fed with a 3.58-MHz sub-carrier generated signal with 90° phase shift.

Let us now consider the construction and working of a colour picture tube in the TV receiver.

10.4.3 Colour Picture Tube

In a monochrome transmission, all three grid voltage would be zero, and the only voltage then modulating the beam current would be the –*Y*, luminance signal applied to all three cathodes in parallel.

The monochrome picture tube is quite similar to the cathode ray tube, about which you have learnt in your earlier classes. The colour picture tube however has a complicated construction to enable the display of colours. In tricolour picture tubes, the screen has red, green, and blue phosphors, and three electron beams are used, one for each primary colour. Effectively there are three picture tubes in a single envelope. The first gun controls electrons that strike only the red phosphor, the second is for the green phosphor, and the third is for the blue phosphor. Trios of red, green and blue vertical lines are used in most of the colour picture tubes.

The dimension of a picture tube screen is usually expressed in terms of its diagonal length.

Separation of the colours is maintained by the shadow-mask principle shown in Fig. 10.21a. The mask is a perforated steel sheet mounted on the back of the screen. The holes, or apertures, can be made for phosphor dots or phosphor lines. Only the electrons that converge at the proper angle can strike the phosphor screen to produce the correct colour. Other electrons are blocked by the mask. About 20 to 30 percent of the beam current is actually used in exciting the screen phosphors. For this reason, colour picture tubes need a much higher anode voltage and have a larger value of beam current, compared with monochrome tubes.

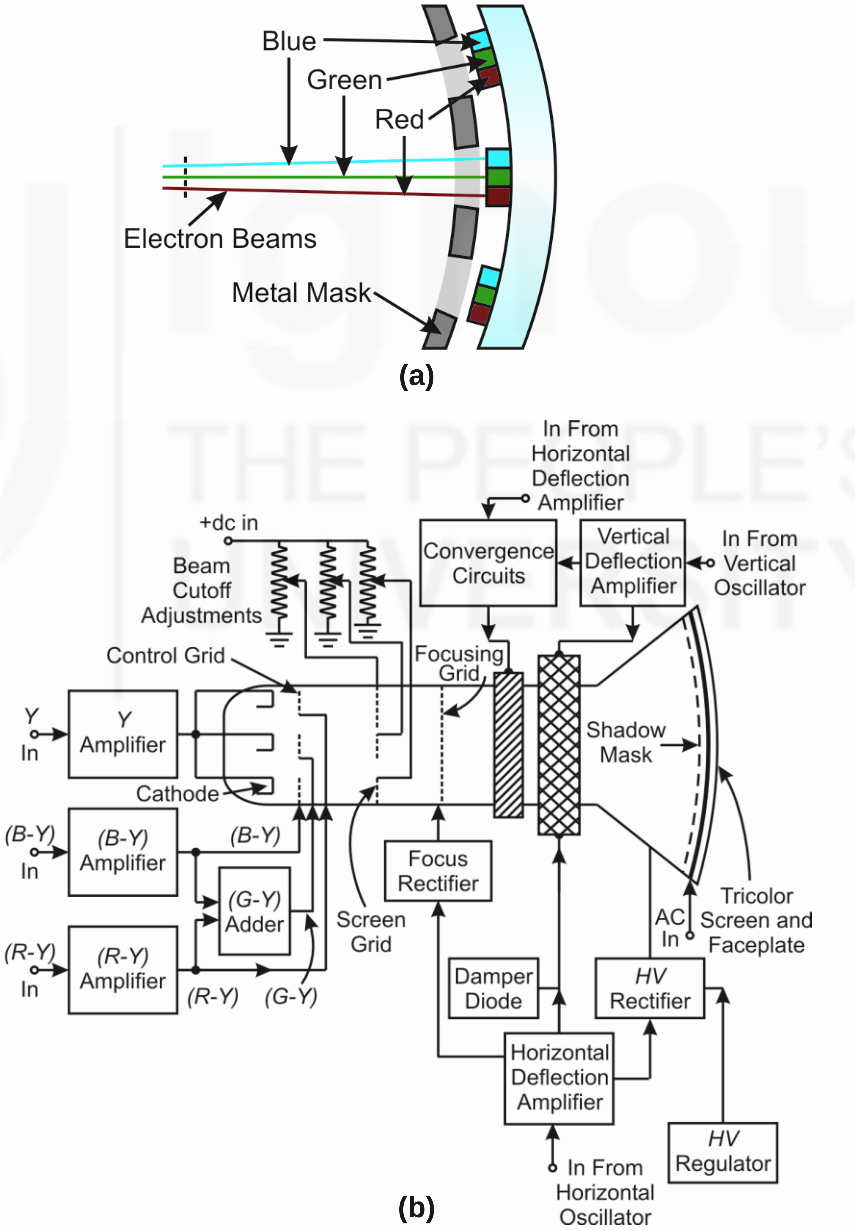

Fig. 10.21: a) Shadow mask; and b) television colour picture tube with associated circuitry

Fig. 10.21b shows the construction of typical tricolour tube. As shown in Fig. 10.20, the output of the colour demodulator has two channels with voltage corresponding to $(B-Y)$ provided in one of the channels and voltage corresponding to $(R-Y)$ provided in the other channel. These two signals are amplified separately, and they are then added in the correct proportions to produce the $(G-Y)$ video voltage [Eq. (10.4)]. The three primary colour voltages (with the luminance voltage, Y, subtracted from each) are now applied to their respective grids, as shown in Fig. 10.21b.

In a colour transmission, the four drive voltages are produced and the luminance signal applied to the cathodes will add to each of the grid voltages, cancelling the Y component of each and ensuring that only the R, G or B video voltages modulated the respective beams from this point onward.

The beam next encounters a series of the three accelerating screen grids. Lastly, these beams are focussed on the tricolour phosphor screen to produce colour picture.

SAQ 7

Spend
3 *Min.*

What would happen if a shadow mask is not used in a colour picture tube?

After considering the construction and working of conventional TV receivers, let us discuss about the modern variant of TV technology viz. digital TV in the next section.

10.5 DIGITAL TELEVISION

Digital TV is the buzz word of the new TV technology. In this course, we have discussed various advantages of digital communication like its noise immunity; simplified, miniature circuitry due to use of digital ICs; low power consumption by circuits etc. However the greatest advantage of digital signals is the ease of using compression techniques on these signals. This allows communication of signals using lower bandwidth. As the use of satellites and computer based communication in transmitting video signals is increasing, the bandwidth budgeting becomes critical. As you will learn in the next unit, the satellites have very limited band capacity due to the limited size of payload and power availability. Hence most economic use of all available bandwidth has to be done:

As you know, the typical bandwidth of an analog TV signal is 6 MHz. To transmit an image on analog TV, every pixel is included in the signal. A typical screen with 525 lines of 700 pixels each (aspect ratio 4:3) will have 367, 500 pixels per frame. This is a large number but fits in the 6 MHz bandwidth of TV channel.

In recent days, the high definition televisions (HDTV) have started capturing the markets. These TVs have a wider horizontal frame (aspect ratio 16:9). This shape of screen is found to provide a better visual experience for the TV spectator. In addition to this new aspect ratio, the HDTV has smaller pixel size, typically having 1080 lines of 1920 pixels each. This amounts to more than two million pixels per frame. Hence for such TV, almost 5 times more information needs to be squeezed into the transmitted video signal. This kind of compression without loss of any information is not possible in analog form. However for digital signals, such compression is achievable.

A compression is considered to be good if it does not introduce any loss of information when the signal is decompressed at the receiving end. You know that for digital signals, the number of bits used to represent any analog signal determines the resolution, (more the number of bits, better the resolution). You must have noticed that in computer monitors, the colours can be represented by various lengths of digital words (like 2 bit, 4 bit, 8 bit, 16 bit etc.). Here a 2-bit word can represent the colour signal only as 4 distinct values, whereas a 16-bit word can resolve the colours into 65,536 colour hues and shades. It is advisable to record the signal with maximum resolution for best results. However, when we wish to use this signal for viewing the image, the colour resolution of the eye should be taken into consideration. For normal viewing, it is not necessary to use a 16-bit long word to represent the colour data. The lesser the length of the word representing a data, lesser the number of bits to be transferred and hence shorter the bandwidth required.

In the case of TV signals you must have observed that all the pixels on the screen do not change their colour/intensity value continuously. Some parts of the image (like the background scene) remain constant, though some part of the image may have moving objects. Hence it is not necessary to send the values of all the pixel colours all the while. It would be beneficial to send the whole image once and then subsequently send only the values of pixels representing the moving objects on the screen.

You must have already encountered other formats like JPEG (Joint Photographic Experts Group) for still images, GIF (Graphic Interchange Format) for simple images etc.

This idea is used in the so called MPEG format of TV signal compression. MPEG stands for Motion Picture Expert Group, which was entrusted the job of setting up the standard formats for TV signal compression.

Let us now understand briefly, how MPEG-2 (second version MPEG) compression works.

MPEG Compression

MPEG compression is accomplished by four basic techniques: pre-processing, temporal prediction, motion compensation, and quantisation coding. Pre-processing filters out non-essential visual information from the video signal, motion compensation takes advantage of the fact that video sequences are most often highly correlated in time: each frame in any given sequence may be similar to the preceding and the following frames.

The compressed digital video encoder scans subsections within each frame, called *macro blocks*, and identifies which ones will not change position from one frame to the next. The encoder also identifies *predictor* macro blocks while noting their position and direction of motion. Only the relatively small difference, called the *motion compensated residual,* between each predictor block and the affected current block is transmitted to the receiver. The receiver/decoder stores the information that does not change from frame to frame in it's buffer memory and uses it periodically to fill in the blanks, or stationary parts of image.

A mathematical algorithm called the Discrete Cosine Transform (DCT) reorganises the residual difference between frames from a *spatial* domain into an equivalent series of coefficient numbers in a *frequency* domain that can be more quickly transmitted. Quantisation coding converts these sets of coefficient numbers into even more compact representative numbers. It also rounds off all coefficient values, within a certain range of limits, to the same value. Although this results in an approximation of the original signal, it is close enough to the original to be acceptable for most viewing applications.

***I*, *P*, and *B* Frames** MPEG-2 provides for up to three types of frames called the *I*, *P* and *B* frames. The intra-frame, or *I* frame, serves as a reference for predicting subsequent frames. *I* frame, which occurs on an average of one out of every ten to fifteen frames, only contains information presented within itself. *P* frames are predicted from information presented in the nearest preceding *I* or *P* frames. The bi-directional *B* frames are coded using prediction data from the nearest preceding *I* or *P* frame and the nearest following *I* or *P* frame. Creation and transmission of these three types of frames reduces the bandwidth of transmission drastically.

Now, since the occupied bandwidth is reduced, it is possible to even send information compatible with wider screens as in the case of HDTV.

New Display Devices

With the advent of technology, there has also been a departure from using the traditional CRT displays. The biggest limitation of CRT display is its bulky size. As the screen size goes on increasing, the depth of CRT also has to increase, in order to allow the beam movement encompassing the entire screen area. This puts a limit on the largest possible display screen with this technology. Further, the rastering of single electron beam over the entire area requires faster scanning to avoid flicker effects. New technology based on LCD and plasma displays provide a solution to the problem. These are so called *flat screens*, that is, they are quite narrow in depth (few centimetres) irrespective of the screen size.

The **liquid crystal displays** (LCD) use special rod like molecules which have property to orient themselves according to the voltage applied across them. You have already learnt about the LCDs in your course of Physics of Solids (PHE-13). As you will remember, the LCD molecules do not produce light, but just modify their orientation and use the ambient light for display purposes. Hence such TV screen needs to have a built-in light source to provide a back-light, which is modified as it emerges out, to be seen by the viewer. The colours in LCD display are provided by using appropriate colour filters in front of each pixel. A construction of typical LCD flat screen is shown in Fig. 10.22.

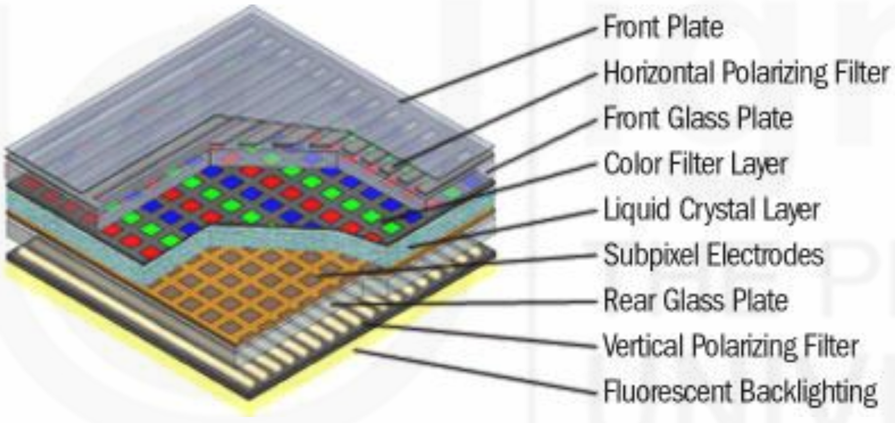

Fig. 10.22: Construction of LCD panel (Source: www.theprojectorpros.com)

Here you will notice that in this case, each pixel is addressable individually by the electrodes provided below the LCD layer. This allows us to turn *on* or *off* any individual pixel by direct application of voltage across it. There is no question of beam rastering. This removes the problem of flickering encountered in CRT displays.

Please remember here that, though it is possible to light the entire LCD panel with image simultaneously by applying signals to all pixels simultaneously, we still have the signal communication from transmitter in serial mode. Hence the pixel-by-pixel information will reach the receiver as a series of pulses only. However the data to the individual pixel can be fed sequentially one-by-one as it serially comes (similar to CRT scheme) or the entire frame data can be stored in the receiver memory and this entire image is transferred to a display panel. Each scheme will have its own merits and demerits; we will not go in to such details, at this point.

Another technology emerging in digital TV is the **plasma display** screens. Here the pixels are in the form of tiny plasma tubes. You already know that the fluorescent tubes used in our homes are using plasma for lighting. In plasma screens, the same principle is used but at an extremely miniature scale. As shown in Fig. 10.23 tiny cells are built, which contain xenon or neon atoms within them. Here the walls of cells are coated with phosphors of different colours.

A unit of three cells of RGB together forms a single pixel. By controlling the voltage provided to each cell, different proportions of *R*, *G* and *B* lights can be produced to result into various colours. The plasma displays are of light generating types and hence don't need any back-light as in the case of LCD panels.

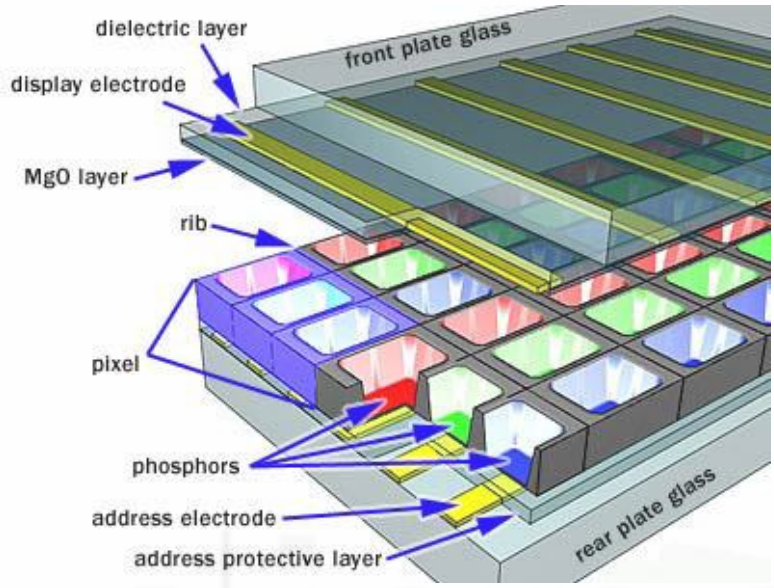

Fig. 10.23: Construction of Plasma display panel (Source: www.plasmatvscience.org)

In both these types of displays, it is always possible to increase the number of pixels in both vertical and horizontal directions and have a large-screen panel, without increase in the depth of the device. This is the biggest advantage of flat screen displays over the CRT displays. Realisation of HDTV is possible because of these new age display devices.

The technology is improving day-by-day and newer and better television receivers are coming into existence. You can keep track of these new developments by reading the recent articles.

Let us now summarise the points covered in this Unit.

10.6 SUMMARY

- The major standards of TV systems are NTSC (American) and PAL (European).
- NTSC has 525 lines per frame with 30 frames per second. PAL system has 625 lines per frame and 25 frames per second. The frame per second is closely related to the line frequency of power supply in the concerned countries.
- Vidicon is the most popular analog TV camera tube. It contains a photosensitive screen, which converts the optical image into electronic image in the form of charge storage. These charges can be sensed by rastering an electronic beam over this screen.
- CCD use MOS devices for trapping the charges created by photons incident on them.
- Additive colour scheme of red, green and blue (RGB) is used to produce colour signals.

- Various arrangements like filter separators, dichroic mirror separators and multi-tube camera are used for capturing colour signals.
- The luminance signal Y in NTSC standard is defined by

  $$Y = 0.30\,R + 0.59\,G + 0.11\,B.$$
- Along with Y, the in-phase signal I and quadrature signal Q are transmitted in order to reach the complete colour information to the receiver.
- A TV transmitter includes video stages, scanning mechanism with synchronisation and blanking circuits, video modulator, audio (FM) modulator and RF stage. Vestigial sideband amplitude modulation is used to send video signal.
- Interlacing technique is used in vertical scanning to avoid flicker.
- A TV receiver comprises of a tuner (VHF and UHF), automatic fine tuning (AFT), picture IF, video stage, synchronising and deflection circuits and a display device.
- The audio is received and demodulated just like in audio receivers.
- Colour receiver reconstructs R, G and B signals from the transmitted Y, I and Q signals.
- MPEG is one of the compression techniques used for reducing the bandwidth of video signals.
- The new flat screens made up of LCD or Plasma devices allow big screen display with high definition.

10.7 TERMINAL QUESTIONS

Spend 20 *Minutes*

1. Match the following pairs:

   1. Vidicon
   2. Base-band signal
   3. TV channel bandwidth
   4. Channel 2 frequencies
   5. Amplitude modulation
   6. Frequency modulation
   7. Picture frames per second
   8. Horizontal lines per frame
   9. Chroma signal

   a. RF picture carrier signal
   b. 54 to 60 MHz
   c. Video signal
   d. RF sound carrier signal
   e. 3.58 MHz
   f. Camera tube
   g. 525
   h. 30
   i. 6 MHz

2. How will the picture look on the TV set if the transmitted signal has aspect ratio of 4:3 while the TV set has aspect ratio of 16:9?

3. Vertical scanning coil of a TV set is damaged, what would be its effect on the TV display?

4. What is the use of colour burst signal?

10.8 SOLUTIONS AND ANSWERS

Self Assessment Questions

1. A TV monitor can be used for various purposes apart from broadcast TV reception. However, in all the cases the picture has to be present on the screen in a stable fashion. In case of scanning electron beam monitors, it is necessary to

refresh every pixel at least 25 times per second, in order to give a stable display for our eyes. Hence a frame repetition rate of 25-30 is mandatory in all the applications.

2. a) False; b) False; c) True

3. This is true of the camera using colour masks for signal capture. A multi-tube camera need not have poorer resolution, as it captures the image for particular colour, in the same way as any camera picks up the monochrome signals.

4. PAL system scans 625 lines per frame with frame repetition rate of 25. Hence each frame has to be scanned in 40 ms.

   This gives $\frac{40\,\text{ms}}{625\text{ lines}} =$ 64 µs per line.

5. If there is no blanking, the TV display will be showing the beam rastering during retrace (horizontal and vertical). This will create unwanted illumination of screen and the picture proper will not be visible.

6. Sync signal sent by a transmitter contains the information regarding vertical and horizontal scanning of the image at the camera end. In order to observe the proper display in a TV set, it is necessary to reconstruct the same scanning scheme at the receiver set as well. Sync separator in a TV set extracts the sync signals from the incoming signal and hence is most significant in achieving proper display.

7. Shadow mask directs the three beams assigned to three colours to proper positions, where phosphors of corresponding colour are placed. If the mask is not present, it is possible that a beam meant for some colour may fall on other colour phosphor (may be in grazing incidence) and will produce unwanted colour display on the screen.

Terminal Questions

1. 1.(f); 2.(c); 3.(i); 4.(b); 5.(a); 6.(d); 7(h); 8(g); 9(e)

2. A 4:3 aspect ratio image would have about 700 pixels per line for 525 lines per frame. When same signal is given to a screen, which has aspect ratio of 16.9 the information confined to 700 pixels will get stretched over $\frac{525\times 16}{9} = 928$pixels.

   This will result in a horizontally stretched figure.

3. If vertical scanning coil is damaged, the beam will keep on rastering at the same horizontal line repeatedly. This will result into a single bright horizontal line on the TV screen.

4. Refer to Sec. 10.3.2

Reference Material:

1. *Basic Television and Video Systems* by Grobe, Barnard; (V Edition) (McGraw-Hill)
2. *Electronic Communication Systems* by Kennedy, George; (III Edition) (Tata McGraw-Hill)
3. www.wikipedia.org

APPENDIX A: TELEVISION CHANNEL FREQUENCY TABLE

These tables given the frequency chart for the US designated Television Channels. There are both VHF and UHF channels listed.

Table A-10.1: General Television Frequencies

Sub CATV Band - T7 - T13	7 - 58 MHz
Low Band - VHF Ch. 2 - 6	59 - 88 MHz
Mid Band - UHF Ch. 14 - 22 - UHF Ch. 95 - 99	121 - 174 MHz 91 - 120 MHz
High Band - VHF Ch. 7 - 13	175 - 216 MHz
Super Band - CATV Ch. 23 - 36	216 - 300 MHz
Hyper Band - CATV Ch. 37 - 62	300 - 456 MHz
Ultra Band - CATV Ch. 63 - 158	457 - 1002 MHz
UHF Band Ch.14 - 83 - CATV Ch. 63 - 158	70 - 1002 MHz

Table A-10.2: VHF Television Frequencies

BAND	CH #	FREQUENCY
VHF LOW	02	54-60 MHz
VHF LOW	03	60-66 MHz
VHF LOW	04	66-72 MHz
VHF LOW	05	76-82 MHz
VHF LOW	06	82-88 MHz
VHF HIGH	07	174-180 MHz
VHF HIGH	08	180-186 MHz
VHF HIGH	09	186-192 MHz
VHF HIGH	10	192-198 MHz
VHF HIGH	11	198-204 MHz
VHF HIGH	12	204-210 MHz
VHF HIGH	13	210-216 MHz

Table A-10.3: UHF Television Frequencies

CH NUMBER	FREQUENCY
14	470-476 MHz
15	476-482 MHz
16	482-488 MHz
17	488-494 MHz
18	494-500 MHz
19	500-506 MHz
20	506-512 MHz
21	512-518 MHz
22	518-524 MHz
23	524-530 MHz
24	530-536 MHz
25	536-542 MHz
26	542-548 MHz
27	548-554 MHz
28	554-560 MHz
29	560-566 MHz
30	566-572 MHz
31	572-578 MHz
32	578-584 MHz

Table A-10.3: continued...

CH NUMBER	FREQUENCY
33	584-590 MHz
34	590-596 MHz
35	596-602 MHz
36	602-608 MHz
37	608-614 MHz
38	614-620 MHz
39	620-626 MHz
40	626-632 MHz
41	632-638 MHz
42	638-644 MHz
43	644-650 MHz
44	650-656 MHz
45	656-662 MHz
46	662-668 MHz
47	668-674 MHz
48	674-680 MHz
49	680-686 MHz
50	686-692 MHz
51	692-698 MHz
52	698-704 MHz
53	704-710 MHz
54	710-716 MHz
55	716-722 MHz
56	722-728 MHz
57	728-734 MHz
58	734-740 MHz
59	740-746 MHz
60	746-752 MHz
61	752-758 MHz
62	758-764 MHz
63	764-770 MHz
64	770-776 MHz
65	776-782 MHz
66	782-788 MHz
67	788-794 MHz
68	794-800 MHz
69	800-806 MHz
70	806-812 MHz
71	812-818 MHz
72	818-824 MHz
73	824-830 MHz
74	830-836 MHz
75	836-842 MHz
76	842-848 MHz
77	848-854 MHz
78	854-860 MHz
79	860-866 MHz
80	866-872 MHz
81	872-878 MHz
82	878-884 MHz
83	884-890 MHz

Source: http//www.csgnetwork.com/tvfreqtable.htm.