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THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne

INTRODUCTION TO TELEVISION

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1. INTRODUCTION.

1.1 Television means "to see at a distance", and as it is known today, is an outstanding tribute to man's ingenuity. An up to date definition is more specific and describes television as "the art of instantaneous reproduction of a visible picture (normally accompanied by sound) at a remote point by an electrical communication system".

Television had been used for mass entertainment and education in a number of other countries for many years before it was introduced into Australia, but progressive development during this period allowed the Australian system to be designed without many of the earlier disadvantages.

Television commenced in Australia with the first major broadcasts in 1956. Since then, various phases have seen the system extended to small centres, and eventually all of the populated parts of Australia will be served by both National and Commercial stations, with nation wide links for television programmes between stations, as required.

1.2 This paper, and other papers in the course of Television, build on the fundamentals of Electricity and Radio covered in other publications in the Course of Technical Instruction.

An outline of the basic requirements of a television system is given, and some of the terms used in explanations in other papers of the course are introduced. In most cases the details are confined to those applying to the Australian system.

2. BASIC OPERATION OF A TELEVISION SYSTEM.

2.1 A complete television system provides facilities for the transmission of both picture signals and sound signals. The sound section of the system follows normal radio broadcasting practice, but uses frequency modulated transmission in the V.H.F. band. Section 8 deals with the television sound signal.

2.2 The object of picture transmission in the system is to transmit a picture to a remote receiving point by electrical means. To do this the light reflected from the scene being televised is changed into electrical energy proportional to the light intensity.

As a scene contains information of many variations of light and shade, it is not practicable to transmit all of this information at the one time. Instead, the information is obtained by sampling or "scanning" the scene in sequence, so that the varying amounts of light from each section of the picture are in turn converted into varying electrical signals.

2.3 Simple Camera Tube. At the transmitting end, the conversion from light information into corresponding electrical information or the "video" signal, is achieved in a television camera containing a camera tube and associated equipment. A number of different types of camera tubes are in common use. The basic principle is illustrated by the simple camera tube in Fig. 1.

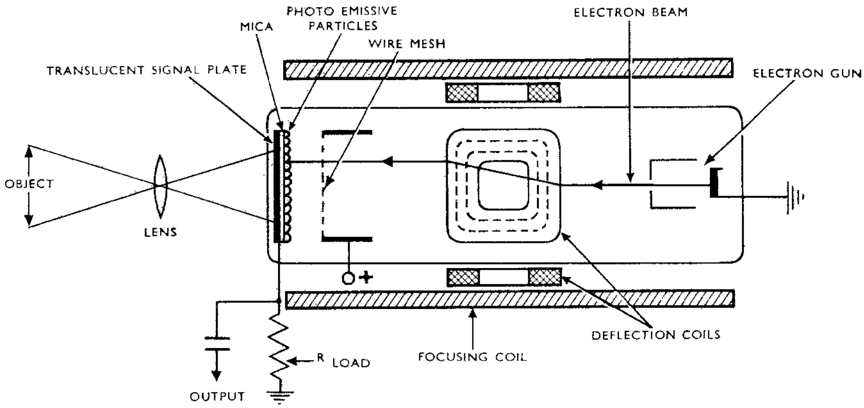


FIG. 1. SIMPLE CAMERA TUBE.

An optical lens focuses the scene on to a photo sensitive surface which is formed by tiny particles of photo emissive material deposited on a sheet of mica. The particles are insulated from one another and form small capacitors with a translucent, conducting signal plate. Spaced away from the photo sensitive surface is a wire mesh with a positive potential with respect to the photo sensitive surface.

Light on the photo emissive material causes electrons to be emitted, and these are collected by the mesh. This leaves the small capacitors with a positive charge, varying in magnitude for individual capacitors, depending on the local light intensity. An electron gun produces a beam of electrons which is made to scan the photo sensitive surface by currents in the deflecting coils. This electron beam completes a circuit for the discharge of the capacitors via the load resistor and the electron gun cathode. The magnitude of the discharge current depends on the magnitude of the charge on the capacitor being scanned. The output voltage across the load resistor is proportional to the current through it, which is in turn proportional to the light on that section of the photo sensitive surface. The electrons not required to reduce the capacitor charge can be collected by the positive mesh.

Camera tubes are described in more detail in another paper of the Course of Technical Instruction.

2.4 Scanning. The scene is scanned as a series of lines from left to right, gradually moving down from top to bottom to completely cover the picture. So that each line is reproduced in exactly the same relative position at the receiver, as it was at the camera, the scanning systems at the camera and the receiver have to be accurately synchronized, or locked together.

2.5 Transmitting. Referring to the basic television system of Fig. 2, a synchronizing (sync.) pulse generator supplies synchronizing information which is used to control the camera deflection circuits, and is combined with the video signal output from the camera. The combined video and sync. signals are amplified and used to amplitude modulate the vision carrier frequency. The complete vision R.F. signal is combined with the sound R.F. signal (which has a different frequency) and is radiated.

2.6 Receiving. The R.F. signals are picked up by the receiver where the desired signal is selected and amplified, using normal superheterodyne principles, and then applied to the A.M. detector. The output voltage of this detector contains a reproduction of the complete video signal (including sync. information) that was fed into the transmitter. This is amplified and applied between grid and cathode of the picture tube, which is a large cathode ray tube usually employing magnetic deflection. The synchronizing information is separated from the complete video signal and is used to control the picture tube deflection circuits that cause the electron beam to scan the fluorescent screen in the same manner as the electron beam in the camera. The video signal varies the intensity of the scanning beam, and therefore the screen brightness, and so an image corresponding to the original scene is recreated on the picture tube screen.

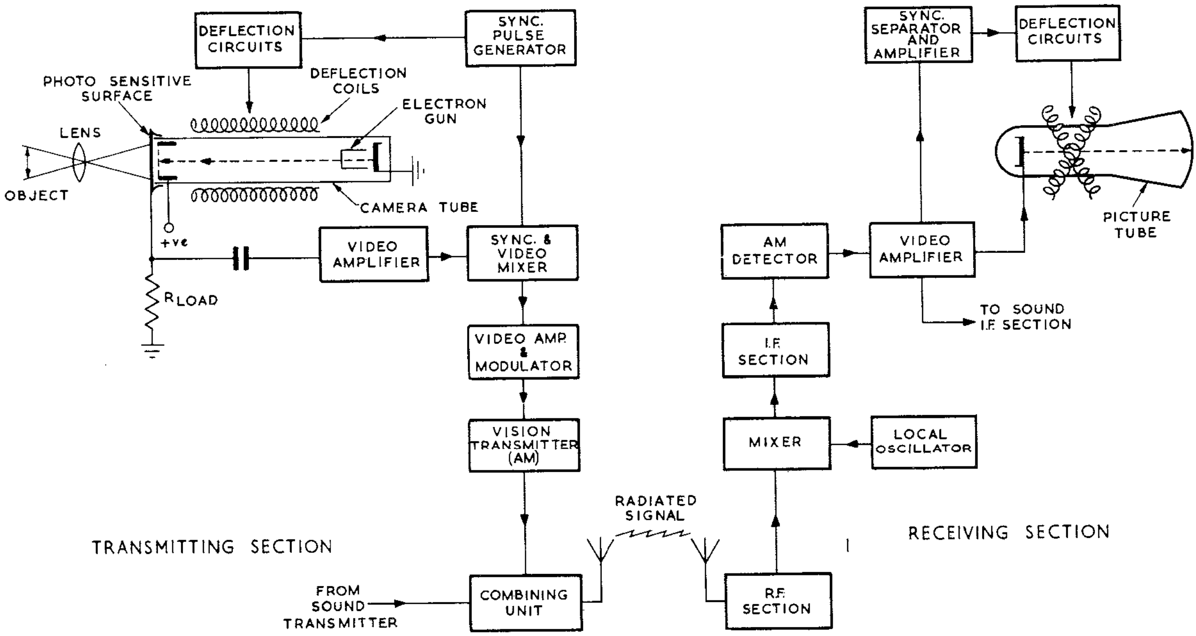


FIG. 2. BASIC BLOCK DIAGRAM OF THE VISION SECTION OF A TELEVISION SYSTEM.

2.7 Picture Elements. There are limiting factors in a television system that determine the size of the fine detail that can be transmitted and reproduced in a televised picture. To enable transmission, the picture is in effect divided into small elements and the elements are scanned progressively line by line down the picture area to provide the video signal. The size of a picture element is the size of the smallest detail able to be transmitted. The smaller the elements able to be distinguished, the greater the detail appearing in the displayed picture. The vertical dimension of a picture element is equal to the line spacing, and the system is designed so that the horizontal dimension of a picture element is similar to the vertical dimension.

It should be noted that the term picture element is only a means of describing picture detail, as in the reproduced picture there is no distinct step between elements. The picture signal actually just varies from one section to another. Sections of a picture without detail such as a grey background, are represented by a constant voltage, and a picture in which the information in the scanned line is of varying shades, is represented by a corresponding varying voltage.

Although a picture is represented as a series of finite size elements, when these are small enough so that they are not easily distinguished as separate units, the viewer "manufactures" reality from an illusion. Fig. 3 illustrates the ability of the mind to interpret a picture. It consists of a series of elements corresponding to different shades from white through grey to black.

Close-up where the viewer can distinguish the separate elements, the picture has no real meaning, but at a distance the mind interprets the whole picture as reality.

FIG. 3. "ABORIGINAL".

Fig. 3 is composed of only 1/100th of the number of elements normally presented on a television screen. To reduce the elements to a similar apparent size to those in a televised reproduction seen from a normal viewing distance, Fig. 3 would have to be viewed from approximately 25 feet. As a comparison, if Fig. 4 is the picture size of a television screen, the insert represents Fig. 3 with picture elements of correct proportions.

Picture elements are similar in some ways to the dot structure of the half tone printing process used for the reproduction of pictures in this paper. However, in the printing process, the size of a black dot determines the average shade of an area, but for television, each element is of the same size but of different brightness. In addition, each section of the printed picture is divided into separate elements discernible on close inspection, but for a televised picture where a constant shade is being reproduced, no division is made between adjacent elements.

FIG. 4. "ABORIGINAL" IN ACTUAL PROPORTION TO A WHOLE PICTURE.

3. SCANNING AND SCANNING SYSTEMS.

3.1 Scanning is the process of examining each of the picture elements in turn to obtain the picture information, and also the process of reassembling this information in the correct position on the picture tube screen. The scanning beam of electrons in the camera tube or picture tube, must traverse the entire picture area for completeness of information.

At the studio, the camera photo sensitive surface is scanned by the electron beam of the camera tube. When the picture elements are scanned in succession according to a standard scheme, a varying voltage is obtained at the output of the camera tube which has instantaneous values proportional to the brightness of the scanned picture elements.

At the receiver, the picture elements must be reproduced in exactly the same order as they were scanned at the studio.

The main requirement of a scanning system, then, is a complete coverage of the picture elements in the same sequence at the studio and at the receiver.

The lines traced out by the scanning electron beam are termed a scanning raster.

3.2 In a television receiver or camera, the scanning beam is controlled by two sawtooth waveforms of either voltage or current, one sawtooth waveform being applied to the vertical deflecting circuit and the other to the horizontal deflecting circuit. The sawtooth waveforms are of current for electromagnetically deflected tubes and of voltage for electrostatically deflected tubes.

For an example, consider two sawtooth waveforms of 1c/s and 5c/s applied respectively to the vertical and horizontal deflection circuits of a receiver. The scanning beam is deflected to produce a raster as in Fig. 5. The vertical waveform deflects the beam gradually down the screen and quickly back to the top. At the same time, the horizontal waveform, which is of a higher frequency, deflects the beam gradually from left to right across the screen and quickly back to the left, so that the beam crosses the screen from left to right five times in the time taken to move from top to bottom. The beam therefore traces a series of approximately horizontal lines.

At time 0, the vertical and horizontal waveforms direct the beam to the top and the left of the screen respectively. With time, the beam moves downwards and across to 1'. When the horizontal sawtooth changes from point 1' to 1, the beam is returned rapidly to the left of the screen with no change in the vertical deflection. This rapid movement is termed "retrace" or "flyback" and, in practice, the circuit is arranged so that the beam is not seen during this period. The beam again moves down and across to 2' and so on to 0'.

When five cycles of the horizontal waveform and one cycle of the vertical waveform have been completed, both waveforms rapidly change from 0' to 0 and the beam returns from the bottom right to the top left of the picture, ready to start the next complete scan. As before, in practice the flyback trace is not seen.

3.3 Sequential Scanning. Fig. 5 is an example of a five line raster produced by sequential scanning. Sequential scanning is a system of producing a raster by one complete series of approximately horizontal lines, traced out in succession to completely cover the screen area after only one vertical scan. Sequential scanning is seldom used, the exception being some closed circuit television systems.

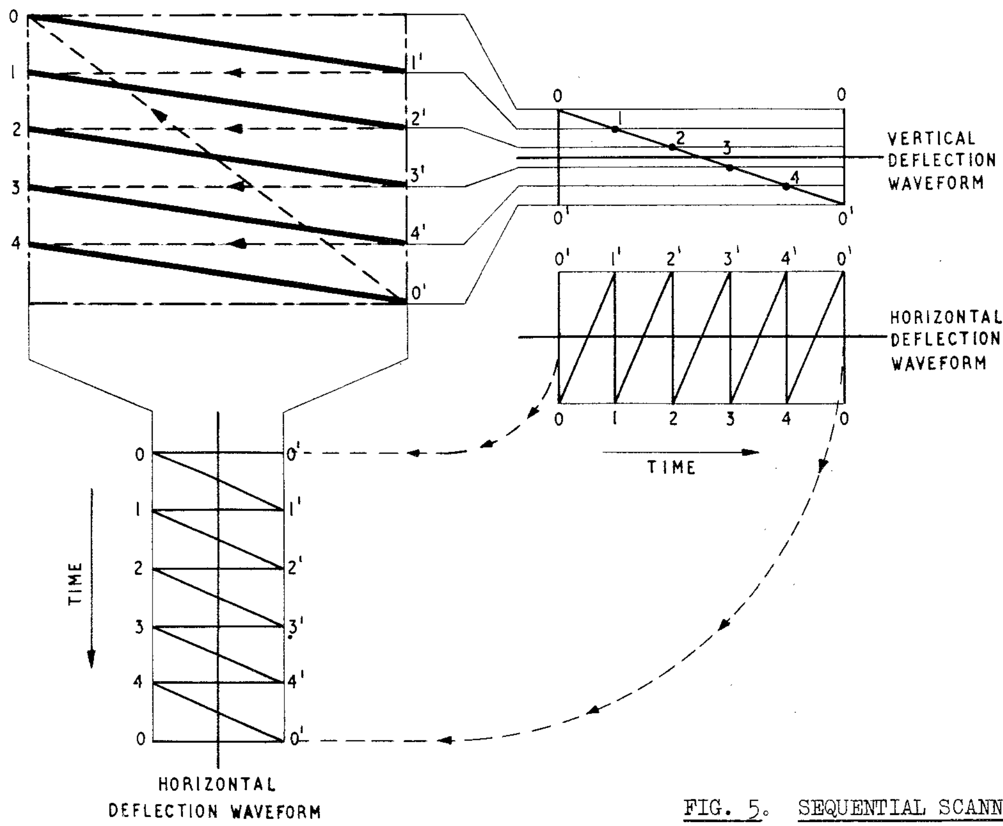


FIG. 5. SEQUENTIAL SCANNING.

3.4 Interlaced Scanning. When the vertical frequency is doubled to 2c/s, the raster traced out (Fig. 6) is an interlaced scanning raster. The beam now moves across and down from point 0 to point 1' and retraces to 1 as before. At the time of the first horizontal retrace, however, the beam is further from the top of the picture than it was for sequential scanning. This is because of the higher vertical deflection frequency and therefore the higher rate of change of the vertical sawtooth waveform. The beam moves from 1 to 2', quickly retraces to 2, and completes half of the next line to 2.5'. At this point vertical flyback occurs to 2.5, but because no horizontal flyback occurs at this stage, the beam continues across the picture to complete another half line to 3'. The rest of the raster is traced out, with the lines in between the lines of the original scan. The picture is completed when the beam reaches 0'. Here, both vertical and horizontal flyback occurs, and the beam returns to 0, ready to commence the next complete scan.

Therefore, when the scanning frequencies are 5c/s and 2c/s, the complete 5 line raster is traced out by two successive scans of $2\frac{1}{2}$ lines. This is a 2 : 1 interlaced raster. The Australian system uses a 625 line 2 : 1 interlaced scanning scheme. The complete "picture" (frame) is produced by two "fields", each of $312\frac{1}{2}$ lines, and designated either "odd" or "even" fields. (The odd field ends in a half line and the even field in a full line).

For a 2 : 1 interlaced raster to be produced, the total number of scanning lines must be an odd number, and the deflecting waveforms must be correctly timed. The rate at which the total 625 line raster is produced is called the picture frequency, and the rate at which each field is produced is called the field frequency. The number of lines in the raster is equal to the ratio of line frequency (i.e. horizontal frequency) to picture frequency.

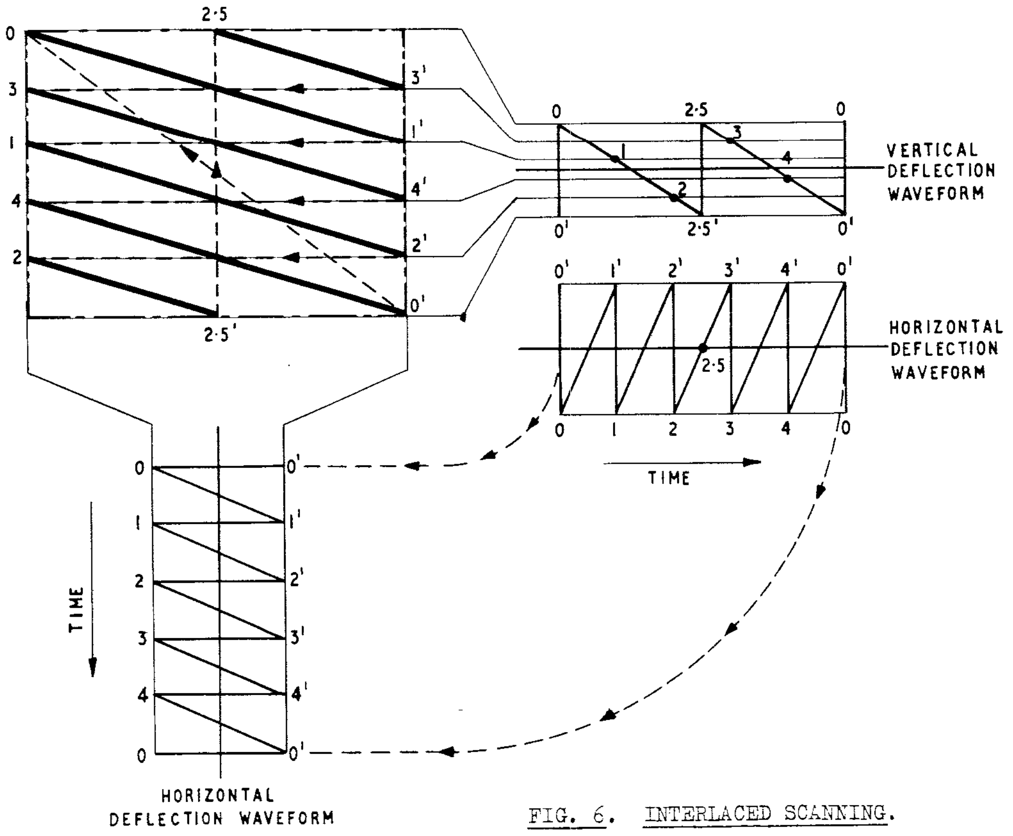


FIG. 6. INTERLACED SCANNING.

4. PICTURE REPRODUCTION.

4.1 Persistance of Vision. The effectiveness of any television system depends upon the persistance of vision of the human eye. The scanning process must be quite rapid if the viewer is to receive the illusion that the picture is complete. Persistance of vision can be defined as the ability of the eye to retain an image for a short period, even after the image has been removed from direct view. The human eye is capable of retaining an image for approximately 1/20th of a second. All the picture elements must be transmitted in 1/20th of a second or less if the eye is to register that the complete picture is present at the one time. The scanning process must be fast enough so that the last line of the screen appears while the impression from the first line still persists in the mind. In the Australian television system, all the elements of the complete picture are transmitted in 1/25th sec.

4.2 Motion Pictures. The illusion of motion is created with a change of as few as 16 progressive pictures or frames per second, though 24 frames per second is the standard in sound motion picture practice. However, when either picture is viewed, the viewer is conscious that the image is being projected, switched off, projected, switched off, and so on. While the illusion of motion is good, the flicker is objectionable because the eye is registering a decay in light intensity though the image still persists.

This flicker may be reduced in one of two ways -

(i) By projecting more frames per second; or

(ii) By keeping the projection rate at a figure which gives a satisfactory illusion of motion (e.g. 24 frames per second) and displaying each frame either 2 or 3 times.

Method (i) is wasteful of film but is otherwise satisfactory. Method (ii) conserves film, but adds some additional mechanism to the projector to cut off the light 2 or 3 times per frame. Although this reduces the total light falling on the screen, it is the method adopted.

4.3 Picture and Field Frequencies. In the television system, a similar process to that used for motion pictures is used to produce motion in the transmitted pictures. Each picture is broken down into many elements and the picture is scanned often enough to provide the illusion of motion in the reproduced result on the picture tube screen. In television, the picture rate is 25 times per second as against 24 for motion film. This picture rate is again not sufficient to give freedom from flicker at the high light levels encountered on the picture tube screen. (The threshold of noticeable flicker is dependant on the image brightness, with the threshold frequency being lowered by an increase in brightness).

The use of a shutter to change the flicker rate is not possible for television, as the information is conveyed progressively and not as a whole as with film reproduction. The problem is overcome by the use of the interlaced scanning system where the field frequency is twice the picture frequency (i.e. 50c/s) and the complete picture is built up with two successive fields. The screen is scanned from top to bottom 50 times per second and the flicker rate of the whole image is satisfactory for viewers.

Sequential scanning with a 50c/s vertical frequency would also give satisfactory flicker results, but we shall see in Section 5 that the bandwidth required would be twice that required for interlaced scanning.

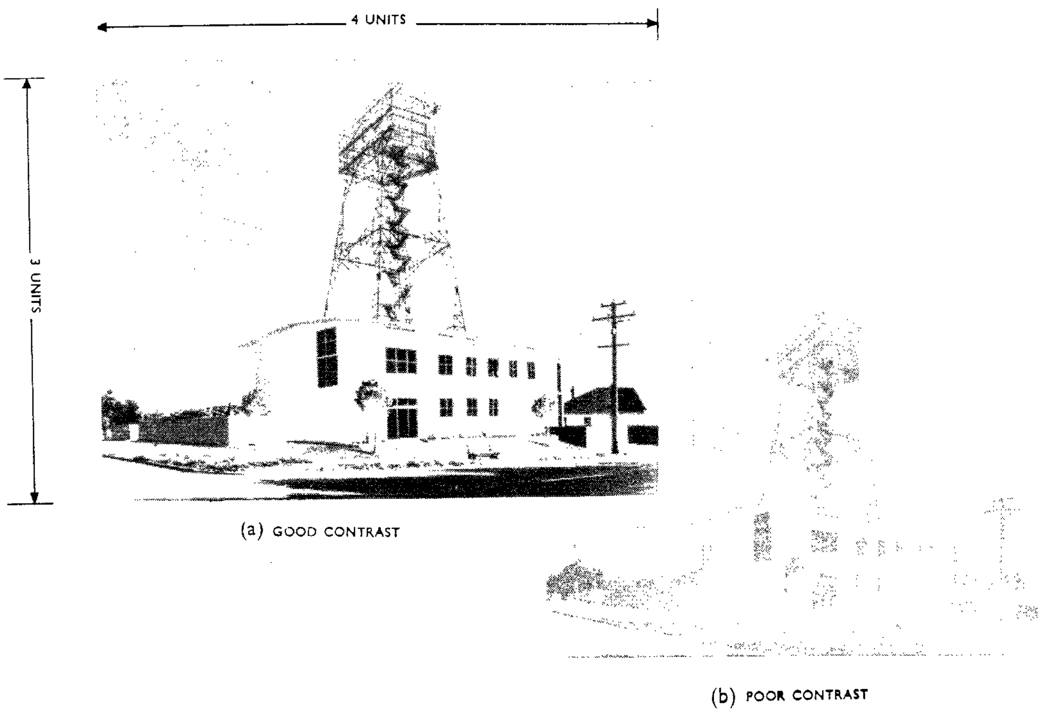
The picture rate of 25 cycles per second is chosen for television because it satisfies the above requirements, and because the prime power supply frequency is 50c/s in Australia. This makes the field frequency and the power supply frequency the same, and reduces the possibility of objectionable beats being produced between the two frequencies. The television system in North America uses a 60c/s field rate which corresponds to the standard power frequency in that area.

4.4 Aspect Ratio. The size of the picture reproduced by a television receiver depends on the size of picture tube used, but under all circumstances the ratio remains constant at four units horizontally to three units vertically (see Fig. 7). As an example, a reproduced picture 4" x 3" has the same "aspect ratio" as one 16" x 12". The 4 : 3 aspect ratio has similar proportions to those used in the motion picture industry, for old type film, (as distinct from the special aspect ratios used for wide screen motion picture systems).

4.5 Brightness. This is the overall or average illumination in the reproduced television picture. The picture must be bright enough to be seen easily under subdued lighting. The brightness required for television reproduction is greater than that used for motion picture reproduction, since a much higher ambient lighting exists in the average home than exists in a theatre.

The brightness required is a problem because the fluorescent screen of the picture tube is illuminated on only one spot at a time. The overall brightness of the picture is very much less than the brightness of the actual spot. The screen is illuminated over its entire surface during a picture period and it retains overall brightness due to the "persistance" of the screen material. A long persistance maintains a higher average brightness, but the persistance must be less than the picture period or the first picture can still be seen when the following one is traced out. This causes blurring of motion to be observed. The characteristics of the eye cause flicker to become very noticeable and annoying when the brightness of a picture is too great.

4.6 Contrast. Contrast is the relative difference in brightness between black and white parts of the reproduced picture. For a pleasing reproduction, the contrast range should be great enough to reproduce complete black and bright white, with a continuous range of shades of grey in between. The dull, flat picture of Fig. 7b shows poor contrast, and results from too little video signal. Excessive contrast makes the picture appear hard, usually distorting the shades of grey between black and white. The brightness and contrast are adjusted to reproduce as many grey shades of the standard test pattern as possible, under the room lighting conditions existing.



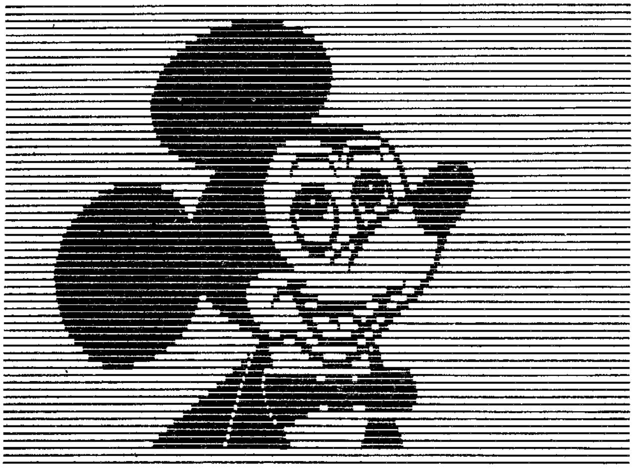
(a) GOOD CONTRAST

(b) POOR CONTRAST

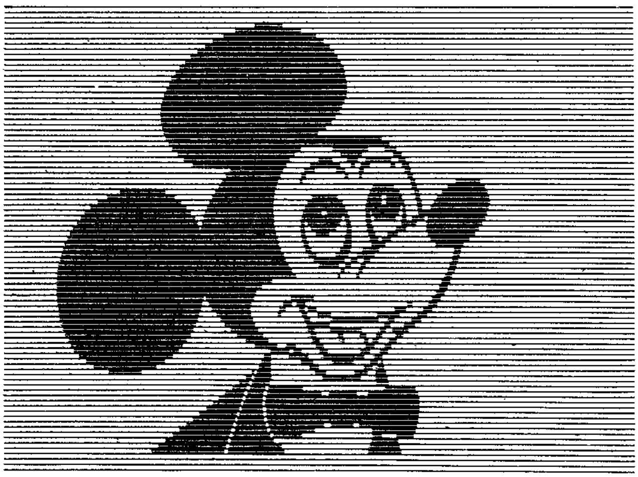
FIG. 7. ASPECT RATIO AND CONTRAST.

4.7 Viewing Distance. Independent of screen size, a television system transmits signals with the same number of picture elements, so that there is a proper viewing distance to get satisfactory viewing results. If the screen is too close, the line structure is seen, and if too far away the fine detail of the picture is wasted. Again, eye fatigue can be caused when the viewing distance is small because the eyes have to move to follow picture motion. Too great a viewing distance is just as fatiguing, as the eyes become fixed on the screen and are not required to move at all.

The optimum distance from the screen is about 4 to 8 times the picture height depending on the picture brightness and the preference of the viewer. This puts the viewing distance of a 23" television set at about 5 to 10 ft.



(a)



(b)

FIG. 8. EFFECT OF THE NUMBER OF LINES ON PICTURE DETAIL.

5. RESOLUTION AND BANDWIDTH.

5.1 Picture Detail and Number of Lines. In a television system the greater the number of lines used to scan the picture, the smaller the picture elements transmitted, and the finer the details of picture information produced. With an increase of picture element size, the quality of the picture is lost in reproduction owing to the lack of detail.

This is shown in Fig. 8, where the picture comprised of a small number of lines (8a) has less detail than the one with a greater number of lines (8b).

The measure of the ability of a system to reproduce fine detail is termed its "resolution" and for high quality and resolution, as many picture elements and lines as possible should be used. However, as we shall see in para. 5.5, the greater the number of lines used, the wider the bandwidth required to transmit the intelligence.

In any television system therefore, the choice of the number of lines represents a compromise between fineness of picture detail and desirable bandwidth. In Australia, 625 lines per picture was chosen as it provides adequate reproduction of picture detail, consistent with a desired bandwidth for transmission of the signal.

We saw in para. 3.4 that the two deflection waveforms must maintain correct timing to produce correct interlace, therefore the picture frequency must be an exact submultiple of the line frequency. In practice this relationship is achieved in the sync. pulse generator by dividing the frequency of a master oscillator the required number of times to produce synchronizing signals for both vertical and horizontal deflection circuits. Frequency division is simplified if the number of lines chosen for the system (625) is composed of simple arithmetical factors, (5 X 5 X 5 X 5). In addition, the figure chosen must be an odd number for a 2 : 1 interlaced scanning system.

5.2 Line Frequency. The number of lines traced per second by the scanning beam in a receiver or camera, is the product of number of lines per picture and the picture frequency. In the Australian system, therefore -

$$\text{Line frequency} = 625 \times 25 = 15{,}625 \text{ lines per sec.}$$

The horizontal oscillator must then operate at a frequency of 15,625c/s.

5.3 Vertical Resolution. The maximum resolution vertically is determined by the number of lines in a television system; it should be possible for one line to be black and the next white, this being the limit of vertical resolution.

All of the 625 lines of the television system are not presented on the screen. Some are lost due to the time allowed for flyback of the vertical deflection oscillator voltage when the spot is returned to the top of the screen. In addition, some detail is lost because the scanning spot may be half on a black section and half on a white section of the picture. Only about 75% of the lines corresponding to maximum vertical resolution are expected to be accurately reproduced. The relation between the maximum possible vertical resolution and the actual resolution expected is called the "vertical resolution factor". This means that the vertical resolution factor is 0.75.

5.4 Horizontal Resolution. Along each line the picture element size should be comparable to the elements represented by the line structure vertically. It is the element size and the number of lines that determines the bandwidth necessary in a television system.

The horizontal resolution is specified as the number of picture elements that can be resolved horizontally in a width equal to the picture height. Assuming vertical and horizontal resolution are the same, it is necessary to multiply the vertical resolution by the aspect ratio to find the number of elements actually presented in the complete picture width.

5.5 Bandwidth. When the picture is a checker board pattern (Fig. 9a), the scanning beam current for the two lines A and B should alternate between two values as shown in Fig. 9b. With each square the size of a picture element, the actual output (Fig. 9c) is very close to a sine wave, because it is not possible to transmit all the harmonics which make up a square wave, and because the finite size of the scanning spot cannot produce an output with an immediate transition from black to white.

It should be noted that two elements, one black and one white, produce a sine wave. Therefore, dividing the number of picture elements in the line by two gives the number of cycles of signal in the time for the forward trace across the screen. Dividing the number of cycles by the time for the trace gives the highest frequency required to reproduce distinguishable picture elements the same relative size as the elements of the original.

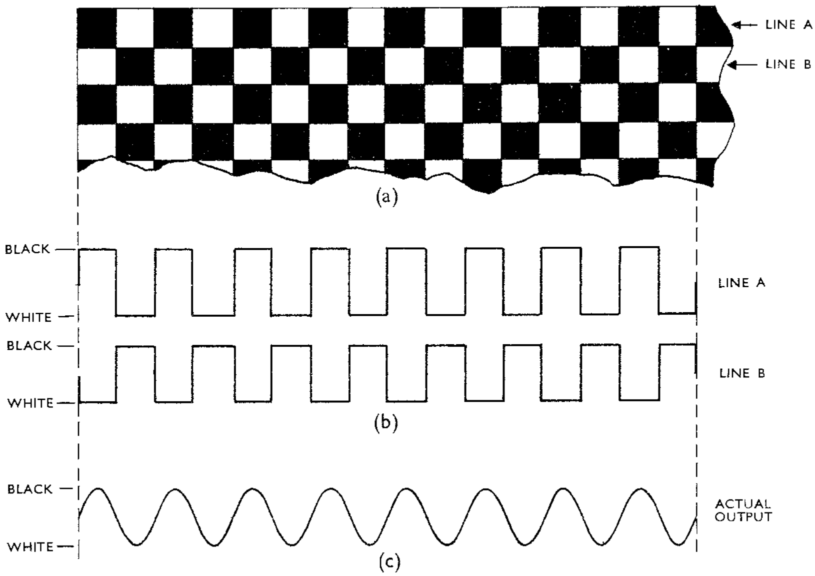


FIG. 9. VIDEO SIGNALS PRODUCED FROM A PICTURE.

Calculations are made in the paper "Composite Video Signals" and it is found that for the Australian television system, a band of frequencies from 0c/s (D.C.) to approximately 5Mc/s is required to transmit the picture signals.

Other standard television systems require different bandwidths. If the number of lines produced in the complete raster is increased, the time for one line is reduced and a higher maximum signal frequency is required. This limits the number of scanning lines that can be used to provide a picture of a given horizontal resolution in a given bandwidth.

5.6 Scanning Systems and Bandwidth. We saw in para. 4.3 that interlaced scanning is used to reduce flicker, and also that sequential scanning with a 50c/s vertical deflection frequency gives similar flicker to that of the Australian system. A 625 line 2 : 1 interlaced raster with a 50c/s flicker rate is produced by a horizontal deflection frequency of 15,625c/s. For a 625 line sequential raster with a 50c/s flicker rate, the horizontal deflection frequency is 625 X 50 = 31,250c/s.

This means that the time for one line of a sequential scan is half the time for one line of the interlaced scan. If the time for one line is halved, the highest frequency of the signal is doubled. Therefore, for the same horizontal resolution and the same flicker rate, a picture produced by sequential scanning requires a bandwidth twice as wide as one produced by a 2 : 1 interlaced scan.

5.7 Considering the number of picture elements possible with film and television, the televised reproduction has slightly more elements than 16mm film, but 16mm film has the advantage that the reproduction is a complete picture, and not a series of lines as with television.

6. COMPOSITE VIDEO SIGNAL.

6.1 Picture Signal. We saw in Section 2, that the output voltage from the camera tube is dependent on the amount of light focused on to the section of the photo sensitive surface being scanned. Different output voltages are produced from different shades of grey from white to black.

Fig. 10a shows the output voltage of a scanned line (line Y) of the picture and indicates the voltage corresponding to different parts of the picture. As the picture is scanned line after line, the voltage outputs for each line follow in succession as shown by line Z in Fig. 10a.

In the example, the picture signal is simple in shape and the same for each scanned line. For the average picture transmitted in practice, the signal is usually irregular in shape, with a variation in the information from line to line.

6.2 Blanking. In a practical deflecting circuit, the waveform cannot change instantaneously to produce instantaneous retrace of the scanning spot producing the raster, therefore some time is allowed between the lines of picture information. It is not desired to reproduce the retrace lines on the screen to interfere with the picture created by the forward trace, so horizontal blanking pulses are included with the picture signal to cut-off the electron beam during the horizontal retrace time. Fig. 10b shows the output voltage of two scanned lines with horizontal blanking included.

At the end of one field, the scanning spot returns to commence scanning the next field. To prevent vertical retrace lines from being reproduced on the screen, a vertical blanking pulse cuts off the beam during this time. Fig. 10c shows the signal for the last two lines of one field (lines Y and Z), vertical blanking, and the first two lines (lines A and B) of the next field.

After blanking signals are added to the picture signals, the result is called a "non-composite video signal".

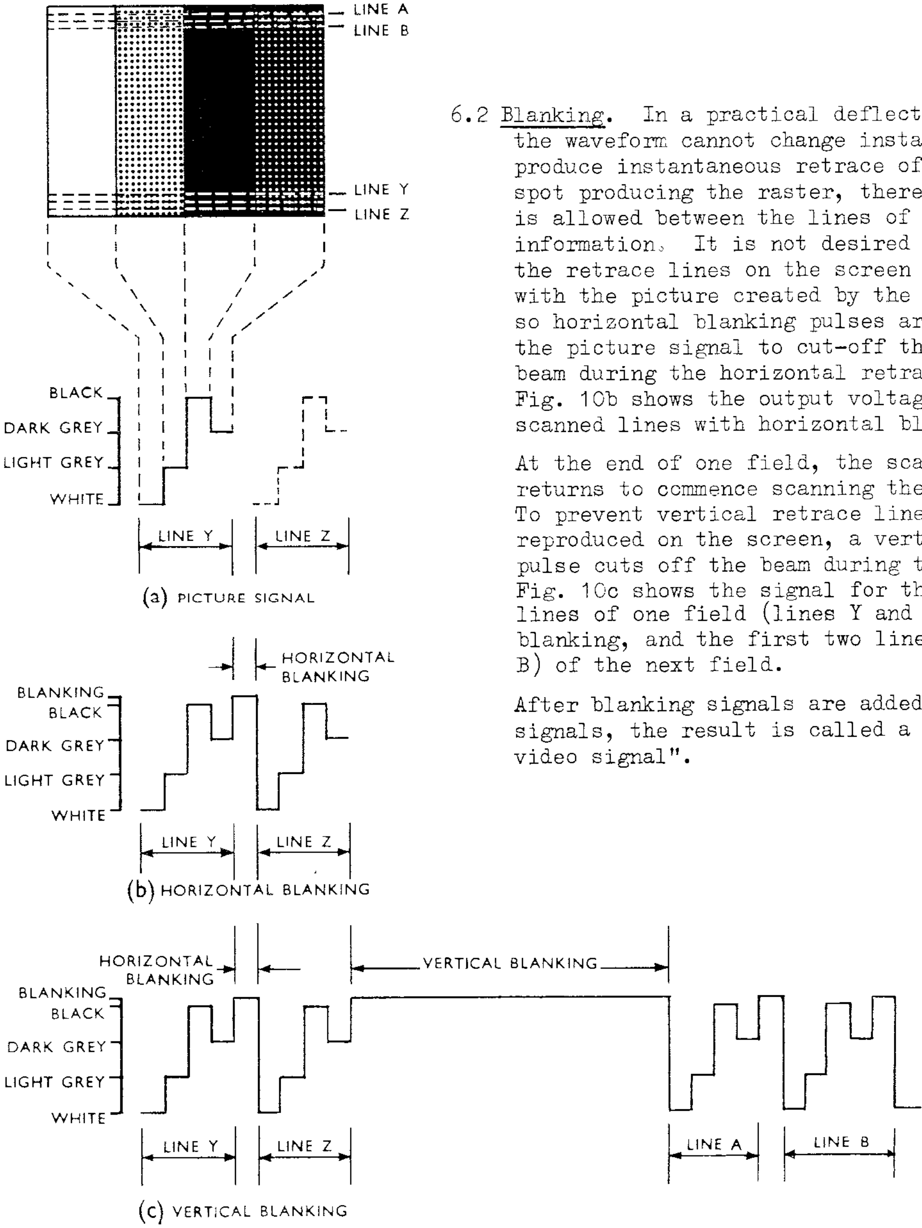


FIG. 10. NON-COMPOSITE VIDEO SIGNAL.

For the Australian system, blanking pulses are required at repetition rates of 15,625c/s and 50c/s, to suppress signals during both the horizontal and vertical retrace times, and the blanking time allowed is:-

(i) Horizontal blanking - 11.5-12μS out of the 64μS ($\frac{1}{15,625}$ secs.) for a complete line, which includes both the picture signal time and the blanking time.

(ii) Vertical blanking - 18-22 lines out of the 20,000μS ($\frac{1}{50}$ secs.) for a complete field.

The waveform shown in Fig. 11 is a non-composite video signal corresponding to the Australian standards.

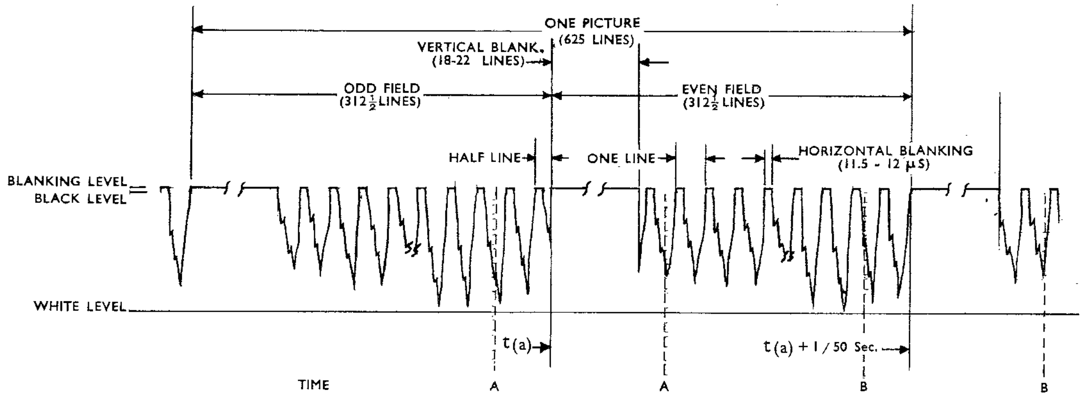


FIG. 11. NON-COMPOSITE VIDEO SIGNAL OF A COMPLETE PICTURE.

6.3 Odd and Even Fields. For a 2 : 1 interlaced scanning system, each field must contain a half line, i.e. for a 625 line system each field has 312½ lines (Fig. 11). A field that starts with a full line must end with a half line (odd field) and one that starts with a half line must end with a full line (even field).

When comparing waveforms existing in each alternate field, and particularly when comparing waveforms for alternate vertical blanking periods, it is convenient to show sections of the waveform on two time scales, one under the other. Fig. 12 shows sections A-A and B-B of Fig. 11 redrawn in this way.

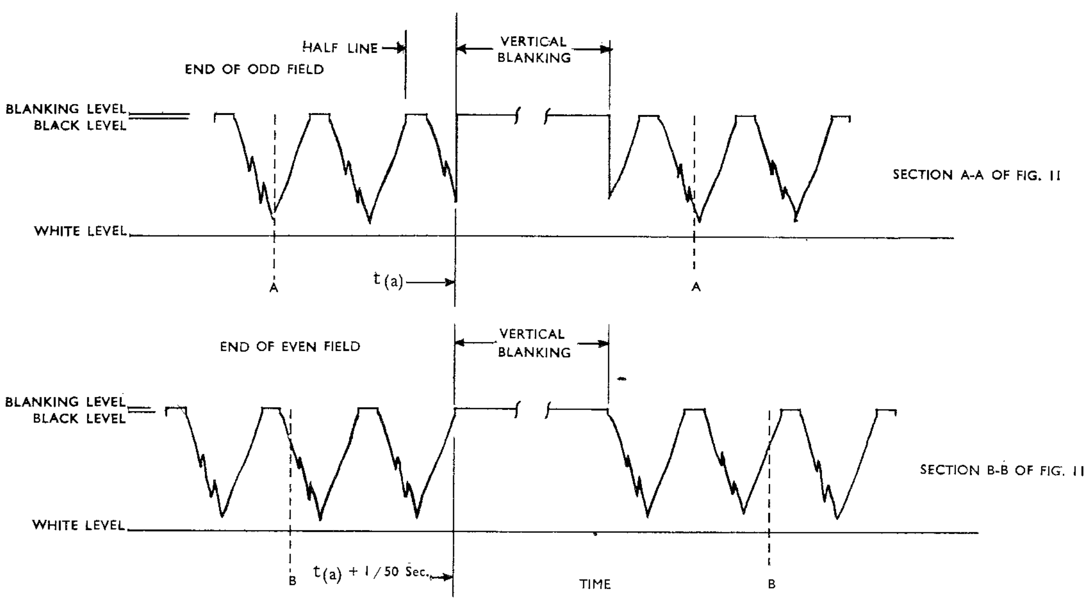


FIG. 12. COMPARISON OF WAVEFORMS OF ODD AND EVEN FIELDS.

Each waveform in Fig. 12 is re-occurring at a 25c/s rate, i.e. the picture frequency, but there is a vertical blanking period re-occurring at a 50c/s rate when both odd and even fields are considered.

Note in Figs. 11 and 12 the method of designating the time scales to show that the start of the vertical blanking following the even field occurs $\frac{1}{50}$ sec. later than the start of vertical blanking following the odd field; i.e. $t_{(a)} + \frac{1}{50}$ sec. is $\frac{1}{50}$ sec. after $t_{(a)}$. The same time designations are used in Fig. 11 to indicate the actual scale when one continuous time scale is used.

Fig. 12 indicates how the horizontal blanking pulses of the even field are interleaved with those of the odd field, showing that the horizontal flyback and therefore the forward trace of the lines of each of the fields of the interlaced raster are interleaved.

6.4 Synchronization. To ensure that the deflection oscillators at both camera and receiver cause the spot to scan corresponding lines of the picture at the same time, sync. pulses are inserted in the blanking periods of the video signal fed into the transmitters. The sync. pulses, derived from the sync. pulse generator, control the deflection oscillators of both the camera and receiver, but do not deflect the scanning beam.

Horizontal sync. pulses are short duration pulses of approximately $5\mu S$ inserted in the horizontal blanking period as shown in Fig. 13.

The small section of blanking pulse ($1-1.5\mu S$) before the horizontal sync. pulse is known as the "front porch", and the section of blanking pulse following the horizontal sync. pulse is the "back porch". The front porch is provided to ensure that the picture tube electron beam is completely cut-off before the synchronizing time. The back porch allows time for any spurious responses, caused by the trailing edge of the sync. pulse, to die away before the beginning of the picture information of the next line. In addition, the back porch provides a time when a voltage at blanking level is available so that blanking level can be "clamped" to a fixed voltage if required.

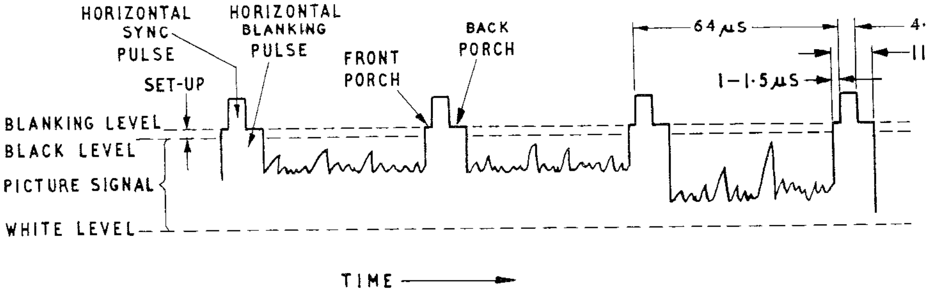


FIG. 13. HORIZONTAL SYNCHRONIZING PULSE.

To reproduce a picture correctly, a receiver is adjusted so that black signals just cause cut-off of the picture tube electron beam, and white signals cause sufficient screen brightness to represent white. When this is the case, both blanking signals and sync. signals cause the picture tube to be driven beyond cut-off and are not reproduced. Signals of these amplitudes are said to be in the "blacker than black" region.

The margin separating black level and blanking level is called "set-up" (Fig. 13). "Set-up" is included to allow a tolerance for clippers adjusted to remove sync. information, and to give a margin to prevent spurious signals in the back porch interval from extending into the picture signal region, so producing visible signals during the flyback time.

For vertical synchronization, five long duration half line rate pulses, known as "broad pulses", are included in the early part of the vertical blanking period to form a complete vertical sync. pulse of approximately $2\frac{1}{2}$ lines duration as in Fig. 14. The serrations of approximately 5μS in the vertical sync. pulse that divide it into broad pulses, are included to maintain horizontal synchronizing information during the vertical sync. pulse interval.

To enable perfect interlace to be obtained, further pulses of approximately 2.5μS duration known as "equalizing pulses", are added to the waveform immediately preceding and following the vertical sync. pulse. Without equalizing pulses, poor interlace can arise as a result of one field ending in a full line and the other field in a half line. Five pre-equalizing pulses and five post-equalizing pulses re-occurring at half line intervals, make the waveforms for both odd and even fields identical immediately before and after the vertical sync. pulse interval. This can be seen from the waveforms for each field that are drawn one above the other in Fig. 14 for easy comparison.

The signal with picture information, blanking information, and synchronizing information combined is called the "composite video signal". Fig. 14 shows sections of the composite video signal of the Australian television system.

6.5 In the television receiver, the video signal out of the detector is applied to the picture tube, but as well, it is necessary to interpret the synchronizing information. In a sync. separator, the picture information is removed leaving only the sync. signals. The vertical sync. pulses are then distinguished from the horizontal sync. pulses. The distinction is made in receiver circuitry which is sensitive to the duration of the pulses.

6.6 Further details of the composite video signal are given in the paper "Composite Video Signals".

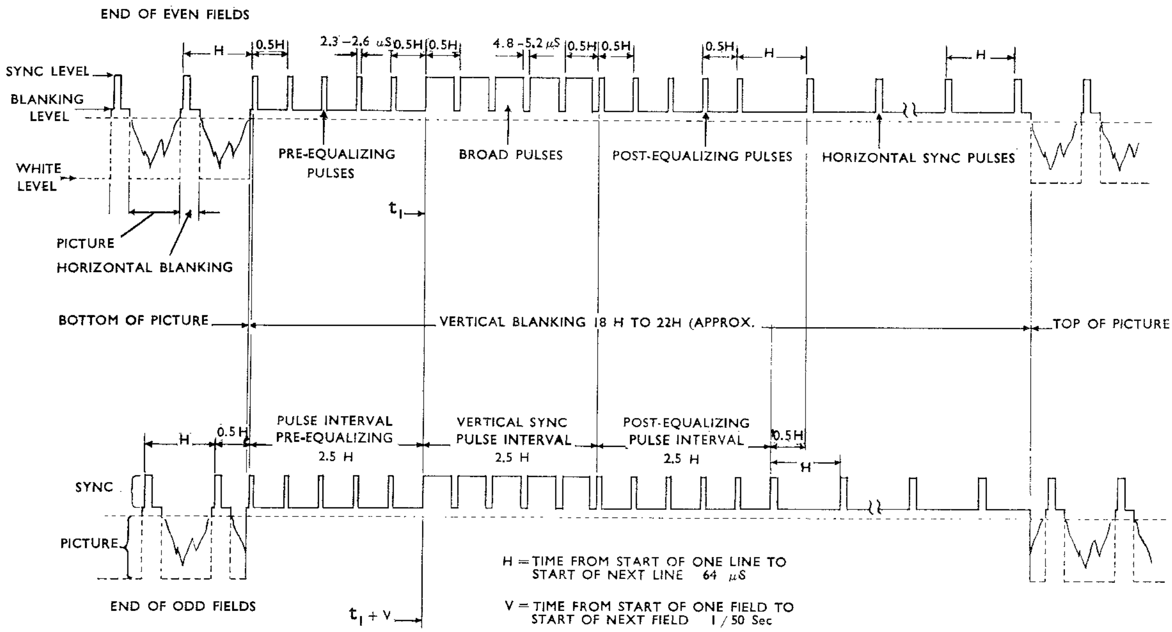


FIG. 14. COMPOSITE VIDEO SIGNAL.

7. PICTURE CARRIER AND CHANNEL BANDWIDTH.

7.1 Polarity of Modulation. The picture carrier is amplitude modulated by the video signal so that the maximum picture brightness causes minimum carrier amplitude. This polarity of modulation in a television system is referred to as negative modulation. Positive modulation is the term applied to a television system in which modulation is carried out so that maximum brightness corresponds to maximum carrier amplitude. The British 405 line television system uses positive modulation. Australia has joined United States and countries using C.C.I.R. standards, by adopting negative modulation. The C.C.I.R. is the International Consulting Council for Radio.

The composite video signal shown in Fig. 15a is of a picture consisting of a single vertical black bar on a white background. A carrier, amplitude modulated by this signal using negative modulation, produces the result shown in Fig. 15b. Using positive modulation, the modulated carrier enveloped is as in Fig. 15c.

Negative modulation has the advantages that:-

(i) The picture information occupies the most linear section of the modulation characteristic.

(ii) The average picture contains more white than black and so the average power of the vision transmitter is lower; (compare Fig. 15b and Fig. 15c).

(iii) Interference such as spots produced by car ignition are less noticeable.

(iv) Receiver A.G.C. circuits are simpler.

A disadvantage of negative modulation is that interference can cause triggering of simple line deflection oscillators. This problem is overcome by using horizontal stabilizing circuits in television receivers.

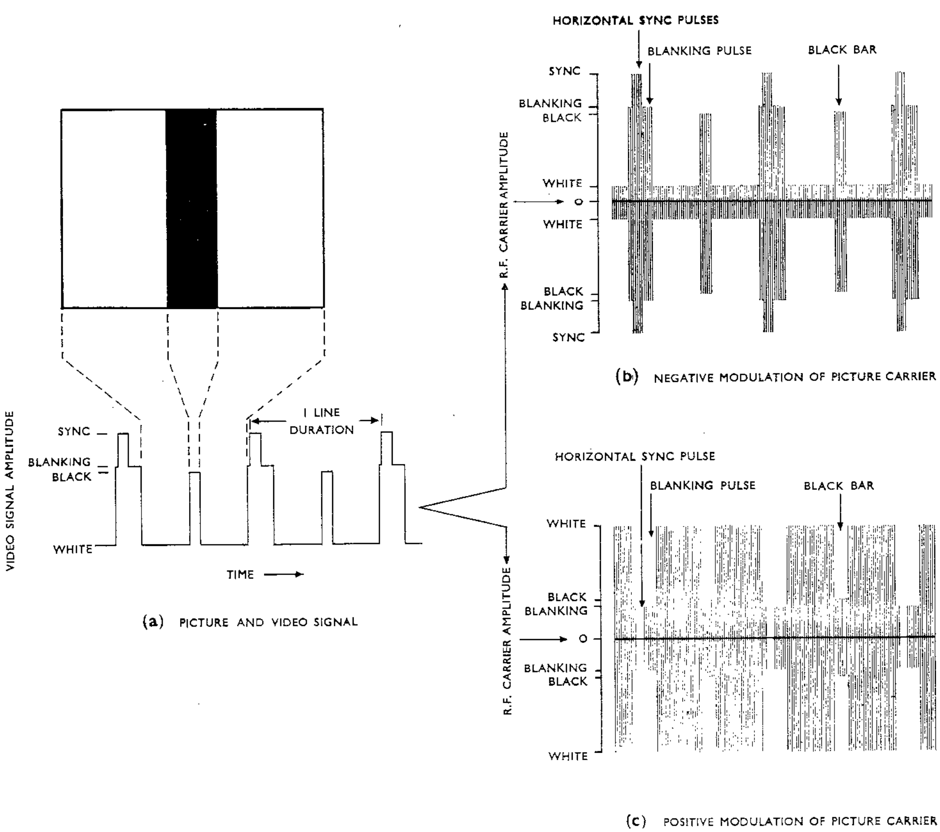


FIG. 15. PICTURE CARRIER SIGNAL.

7.2 Channel Bandwidth. As the video bandwidth used in the Australian T.V. system is 5Mc/s, a double sideband amplitude modulated transmitter would require the use of a band of frequencies 10Mc/s wide. As this is excessive and unnecessary, a "vestigial" sideband amplitude modulated transmission is used. This means that one sideband and a small portion of the other sideband is transmitted. The complete suppression of one sideband would further reduce the bandwidth, but difficulties are experienced in sharply cutting off one sideband because of the introduction of severe phase distortion.

Fig. 16 shows the relative amplitude of the sideband frequencies for the Australian television system, with frequency designations related to the channel lower limit.

The upper sideband is transmitted at maximum amplitude for all video modulating frequencies up to 5Mc/s, and is then attenuated to zero before a frequency 5.5Mc/s above the picture carrier. The lower sideband is transmitted at maximum amplitude for video frequencies up to only 0.75Mc/s, and is then reduced to zero over the next 0.5Mc/s. The F.M. sound carrier is located 5.5Mc/s higher than the picture carrier, and a small guard band of 0.25Mc/s is left between the sound carrier and the channel upper limit.

Because of the wide band of frequencies necessary, the V.H.F. band of the spectrum is used for allocated channels.

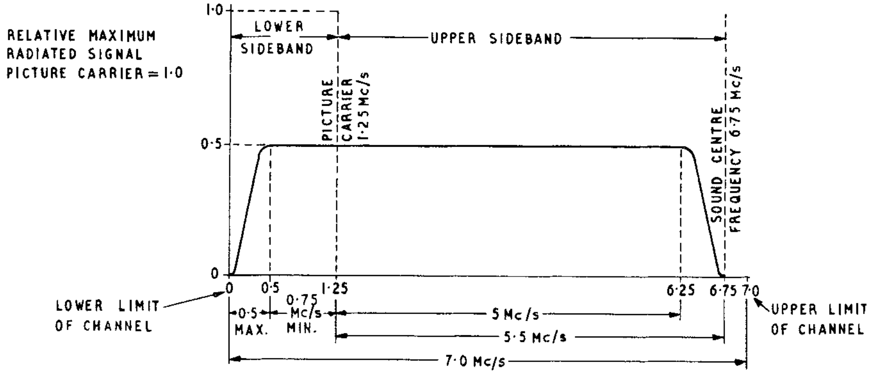


FIG. 16. UTILISATION OF CHANNEL WIDTH.

7.3 As sideband frequencies produced by modulating frequencies to 0.75Mc/s are transmitted in both sidebands, and only the upper sideband is transmitted for higher modulating frequencies, the response of the receiver is made as in Fig. 17. This is to keep the output of the video (A.M.) detector the same for signals from 0 to 0.75Mc/s, as for equal amplitude signals from 0.75Mc/s to 5Mc/s.

Consider a modulating frequency of 0.5Mc/s. The sum of the amplitudes of the lower sideband frequency and the upper sideband frequency for this modulating frequency is equal to the amplitude of the upper sideband frequencies for video signals above 0.75Mc/s, and the overall response is constant over the video band.

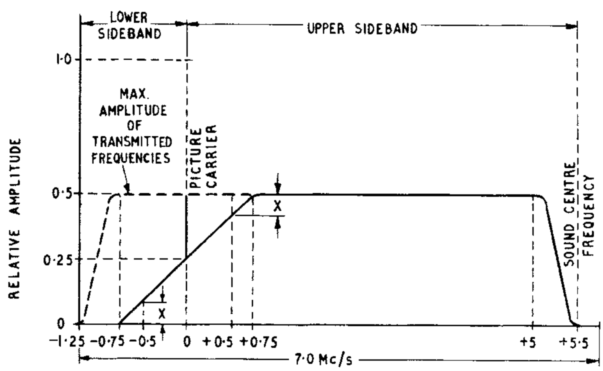


FIG. 17. IDEAL RECEIVER RESPONSE FOR VESTIGIAL SIDEBAND TRANSMISSION.

8. TELEVISION F.M. SOUND SIGNAL.

8.1 The sound is transmitted simultaneously with the picture signal to permit complete visual and sound reproduction of the televised programme. The sound channel uses a completely separate frequency modulated carrier spaced 5.5Mc/s from the picture carrier. The maximum deviation for full modulation is ± 50kc/s, so that the total bandwidth required for the sidebands of the sound channel is still within the 7Mc/s channel.

The frequency response of the sound transmitter is increased gradually at high frequencies, and to obtain a level response over the complete sound system, the receiver is designed with a falling high frequency response to compensate for the transmitter response. The increasing of the high frequency response is called high frequency "pre-emphasis" and the restoration of the correct overall response in the receiver is called "de-emphasis". In an F.M. receiver, noise and interference increases at higher output frequencies and the de-emphasis gives an improvement in the receiver noise figure.

8.2 The use of F.M. sound and A.M. picture carriers enables the sound and vision to share common intermediate frequency and detector stages in a television receiver. As the two carriers are 5.5Mc/s apart, a beat occurs in the detector producing a 5.5Mc/s frequency which is mainly frequency modulated. This is filtered from the video and amplified by the 5.5Mc/s sound intermediate frequency. After amplification it is applied to the discriminator and converted to audio frequency variations. A receiver using the beat between sound and picture carriers to produce the sound I.F. is an "intercarrier" receiver. A simple block diagram of the sound section of a television system is shown in Fig. 18.

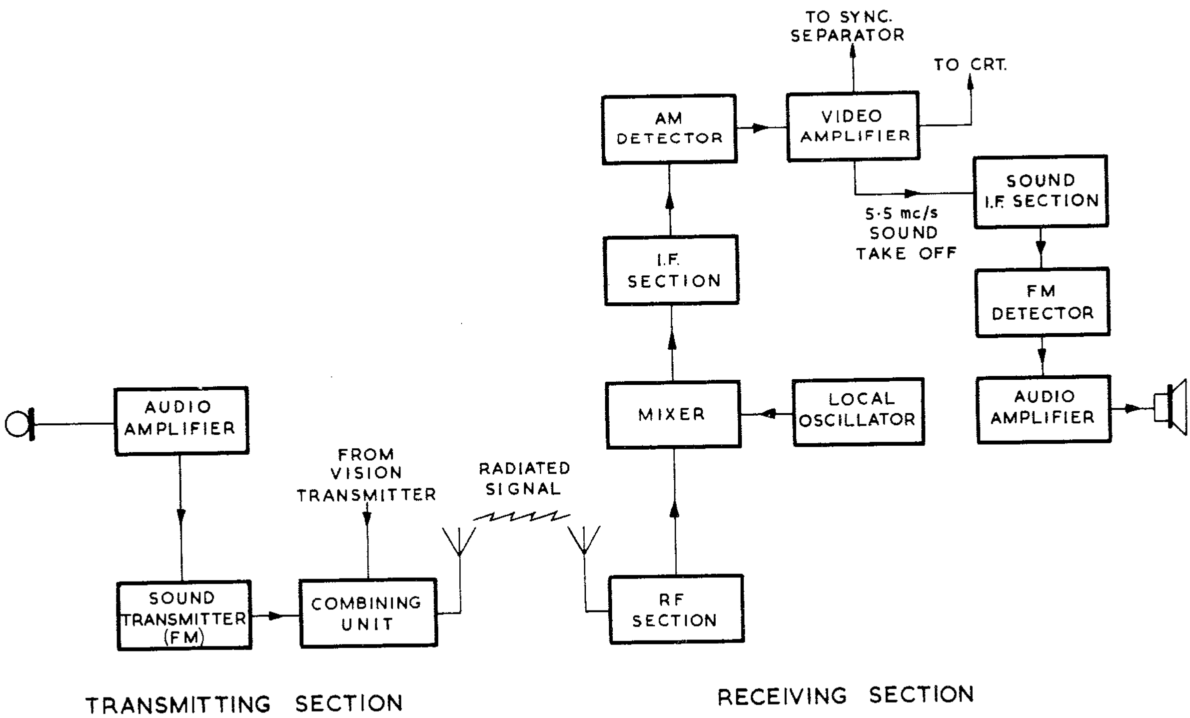


FIG. 18. BASIC BLOCK DIAGRAM OF THE SOUND SECTION OF A TELEVISION SYSTEM.

9. TRANSMISSION OF THE TELEVISION SIGNALS.

9.1 The output of the amplitude modulated vision transmitter and the output of the frequency modulated sound transmitter are combined together in such a way as to prevent interaction between each of the circuits. The R.F. is then fed via coaxial cables to the aerial system.

9.2 The output power of the vision transmitter is required by standards to be five times that of the sound transmitter. The power is specified as "Effective Radiated Power" (E.R.P). This is the power radiated, taking into account the actual transmitter power, the loss in the transmission lines, and the gain of the aerial averaged over the coverage arc. For an omnidirectional aerial system this will be the effective radiated power in any one direction. The E.R.P. for the vision transmitters is at present 100kW, this power being a measure of the peak power, i.e. power at sync. pulse tips. An E.R.P. of 20kW is required for the F.M. sound transmitter which has no power variation with modulation.

9.3 The radiated signals for the majority of the transmitters are horizontally polarised. In some cases, vertical polarisation is used to reduce the possibility of interference between two adjacent stations sharing the same channel. Again, interference and waste of power is reduced in some cases by changing the normal omnidirectional radiation pattern of the aerial into a directional pattern to favour one particular area. In the interests of reduced interference between stations serving the one area and to simplify aerial installation at the receiver, all television stations in that area are situated as close together as practicable.

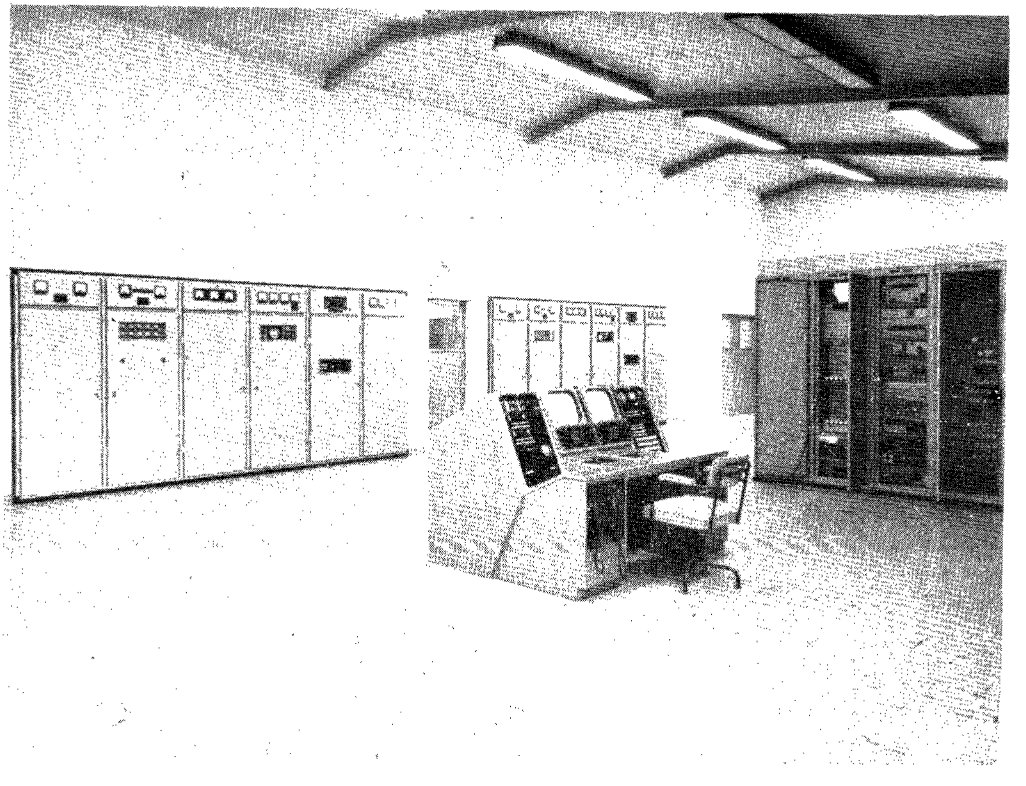


FIG. 19. TELEVISION TRANSMITTER AND CONTROL DESK.

10. PROGRAMME SOURCES.

10.1 The programmes transmitted over the television system, in general, originate from the following sources:-

(i) Live artists in the studio producing programmes per medium of one or more camera chains. Such programmes as news reading and interviews are included in this type of production.

(ii) Motion pictures originating in the "telecine" room of the studio.

(iii) Video tape from machines allowing the recording of both video and sound signals on magnetic tape, and the replay of this programme material at the required time.

(iv) Outdoor scenes, sporting or other events away from the studio, picked up by the cameras of mobile outside broadcast (O.B.) vans, and relayed to the transmitter, often via the studio.

(v) Slides or cards, and test patterns, provided for small interludes, titles or testing purposes.

The signals from the separate programme sources are fed to a master control room, where the required programme is monitored and selected, and fed to the transmitter. A typical arrangement is shown in Fig. 20.

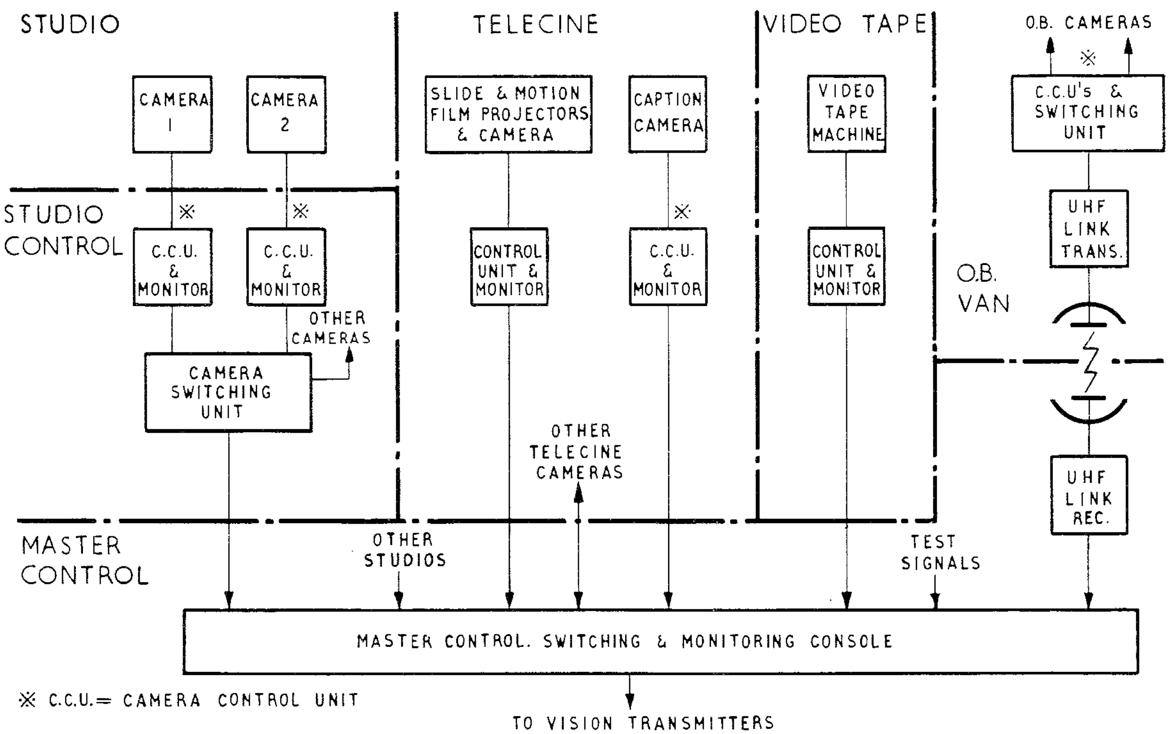


FIG. 20. TYPICAL VIDEO DISTRIBUTION FROM PROGRAMME SOURCES.

10.2 When the studio and transmitter are close together, the video and sound signals are fed over cables, with coaxial cables being used for the video signal. For separated studio and transmitter installations, the normal practice is to use wideband microwave (U.H.F. or S.H.F.) radio bearers for the video signals, and V.H.F. radio links for the sound signals, although equalised cables are quite practicable. In practice, a number of combinations of the possible arrangements are used.

11. SUMMARY.

11.1 The information included in this paper is summarised as follows -

(i) Television is the systematic conversion of small sections of a picture into electrical signals corresponding to picture brightness, the transmitting of these signals to a receiver, and the assembling of spots of light proportional to the received signals in correct order and position to form the picture again.

(ii) The picture reproducing device is a cathode ray tube.

(iii) The basic structure of any picture consists of areas of light and shade known as picture elements, which must be small and numerous for good detail.

(iv) The aspect ratio of the picture is 4 units wide to 3 units high.

(v) The electrical signals from the camera tube, produced by scanning the picture image, are transmitted one by one in an orderly sequence and are reproduced on the screen of the picture tube in the same order.

(vi) All the elements in the picture are transmitted in 1/25th of a second, which is fast enough for the mind to receive the impression of one complete picture, even though the picture is built up element by element and line by line.

(vii) Television depends on persistence of vision.

(viii) Flicker is overcome in the television system by the use of interlace scanning, which requires a narrower bandwidth than a sequential scan producing the same flicker rate.

(ix) The rate at which the image is partially scanned (i.e. one scan from top to bottom) is known as the field frequency and is 50 cycles per second.

(x) The field frequency is the same as the power supply frequency.

(xi) The rate at which the image is completely scanned is known as the picture frequency and is 25 cycles per second.

(xii) Each field consists of $312\frac{1}{2}$ lines of which approximately 18-22 lines are lost due to vertical blanking.

(xiii) The bandwidth of the Australian television channel is 7Mc/s.

(xiv) The bandwidth required for the transmission of the video signal is 5Mc/s which determines primarily the horizontal resolution.

(xv) Synchronizing signals which time the start of each horizontal scanning line are called line or horizontal sync. pulses.

(xvi) Synchronizing signals which time the start of each vertical scanning period of 1/50th of a second are called field sync. pulses or vertical sync. pulses.

(xvii) Blanking signals cut off the picture tube scanning beam when it is moving from right to left and from bottom to top.

(xviii) Equalising pulses are included to ensure accurate vertical synchronizing with interlaced scanning, by making each field identical in the region of the vertical sync. pulse.

(xix) The picture and sound signals are transmitted simultaneously by using separate transmitters on different frequencies, the sound carrier being frequency modulated by the sound signal, and the picture carrier being amplitude modulated by the picture signal and the synchronizing pulses.

(xx) The maximum allowable deviation of the sound carrier frequency on peaks of modulation is $\pm$ 50kc/s.

(xxi) Vestigial sideband transmission is used to allow the channel bandwidth to be 7Mc/

(xxii) The polarity of the picture modulation is negative.

(xxiii) The sound and picture signals use the same sections of a television receiver up to the video detector. The sound signal is filtered from the video, after detection, and applied to a 5.5Mc/s I.F. stage.

12. TEST QUESTIONS.

1. With the aid of a diagram describe the basic operation of a simple camera tube.
2. State the function of the picture tube.
3. What is a picture element?
4. Describe sequential scanning.
5. Describe interlaced scanning.
6. How many horizontal lines are scanned in 1/25th of a second in the Australian television system?
7. How is the problem of flicker overcome in commercial motion picture practice?
8. What is the line frequency in the Australian television system?
9. For what reason was 50c/s chosen as the field rate?
10. State the time taken to scan a complete horizontal line, i.e. from the start of one line to the start of the next.
11. Define contrast.
12. Define resolution.
13. What is meant by vertical resolution factor?
14. Why was 625 chosen as the number of lines in the Australian television system?
15. A 2 : 1 interlaced scanning system of 525 lines has a picture repetition rate of 30 per second. What are the frequencies of the horizontal and vertical scanning waveform?
16. Why is synchronization necessary in a television system?
17. What is meant by the term composite video?
18. With a diagram, show the allocation of the bandwidth of an Australian Television channel.
19. Illustrate and define the term negative modulation as applied to a vision transmitter.
20. What type of modulation is used for the sound channel of a television station?
21. What is the deviation used for the sound channel of television?
22. Define effective radiated power.

END OF PAPER.