CP 305
PRICE 15c

THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2.

COMPOSITE VIDEO SIGNALS

★ AMENDED 1965

1. INTRODUCTION.

1.1 For the requirements of television circuits to be specified, the composite video signal must be considered in detail so that the effects of circuits associated with the generation and transmission of the signal can be studied.

This paper examines the video signal to find the reasons for the inclusion of the different sections of the composite video signal, and to see what frequencies are required to transmit the complex waveform representing the picture information and the synchronizing information. In order to maintain continuity, some information given in the "Introduction to Television" paper is revised in this paper.

Also, it is necessary to have some knowledge of the behaviour of pulses in circuits containing C and R or L and R, as covered in the papers "Introduction to Pulse Techniques" and "Basic Pulse Circuits" and mentioned in A.E.2 paper "Waveforms, Timing and Oscillatory Circuits", and if necessary these papers should be revised before proceeding further.

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2. REASONS FOR THE TELEVISION WAVEFORM CONFIGURATION.

2.1 Horizontal Blanking. In a practical television system, the sweep generator producing the horizontal scan of the screen takes a finite time to return the deflection voltage or current ready to restart the linear motion of the electron beam across the picture tube screen. The time for the transition depends on the inductance and capacitance present in the circuit.

So that no signals are produced on the picture tube screen during retrace times, the video signal is returned to black or "blacker than black" for a period of from 11.5 to 12μS. In practice this allows ample time for horizontal retrace. This time amounts to approximately 18% of the time for one complete line. (With a line frequency of 15,625c/s, the time for one line is 64μS.)

A receiver or monitor is correctly adjusted when a black signal just causes the picture tube screen brightness to be zero; that is black signals just cause cut-off of the picture tube electron beam. White picture signals allow beam current to flow and so cause screen brightness. A signal in the blacker than black region, then, is a voltage beyond cut-off of the picture tube electron beam and is not reproduced on the screen.

2.2 Vertical Blanking. For the same reasons as for horizontal blanking, it is necessary to provide a vertical blanking period as part of the composite waveform. Here though, a time equal to between 18 and 22 lines is allowed for each vertical retrace, which occurs every 1/50 sec., (or every 20,000μS). This vertical blanking time, although much longer than that for horizontal blanking, is only approximately 6% of the total field period, and this is possible because of the lower frequency concerned. (The variation of the duration of vertical blanking between the limits of 18-22 lines is only allowed for long time variations.)

The two sets of blanking pulses when combined are referred to as "complete blanking". Complete blanking is added to the video signal output of the camera or other reproducing device and the result is called the "non-composite video signal" (Fig. 1).

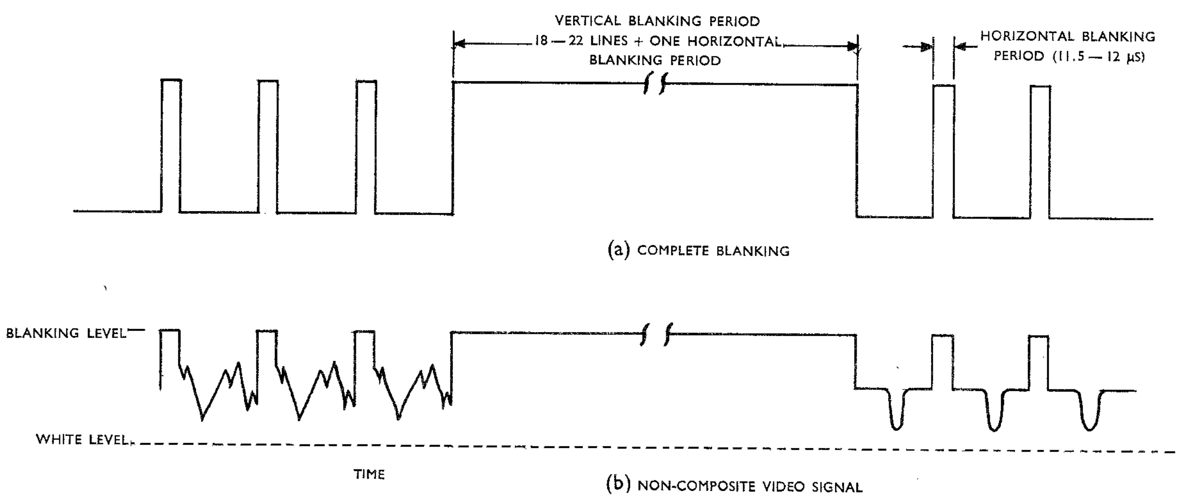


FIG. 1. NON-COMPOSITE VIDEO SIGNAL.

2.3 Horizontal Sync. So that the deflection circuits associated with the picture tube in the receiver produce deflection in step with the deflection circuits of the camera at the studio, synchronizing pulses are included in the signal transmitted.

The horizontal sync. pulses are conveniently inserted in the horizontal blanking period so that they drive the picture signal into the blacker than black region, and so are not reproduced. The start of the sync. pulse is delayed beyond the start of blanking by from 1 to 1.5μS to form a step called the "front porch". This porch is to ensure that the scanning beam of the picture tube is completely cut off before the beginning of the horizontal retrace which is controlled by the sync. pulse. It also ensures that degrading of the leading edges of blanking does not affect the amplitude or the timing of the leading edge of the horizontal sync. pulse.

The duration of the horizontal sync. pulse is required to be long enough so that the energy contained in the pulses is large compared with any noise that is likely to be introduced into the system. This gives the horizontal sync. signal immunity to noise. However, it should not be too long, since with negative modulation used in the transmitters, increase in the length of the sync. pulse represents a greater average transmitter power. A conflicting requirement is that the horizontal sync. pulse should be short, as the segregation of vertical sync. from the horizontal sync. is achieved by distinguishing between the durations of the two types of pulses. This is explained in paras. 2.5 to 2.8.

The section of blanking trailing the horizontal sync. pulse, is referred to as the "back porch", and is necessary to allow any spurious responses caused by the trailing edge of sync., to die away before commencement of the next line picture information. The back porch is used when "clamping" to restore the D.C. component of the video signal (see Section 4). For this application the back porch should be as wide as possible.

With the preceding reasons in mind the horizontal sync. pulse is specified as 4.8 to 5.2μS. Fig. 2 shows the horizontal blanking period and the horizontal sync. pulse inserted in this period

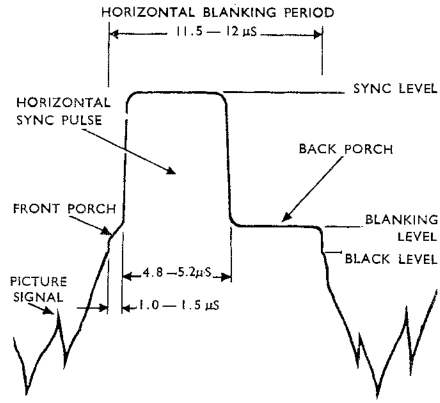


FIG. 2. HORIZONTAL SYNC. PULSE.

2.4 Vertical Sync. The vertical sync. information is inserted in the early part of the vertical blanking interval. Fig. 3 gives an overall indication of the television waveform, although it is not possible to draw it to scale in this reduced size. Note the designation of the time scale that repeats every picture (1/25 sec.). This designation is used in the following figures to indicate the time relationship of waveforms, drawn together to show the difference between alternate fields. As each field contains 312½ lines (including the time for vertical blanking), a field that starts with a full line finishes with a half line and vice versa.

Vertical and horizontal sync. pulses together are called "composite sync." and when combined with complete blanking and video signals, the result is a "composite video signal".

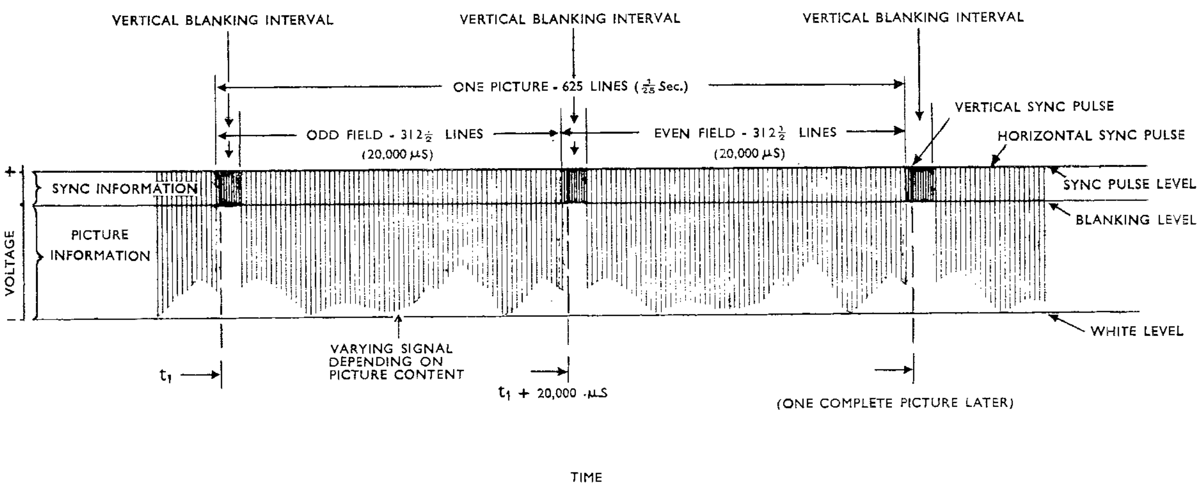


FIG. 3. COMPOSITE WAVEFORM OF A COMPLETE PICTURE.

2.5 The simplest vertical sync. pulse that could be used would be a single rectangular pulse of long duration compared with the horizontal sync. pulse, e.g. 2 to 3 lines long. If the pulses are fed into an integrating circuit with a time constant of 2 lines duration, the output voltage of the circuit increases during the vertical sync. pulse as shown in Fig. 4. The capacitor accumulates little charge during the short duration of the line sync. pulses, and has time between pulses to almost completely discharge. The rise in output due to the duration of the vertical sync. pulse is used to synchronize the vertical deflection oscillator. An integrating circuit, therefore, segregates the vertical sync. information from the rest of the sync. information.

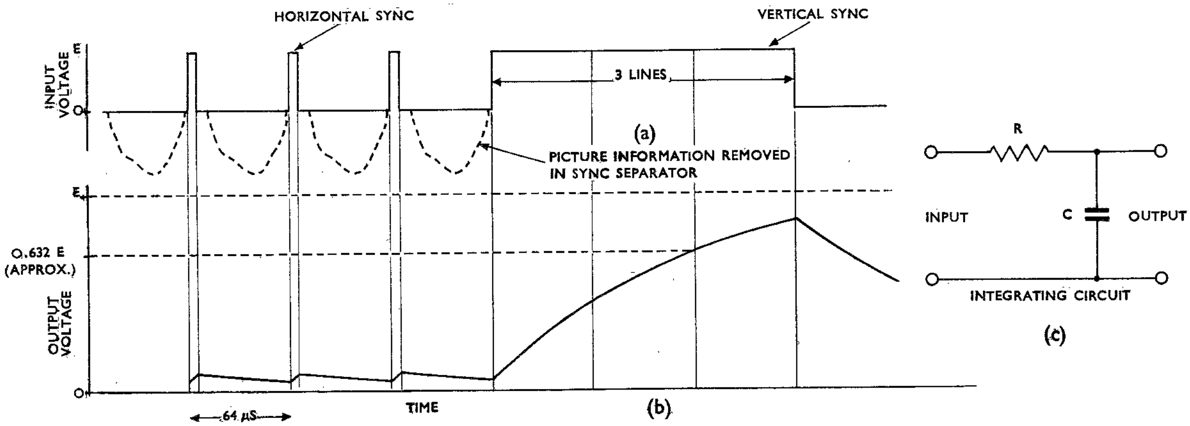


FIG. 4. SIMPLE VERTICAL SYNC. PULSE.

Note that in Fig. 4 and following figures, the synchronizing information is extracted from the composite waveform in a sync. separator, before further processing to segregate the horizontal and the vertical sync. information.

2.6 Inclusion of Horizontal Sync. Information. This single vertical sync. pulse has the disadvantage of not containing any horizontal synchronizing information. It might be possible for the horizontal oscillator producing the horizontal deflection voltage, to lose synchronization during this period. In modern receivers this does not normally occur, as an automatic frequency control circuit with a long time constant ignores the loss of a small amount of horizontal sync. information.

It is possible to include horizontal sync. information in the vertical sync. period by serrating the vertical sync. pulse (Fig. 5a and b). Five "broad" pulses, which together make a vertical sync. pulse of 2½ lines duration, are used in the Australian system. This allows simple horizontal synchronizing circuits to be used in receivers if it is desired.

Fig. 5 shows the voltage that exists across the output of the integrating circuit when a serrated vertical sync. pulse and associated horizontal sync. pulses are applied to the input. The charge on the capacitor of the integrating circuit builds up only slightly because of the horizontal sync. pulses. However, a larger increase in charge occurs during each broad pulse, with only a small discharge due to the small vertical sync. serrations, giving an overall rise in voltage output during the vertical sync. period. After the end of the broad pulses, the charge on the capacitor gradually decreases to a low average value that is maintained until the next group of broad pulses.

The important fact is that the capacitor starts the vertical sync. pulse interval with a different charge for odd fields than for even fields, and the voltage reaches the value required to cause synchronization much sooner after the end of the odd field, than after the end of the even field. The reason for this difference in charge at the start of the vertical sync. pulse interval is that the last horizontal sync. pulse of the even field is one complete line before the start of a vertical sync. pulse, and the last horizontal sync. pulse of the odd field is only a half of a line before the start of a vertical sync. pulse.

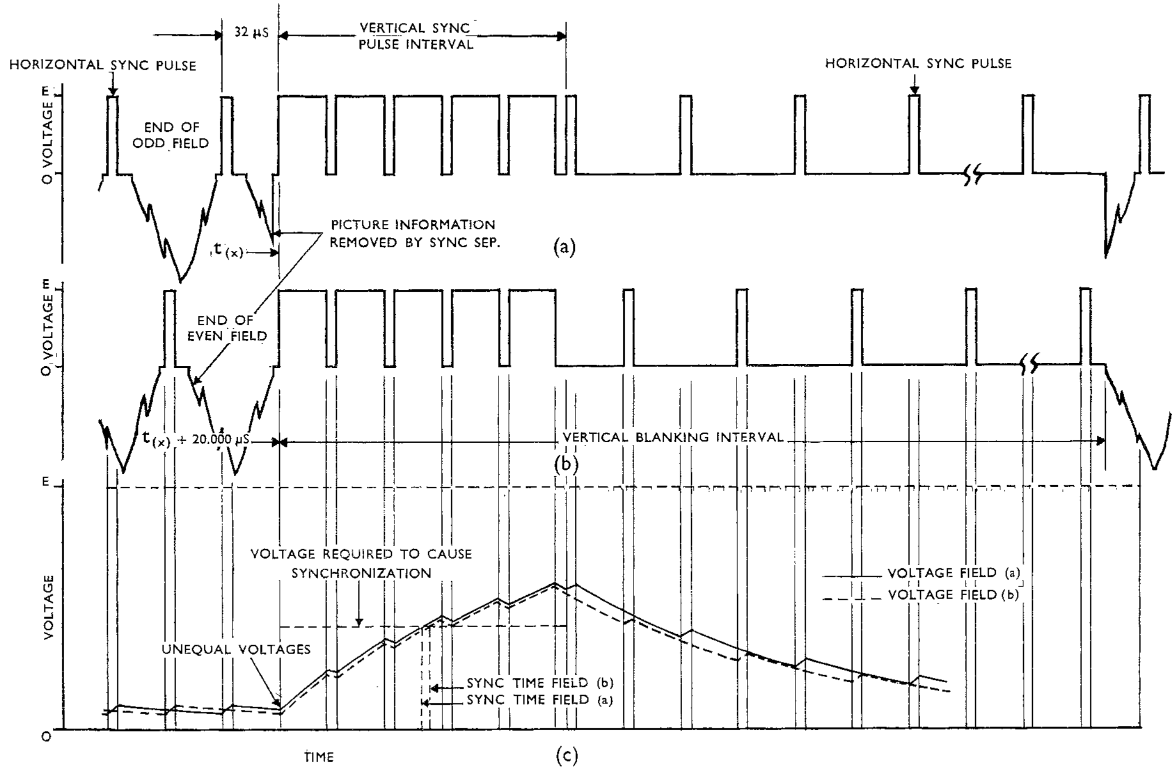


FIG. 5. VERTICAL SYNC. SEGREGATION (NO EQUALIZING PULSES).

The sync. pulses which re-occur at intervals of 20,000μS do not cause correct synchronizing in this case (Fig. 5). One scan takes slightly less than 20,000μS, and the other scan slightly more than 20,000μS.

2.7 Pairing. To reproduce the picture properly, vertical synchronization must be properly maintained. If odd and even fields are not initiated exactly $\frac{1}{50}$ sec. apart, "pairing of lines" occurs. This means that the lines of one field do not interleave properly with the lines of the other field, and adjacent lines of the picture are not evenly spaced. The effect is shown in the simplified example of Fig. 6, where the time to trace out lines 1,3 and the first part of line 5 is less than the time for the second part of line 5 and lines 2 and 4, and an uneven spacing of lines results. In extreme cases, odd and even lines can coincide, and the number of lines of the raster is apparently halved. When pairing occurs, it is necessary to sit further from the screen of the picture tube to make the line structure indiscernible.

A change of the synchronizing time equivalent to only a fraction of a line is required to cause noticeable pairing. Considerable accuracy is therefore required, as an error of $\frac{1}{2}$ a line duration, which would give complete pairing, represents approx. 30μS in 20,000μS or only 0.15% of the field period.

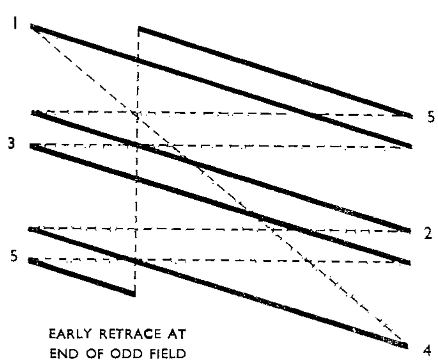


FIG. 6. PAIRING OF LINES.

2.8 Vertical Sync. (With equalizing pulses). The Australian standard television waveform minimises the possibility of poor interlace by including in the vertical blanking interval, five short duration equalizing pulses between the last horizontal sync. pulse of each field and the vertical sync. pulse, and, as well, five short duration equalizing pulses immediately following the vertical sync. pulse (Fig. 7). The pulses occur at twice line rate, (every 32μS.) The pre-equalizing pulses and the post-equalizing pulses, therefore, each occupy a period equal to $2\frac{1}{2}$ lines on either side of a serrated vertical sync. pulse of $2\frac{1}{2}$ lines duration. The vertical sync. pulse is serrated to form five broad pulses, each serration being nominally equal in width to a horizontal sync. pulse (4.8–5.2μS).

The voltage which is developed across the capacitor of the integrating circuit when equalizing pulses are included in the waveform is shown in Fig. 7c. The pre-equalizing pulses which have a duration of approximately half that of a horizontal sync. pulse, produce a general reduction of the output voltage from the integrating circuit, during the pre-equalizing pulse period following the end of the odd field. This makes the output voltage present at the start of the broad pulses for each field, practically identical. With the equalizing pulses of half the duration but at twice the frequency of the horizontal sync. pulses, the average energy of the two sets of pulses over a period is the same. This prevents any rise in output voltage that would occur if the pulses were of the same width as the horizontal sync. pulses but twice the horizontal frequency. Para. 2.12 shows that equalizing pulses and vertical sync. pulse serrations are required at twice horizontal frequency.

2.9 One point which must be remembered is that the synchronizing signals fed to the deflection oscillator circuits start the retrace, not the forward trace, of the sawtooth deflection voltage or current. This means that to have perfect interlace, the retrace times must be identical for each line, and for each field.

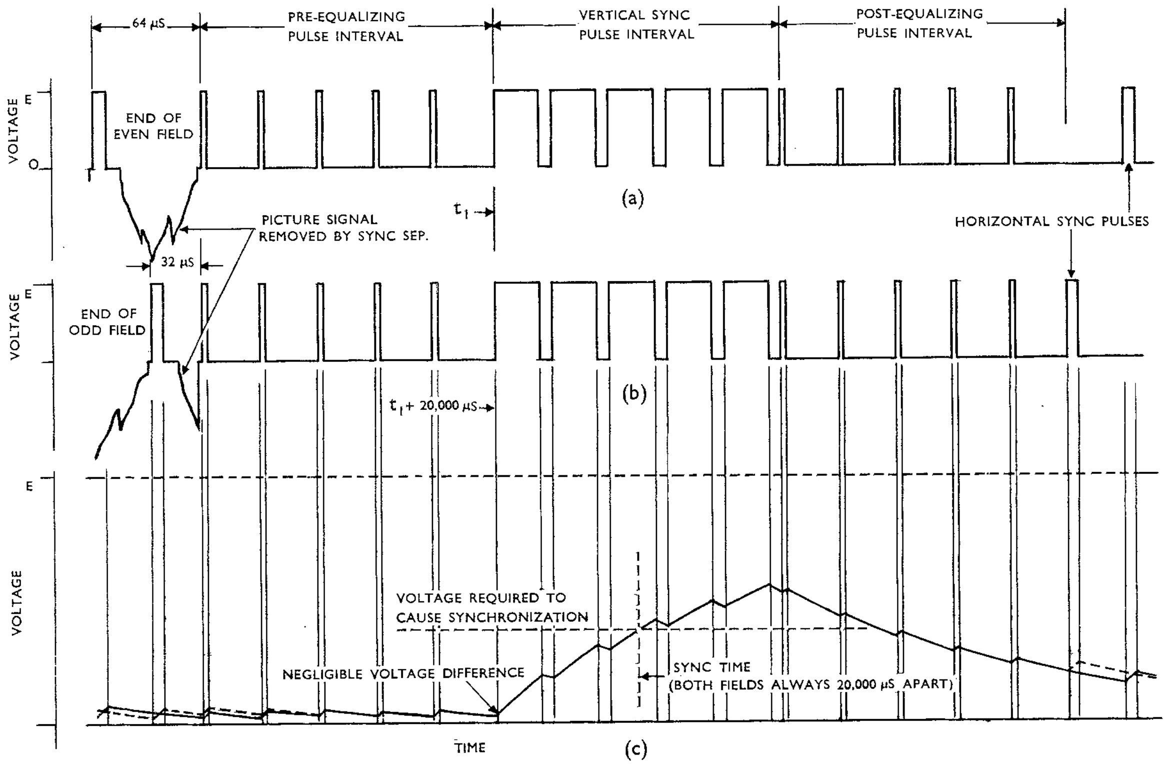


FIG. 7. VERTICAL SYNC. SEGREGATION (WITH EQUALIZING PULSES).

The circuit and waveforms of a blocking oscillator sawtooth voltage generator are shown in Figs. 8a and b. The flyback of the output waveform is produced by anode current, which discharges C_2. Any change in the conducting time of the valve, changes the flyback time, and can produce poor interlace.

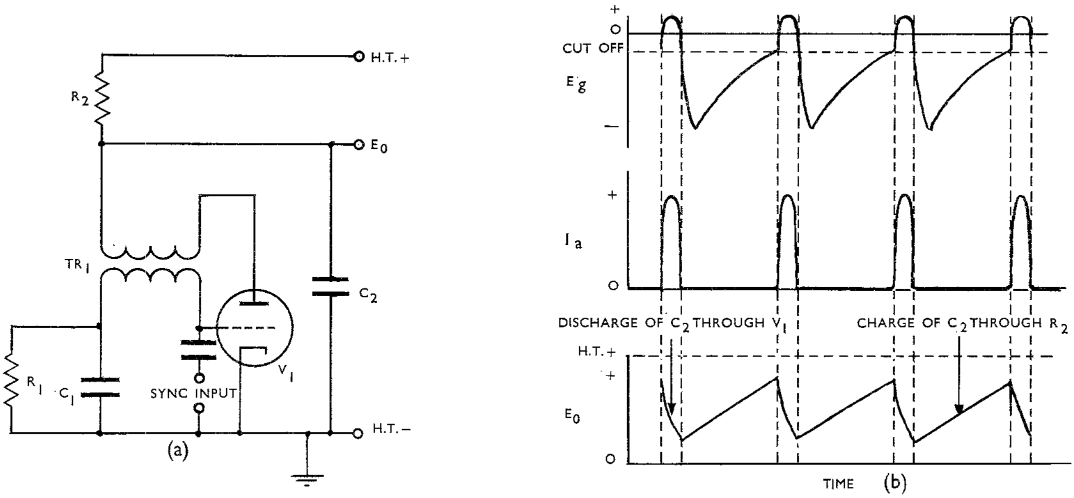
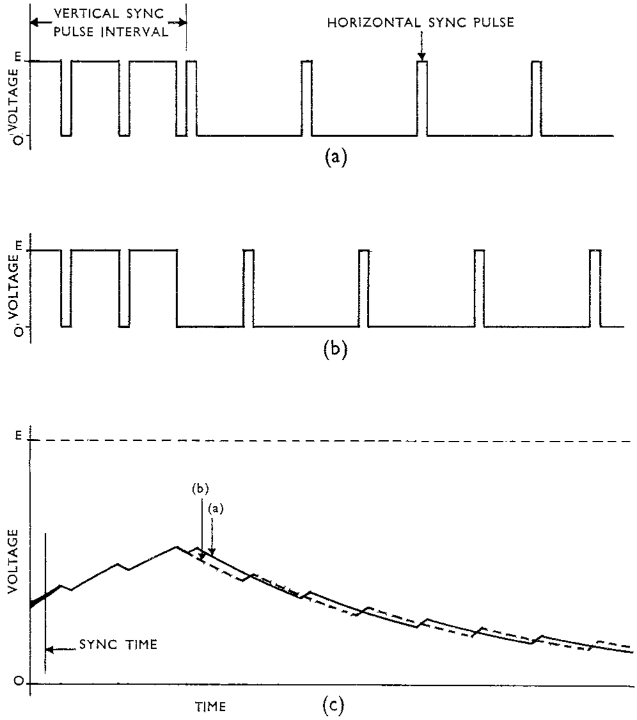


FIG. 8. BLOCKING OSCILLATOR SAWTOOTH VOLTAGE GENERATOR.

2.10 The output voltage from an integrating circuit fed with a waveform without post-equalizing pulses, (Fig. 9), has different discharge curves following the vertical sync. pulse of each adjacent field. This is not the case when post-equalizing pulses are present (Fig. 7).

In a typical field frequency blocking oscillator, the valve is conducting for about two or three lines. When the integrating circuit output voltage is applied as the synchronizing waveform onto the grid of the blocking oscillator, the slight change in the trailing edge of the integrated vertical sync. pulse occurs as the grid voltage is negative going and approaching cut-off. The change in the grid voltage in this region can modify the time when the grid is actually cut-off, and can therefore modify the conducting time of the valve and the flyback time. Therefore, the post-equalizing pulses are as important as pre-equalizing pulses for good interlace to be achieved. The flyback time of other sawtooth generators can also be modified in the same manner.



VERTICAL SYNC. (NO POST-EQUALIZING PULSES).

FIG. 9.

2.11 Incorrect Sync. caused by Sync. Serrations. The output of a single R-C circuit used for integration is notched during the vertical sync. period by the vertical sync. serrations. Fig. 10 shows that the same voltage exists at different times during the voltage rise, for example at points (x) and (y).

When the voltage required to cause triggering of the vertical deflection oscillator is E_1 volts, vertical flyback occurs at time t_1. Consider that, because of variations of the power supply voltage, or noise injected into the circuit via the power supply or other sources, the voltage required for triggering is slightly increased to E_2 volts. Flyback occurs at time t_3, which is slightly after t_2 (where the voltage is also E_1) but an appreciable time after t_1. Because of the notches, the synchronizing time may vary at random by an amount which could give noticeable pairing. Without the notches the effect of the change of synchronizing voltage would be negligible.

Changing the time constant of the integrating circuit (Fig. 10) changes the size of the notches, but does not greatly effect the timing of points (x) and (y), except for very short time constants. The notches can be filtered out, and so the accuracy of the synchronizing improved, by using a number of R-C sections in cascade, each with a relatively short time constant, but together having an effective time constant of approximately two lines duration. In practical circuits the integrating circuit often has up to four sections. A long time constant integrating circuit is not the only way of segregating the vertical sync. information, but it is the most common circuit used in practice.

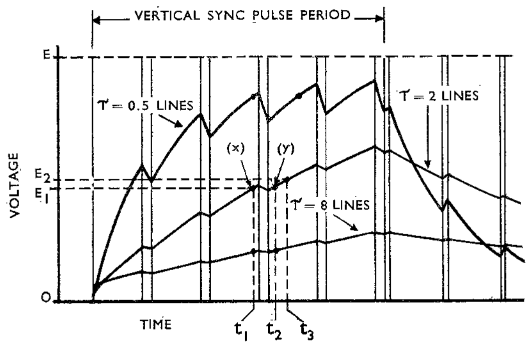


FIG. 10. TIME CONSTANT CHANGE OF INTEGRATOR CIRCUIT.

2.12 Horizontal Sync. in Vertical Blanking Period. The extraction of the horizontal sync. information from the television waveform may be achieved by differentiating the waveform and clipping the resultant to produce a peaked waveform. Each peak corresponds to the leading edge of one of the pulses. This output is shown in Fig. 11 for each of the two fields. As horizontal sync. is required every 64μS, only alternate pulses during the $7\frac{1}{2}$ line equalizing and sync. pulse period are used. But with the even field ending in a full line, and the odd field ending in a half line, one group of pulses at 64μS intervals is used for even fields, and the other group at 64μS intervals, but between the pulses of the first group is used for odd fields. Therefore, equalizing pulses and broad pulses must be included at twice line rate. The arrows in Fig. 11 indicate the horizontal synchronizing times during the vertical blanking period.

2.13 Set-Up. Fig. 12 shows that black level is separated from blanking level by a safety margin called "set-up". Set-up should be as large as possible without reducing unduly the signal amplitude. The reduction of the signal amplitude would reduce the signal-to-noise ratio. For the Australian system, set-up is defined as approx. 5 to 10% of the blanking to white interval, or 3 to 6.5% of the maximum carrier amplitude.

When the television signal is relayed over a radio bearer, for example between outside broadcast sites and the studio, or between the studio and transmitter sites, it is possible for the synchronizing information to be degraded by noise or distortion. In these cases the sync. pulses are stripped off and "clean" sync. pulses re-inserted. Without the set-up margin there would be no tolerance for the clipping level, and there would be a possibility of clipping black peaks and destroying the shadow detail.

In addition, the set-up reduces the possibility of peaks of the video signal getting into the sync. region, where they may cause poor receiver synchronization. Also, distortion in amplifiers may cause "ringing" or "overshoots" to be produced on the trailing edges of the sync. pulses. The ringing or overshoots may extend into the picture signal region and cause a vertical bar to be produced on the screen during the retrace time. Set-up reduces the possibility of distorted sync. signals from degrading the displayed picture.

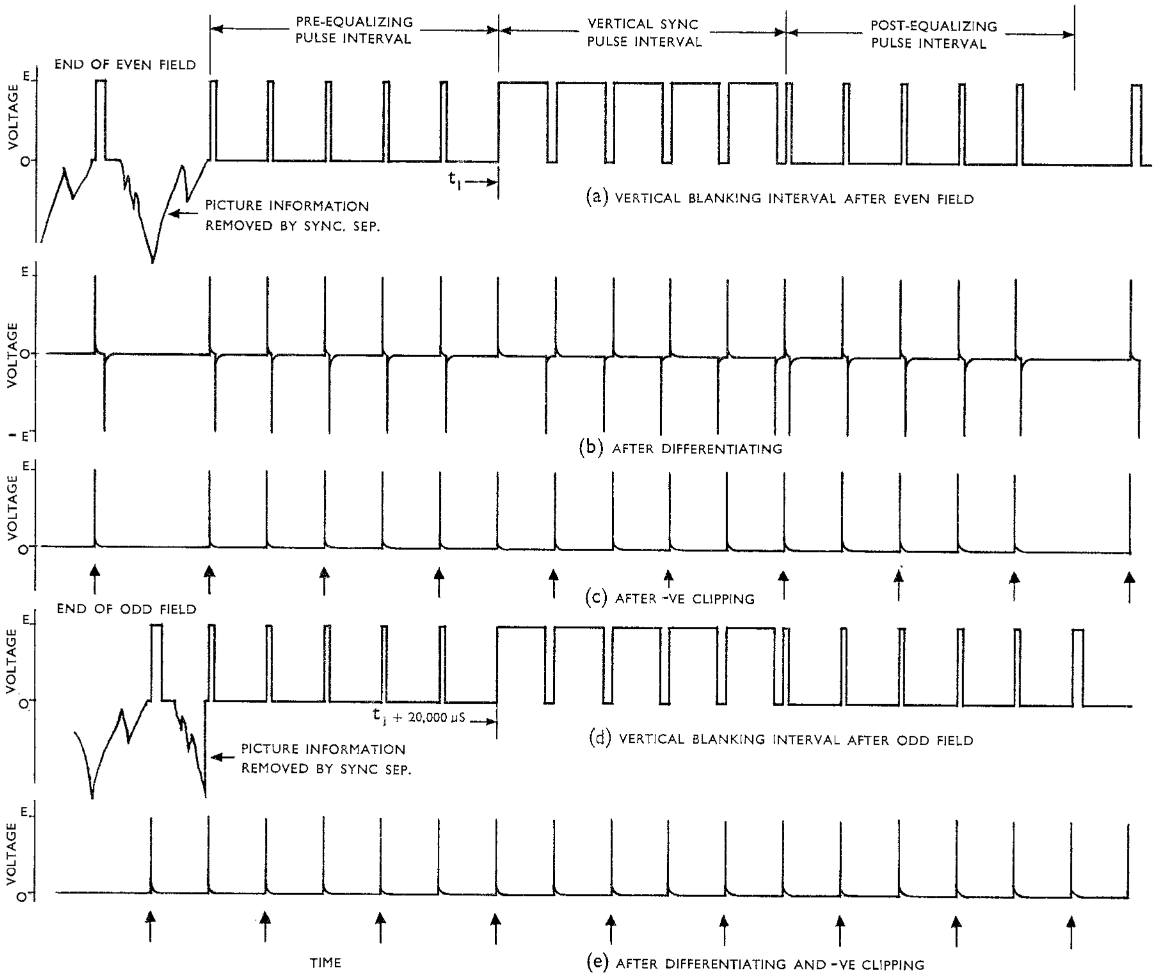


FIG. 11. HORIZONTAL SYNC. INFORMATION IN VERTICAL BLANKING PERIOD.

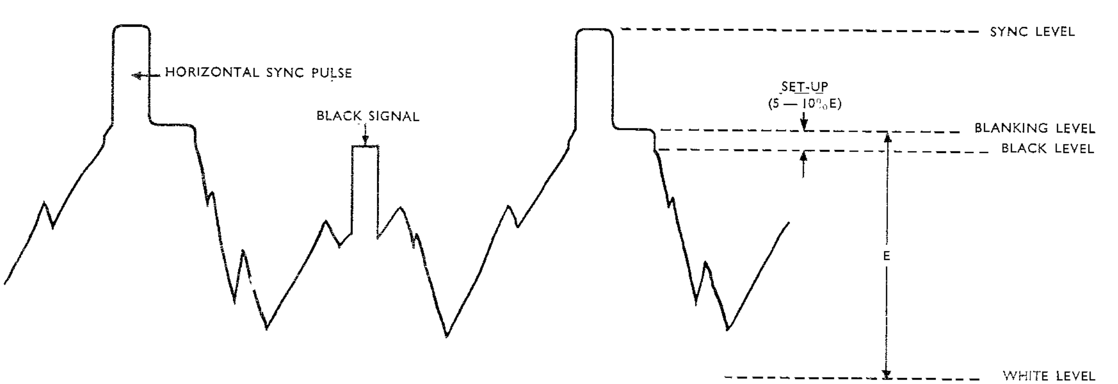


FIG. 12. SET-UP.

✱ 2.14 Transmission Amplitude and Polarity. It is standard practice to transmit video signals from place to place, and from one piece of equipment to another, with the sync. pulses as negative pulses, and the white video information maximum positive. The transmission level is normally one volt peak-to-peak (p-p).

The normal method of drawing video waveforms is as they appear at the particular point in the circuit, that is with sync. pulses negative for transmission. In the preceding paragraphs of this paper, the waveforms are shown with sync. pulses positive. This is to coincide with the standard video waveform shown in the "Standards of the Australian Television Service", which is drawn to represent the carrier voltage of a negative modulation system.

The voltage levels of video signals are measured and calibrated on waveform monitors or cathode ray oscilloscopes, fitted with calibrated graticules. The graticule shown in Fig. 13a is used on waveform monitors of transmitter installations. The signal levels that correspond to the graticule designations are shown in Table 1.

The designations on the left of the graticule refer to the relative amplitudes of sections of the video signal with the blanking to white interval taken as 100. The designations on the right indicate the vision transmitter percentage modulation that will be produced by the video signal. Vision transmitter percentage modulation is the ratio, expressed as a percentage, of the R.F. amplitude corresponding to any section of a video signal, to the maximum R.F. amplitude which occurs during sync. pulses.

Level	Video Scale Reading	Percentage Modulation
Zero Carrier Amplitude	120	0%
Absolute limit of white	104	10%
Reference White	100	12.5%
Reference Black	8	70%
Blanking	0	75%
Sync. Pulse Peak	-40	100%

TABLE 1. GRATICULE DESIGNATIONS.

To adjust the composite video signal to 1V p-p, a calibrating signal of 1V p-p is fed into the C.R.O., and the vertical amplifier gain adjusted so that the reference signal occupies the space between 100 and -40 on the video scale. The video signal is then applied to the C.R.O. and the sync. amplitude, set-up, and picture signal amplitude adjusted to the correct levels.

The ratio of the picture signal amplitude to the sync. signal amplitude is termed the "picture-sync. ratio", and from the values in Table 1, is 5 : 2. This value was chosen so that when a received signal is degraded by noise to the extent that the reproduced picture is of unacceptable quality, the degradation also causes poor synchronization of the receiver deflection circuits.

In coaxial cable and radio relay systems for video signals, the picture-sync. ratio is commonly different from that used for television broadcasting and is normally 7 : 3. A graticule showing the standard levels for relay systems is shown in Fig. 13b. This difference in the specifications of the relative amplitudes of the video signal is of little practical consequence as facilities for independant adjustment of the levels of picture, set-up and sync. are available at all transmitter installations. Further, the television relay system amplitude specifications are within the tolerances of the television broadcasting amplitude specifications.

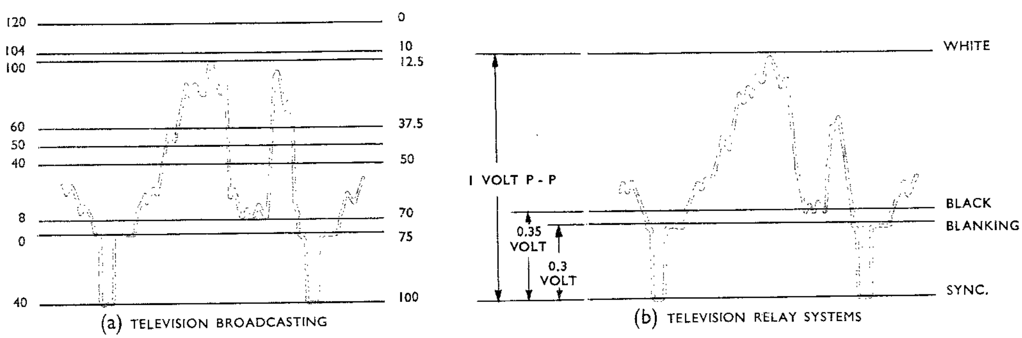


FIG. 13. WAVEFORM MONITOR GRATICULES.

2.15 Drawing the Television Waveform. It is helpful to remember when the waveform is to be drawn, that the leading edge of each sync. pulse must occur at 64μS or 32μS intervals. Keeping in mind that horizontal sync. is required every 64μS shows the position of the first horizontal sync. pulse after the post-equalizing pulses.

Procedure to simplify drawing:-

(i) Draw 15 vertical lines for each field at ½ line (32μS) spacing to form the leading edges of the equalizing and broad pulses.

(ii) Complete -

(a) five 2.5μS pre-equalizing pulses using the first group of five lines;

(b) five 27μS broad pulses using the second group of five lines;

(c) five 2.5μS post-equalizing pulses using the third group of five lines.

(iii) Draw the leading edge of the last horizontal sync. pulse of -

(a) the odd field, 32μS before the first pre-equalizing pulse;

(b) the even field, 64μS before the first pre-equalizing pulse.

(iv) From the last horizontal sync. pulse of each field mark the horizontal synchronizing times at 64μS intervals, to indicate the positions of the leading edges of the horizontal sync. pulses before and after the vertical sync. period.

(v) Complete the 5μS horizontal sync. pulses.

(vi) Draw the vertical blanking period of 18-22 lines plus one horizontal blanking period (usually with some lines missing and indicate by a break).

(vii) Draw the horizontal blanking time of 12μS, i.e. front porch (1μS) and back porch (12 - 5 - 1 = 6μS), and include leading and trailing edges to show set-up.

(viii) Draw the picture information.

The waveform is shown in different stages of development in Fig. 14.

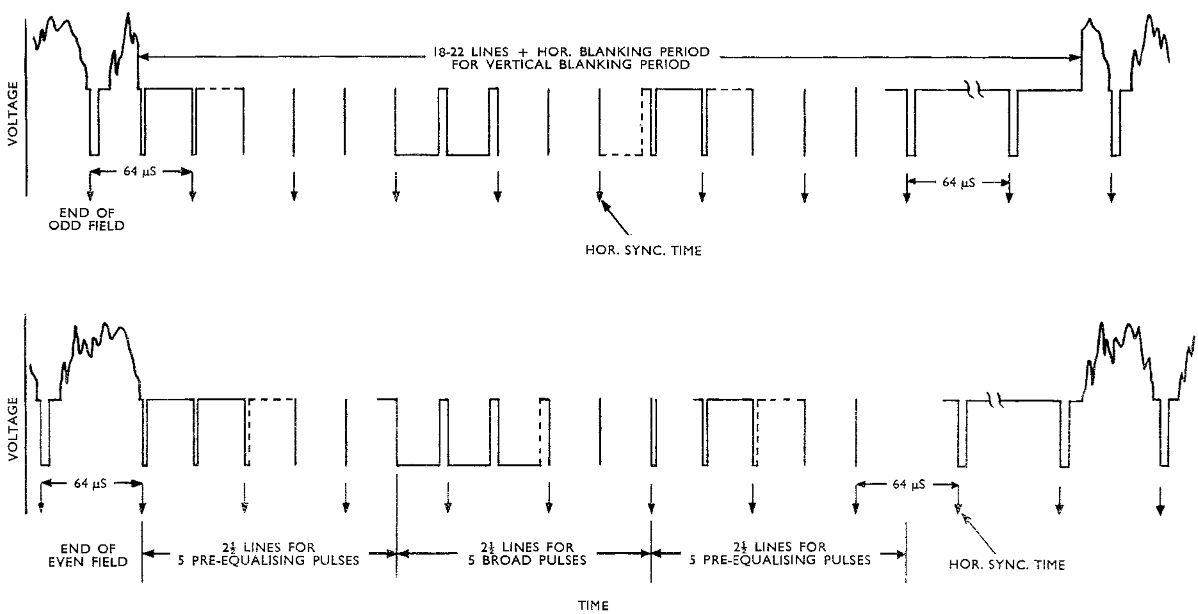


FIG. 14. SIMPLE DEVELOPMENT OF AUSTRALIAN TELEVISION WAVEFORM.

3. BANDWIDTH OF THE VIDEO SIGNAL.

3.1 Resolution. Resolution is the ability of the picture reproducing system to represent the fine detail of the picture, as was discussed briefly in the "Introduction to Television". In a television system, resolution is the ability to reproduce a series of black and white lines. The capability is specified as the number of lines able to be reproduced (counting black and white lines separately) in a length equal to the picture height. With television, the amount of detail presented vertically is independent of the amount of detail horizontally, and so vertical and horizontal resolution are dealt with separately.

3.2 Vertical Resolution. In the ultimate the vertical resolution should be the same as the number of lines in the television system, i.e. it should be possible to present one line black and the next white, all the way down the picture. In a practical case time is allowed for flyback when producing the scanning raster. As is seen from the Australian standards, allowance is made for a time equal to approximately 20 lines for each vertical retrace, i.e. each field. Forty of the 625 lines per picture are then blanked out, so that the maximum vertical resolution is 585 lines.

3.3 Vertical Resolution Factor. Consider a series of horizontal lines as in Fig. 15a. Scanning of line 1 produces the signal for a black picture, and line 2, the signal for a white picture and so on. 100% resolution is possible and the picture is reproduced exactly the same at the receiver (Fig. 15b). This assumes that the scanning spot diameter at the receiver is equal to the width of one line.

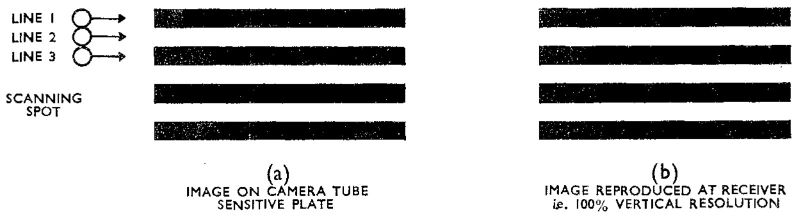


FIG. 15. VERTICAL RESOLUTION (IDEAL CASE).

Consider again that a very slight relative movement of the camera and the scene to be televised, causes the spot to scan so that half of its area is on black and half is on white as in Fig. 16a. The resultant picture produced in the receiver is a complete picture of mid grey as in Fig. 16b, and the vertical resolution is zero.

It is realised that if the spot size at the camera is smaller, the possibility of the spot scanning part of two adjacent lines together is reduced. But an extremely small spot is not practical and in addition will not satisfactorily discharge the camera tube target in a complete scan. If the receiver scanning spot is too small, the reproduced white line is very narrow. The black line is wider than it should be as it includes the unscanned space between lines.

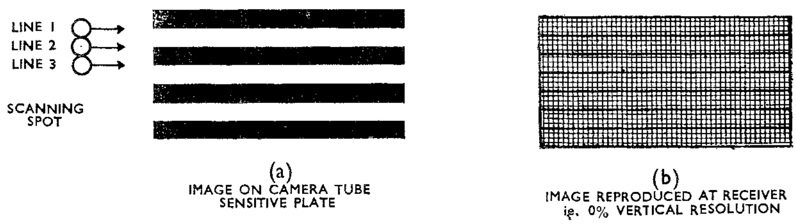


FIG. 16. VERTICAL RESOLUTION (WORST CASE).

In practice, vertical elements in an average picture are not stacked in a regular pattern, but are scattered throughout the scene. The number of lines expected to be resolved is about 75% of the total possible. The vertical resolution factor (ratio of number of lines resolved and number of lines possible) is then 0.75. This value, which has been determined by experiment, is the normal one used for calculations.

Vertical resolution expected for the Australian system is:-

$$585 \times 0.75 = 439 \text{ lines (approx.)}.$$

3.4 Horizontal Resolution. The horizontal resolution should be the same as the vertical resolution for consistency of picture detail. Horizontal resolution is specified as the number of lines that can be resolved in a width equal to the picture height. The actual number of lines resolved in the complete picture width must take into account the aspect ratio, giving us:-

$$\text{Actual number of lines resolved horizontally} = \frac{4}{3} \times 439 = 585.$$

The spot now scans a series of vertical lines corresponding to the maximum required horizontal resolution, as in Fig. 17a. If the spot size is very small, the output signal from the camera is a square wave and the reproduced picture is close to perfect horizontally, if the size of the picture tube spot is also very small.

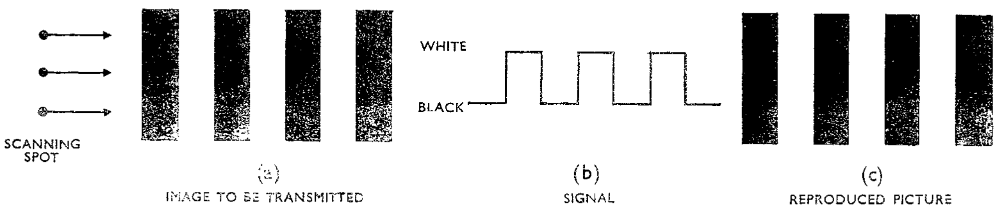


FIG. 17. HORIZONTAL RESOLUTION (VERY SMALL SPOT).

When the spot is of finite size, the transition of the signal from black to white cannot be instantaneous. There must be an intermediate stage when the spot is partly on white and partly on black, producing a grey signal. The edges of the square wave of Fig. 17b are rounded off and can approach the sine wave of Fig. 18b. The picture reproduced is modified from the original with a gradual change between black and white.

Square waves contain many harmonics, and loss of these also makes the signal close to a sine wave. Reducing the highest frequency passed by the system gives similar results to increasing the scanning spot size. As a practical limiting factor to horizontal resolution, amplitude response at high frequencies is more important than spot size.

From Fig. 18, the signal for two adjacent lines, i.e. one white and one black, represents one cycle of signal.

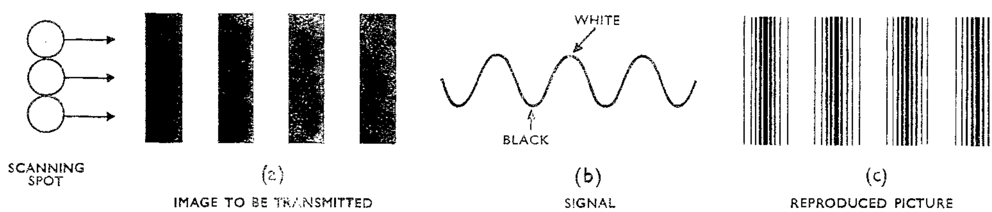


FIG. 18. HORIZONTAL RESOLUTION (FINITE SPOT SIZE AND LOSS OF HARMONICS).

3.5 Scanning Spot Size. When a picture is reproduced by a very small scanning spot, the line structure is easily seen, as an unscanned space is left between the scanned lines. Ideally, the scanning spot should have an effective height equal to the line spacing, but no width; but this is not practical. As well, it is not necessary as horizontal detail is not required smaller than vertical detail. The best picture results when the focus control, which affects scanning spot size, is adjusted so that the spot adequately fills in the space between the lines without decreasing the resultant horizontal resolution. Under these conditions, the line structure is almost invisible even when viewed closer than normal viewing distances, and for an ideal picture signal, the limiting factor for horizontal resolution is still the bandwidth and not the scanning spot size. The loss of resolution because of the finite size of the scanning spot is called "aperture distortion".

3.6 High Frequency Limit of Bandwidth. For horizontal resolution equal to the expected vertical resolution, it is necessary to produce 585 elements horizontally in the active line time. The active time for one line equals line time minus horizontal blanking time.

$$\text{i.e. } 64\mu S - 12\mu S = 52\mu S.$$

As one cycle of signal produces two elements, $\frac{585}{2}$ cycles are required in $52\mu S$; or -

$$\text{High frequency limit of Bandwidth} = \frac{\text{Number of elements horizontally}}{2} \div \text{active line duration.}$$

$$= \frac{585}{2 \times 52} \text{ Mc/s} = 5.6\text{Mc/s.}$$

The Australian standards allow for a maximum video frequency of 5Mc/s, so the horizontal resolution is slightly less than the vertical resolution.

Reversing the calculation; if a 5Mc/s bandwidth is available, what is the horizontal resolution?

$$\text{Horizontal Resolution} = \frac{2 \times \text{Highest video frequency} \times \text{Active line duration}}{\text{Aspect ratio}}$$

$$= \frac{2 \times 5 \times 52 \times 3}{4} = 390 \text{ lines.}$$

This is compared with an expected vertical resolution of 439 lines.

$$\text{As an approximation } \frac{2 \times 52 \times 3}{4} \text{ is approximately 80.}$$

$$\therefore \text{ Horizontal resolution} \simeq 80 \times \text{bandwidth in Mc/s.}$$

The above calculations assume that the lines are reproduced as sine wave variations between black and white. If the amplitude response falls off gradually above the high frequency limit where no reduction in amplitude occurs, frequencies present at reduced amplitude produce lines varying between dark grey and light grey. Lines can still be distinguished when the amplitude has fallen to 20% of the low frequency value, so that the number of distinguishable lines is slightly greater than the number calculated, depending on how quickly the amplitude versus frequency response falls.

3.7 Bandwidth. The upper limit of the video bandwidth is 5Mc/s, and frequencies in this region are required to produce the fine horizontal detail. When the video signal has a fundamental component of picture information that is lower in frequency, the picture information is larger. For example, when the picture signal is a square wave with a repetition rate of approximately seven times line frequency (combined with suitable sync. pulses) as in Fig. 19a, a series of wide vertical bars are produced on the screen. A picture signal with a repetition frequency of 15,625c/s (Fig. 19b) reproduces one half of the screen black and the other half white. Both of these signals required their fundamental repetition frequency and many harmonics to properly represent the picture.

Figs. 19a and 19b are cases where the same waveform repeats every line. Where this does not occur (i.e. the repetition rate of the picture signal is not a multiple of the line frequency) the information is changing its relative position in the line. The resultant picture produced has information at an angle across the screen, the angle depending on the relative frequencies of the picture signal and the horizontal deflection. Fig. 19c shows the resulting picture when the repetition frequency of the picture information is slightly less than the line frequency, and the drift of the bar across the line takes exactly a complete field. In Fig. 19d, the fundamental frequency of the picture signal component is further reduced so that the bar shifts its position to move across the line exactly three times in one field.

For horizontal motion to be produced on the screen, the signal component must vary from field to field. As an example of this, Fig. 19e shows a black bar and the change in the position of the bar for the waveform of a later field (shown dotted). The frequency components of this signal are basically that of the repetition rate of the pulse (i.e. 15,625c/s) but there is also a fundamental component of approximately 50c/s which changes the position of the bar for consecutive fields to give the motion.

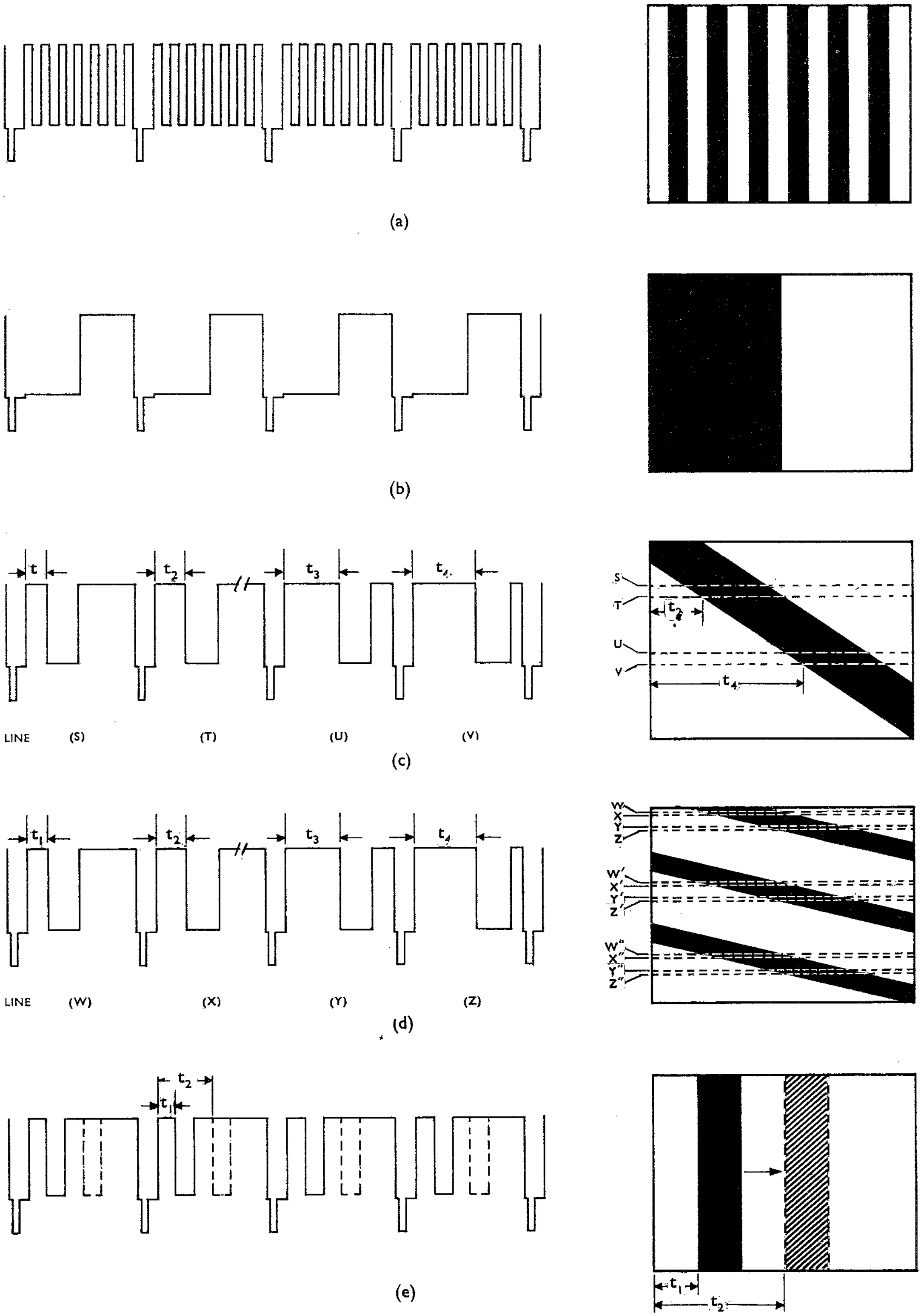


FIG. 19. PICTURES FROM HIGH FREQUENCY SIGNAL COMPONENTS.

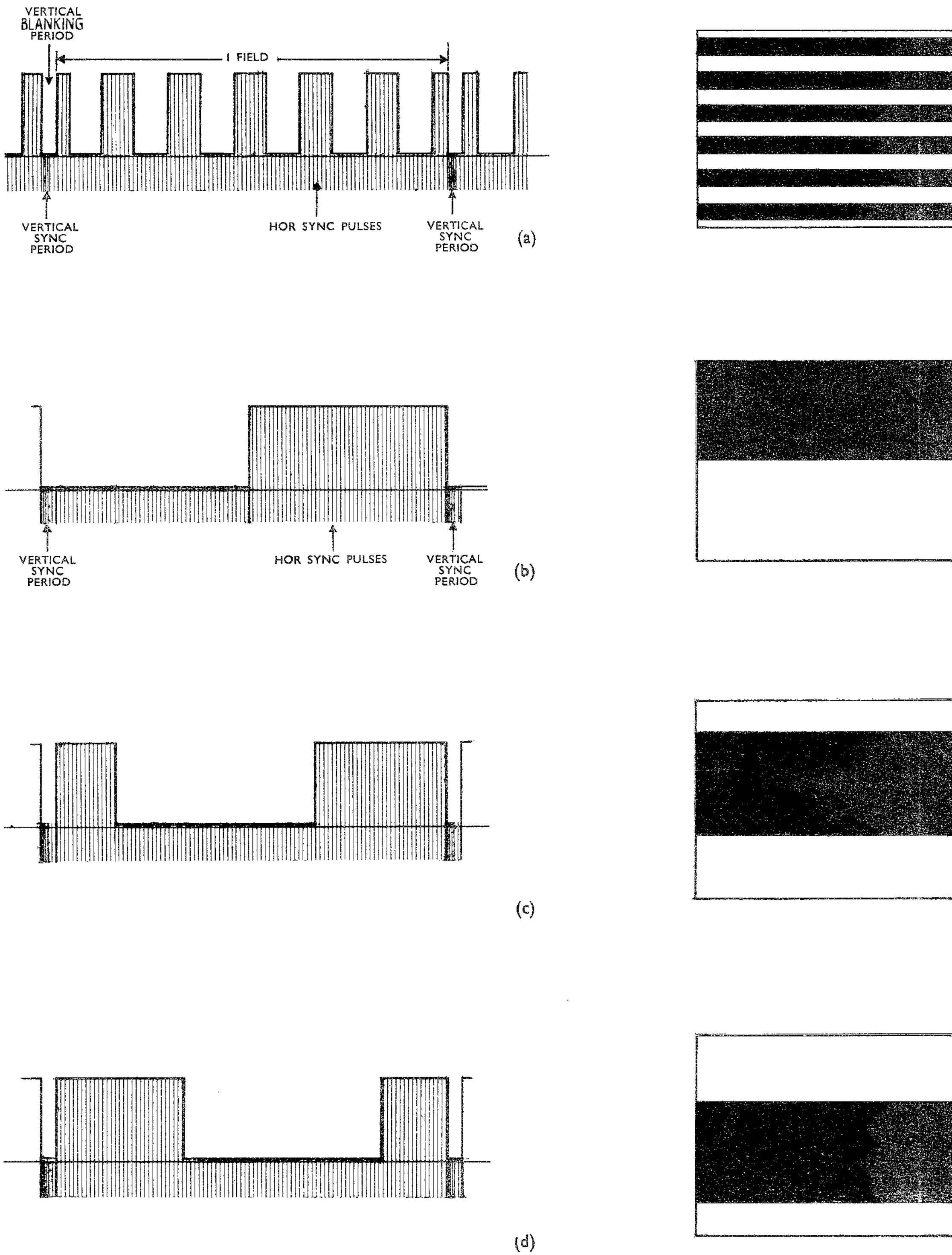


FIG. 20. PICTURES FROM LOW FREQUENCY SIGNAL COMPONENTS.

When the repetition frequency of the video signal is lower than the line frequency, the information is related to change of light intensity in the height of the picture, not the width as for higher frequencies. A picture signal with a repetition rate of about six times the field frequency as in Fig. 20a produces a series of horizontal bars. A lower picture signal frequency produces less horizontal bars; e.g. Fig. 20b represents a picture signal repetition rate of 50c/s.

It is also possible to have signal components which are harmonics of 25c/s if the scanned information is varying at the picture rate, though for the average picture, these components are usually relatively small.

For signal components that are not a prime multiple of the field frequency, the horizontal bars appear to roll up or down the picture area. This is illustrated by the relative movement of the bar in Fig. 20b, c and d, where a signal repetition frequency lower than the field frequency causes the bar to move down the picture.

From the examination of the different signals required to produce possible pictures, it is seen that all frequencies from very low values below the field frequency, up to the limit of 5Mc/s have to be passed by the system. The frequencies higher than the line frequency affect picture information across the width of the reproduced picture, and the lower frequencies affect picture information in the height of the reproduced picture. Vertical lines in the picture are produced by signals that are harmonics of the line frequency, and lines at an angle by signals that are not harmonics of the line frequency.

Signals of stationary picture information have components which are multiples of the line frequency and moving information has additional components which are not exact multiples of the picture frequency. As motion in the average picture is relatively slow (and has to be or the motion appears to be jerky), no component has a fundamental frequency much removed from the picture frequency.

Section 4 shows that the lower limit of the picture signal information is actually 0c/s or D.C.

3.8 Phase Response. At this stage, resolution has been related only to the amplitude versus frequency characteristics of the system. The phase versus frequency characteristics are equally important to produce a good picture. Frequencies may be present up to the desired limit, but if phase-frequency distortion is present, the resulting picture may be far from acceptable. The effects of phase-frequency distortion are seen in the papers "Distortion and Interference", and "Video Test Signals".

4. D.C. COMPONENT OF THE VIDEO SIGNAL.

4.1 Receiver Adjustment for Correct Pictures. When a video signal is applied to the picture tube of a television receiver, to obtain the correct picture, the "brightness" of the picture is adjusted by adjusting the D.C. bias between grid and cathode of the picture tube so that the black level of the signal is at the cut-off voltage of the picture tube electron beam. The "contrast" is adjusted by varying the amplitude of the signal so that the white sections of the picture are of satisfactory brightness with the black signals still causing electron beam cut-off. (In most receivers, there is an interaction between the "brightness" and "contrast" controls.)

It is important for the correct reproduction of the shades of the picture, that the black level be maintained at cut-off and that all other signals vary relative to this reference point. In the paper "Distortion and Interference", the distortion introduced by incorrect setting of the brightness and contrast controls is considered.

4.2 D.C. Component of the Signal. With sound transmission, the signal waveform is generally symmetrical. However, with television picture signals the waveform is asymmetrical, and in addition the average amplitude of the signal varies depending on the picture content.

Fig. 21 shows that for different pictures the average signal amplitude varies over wide limits. The average signal amplitude is that amplitude which makes the area of the signal component above the average line equal the area below the average line.

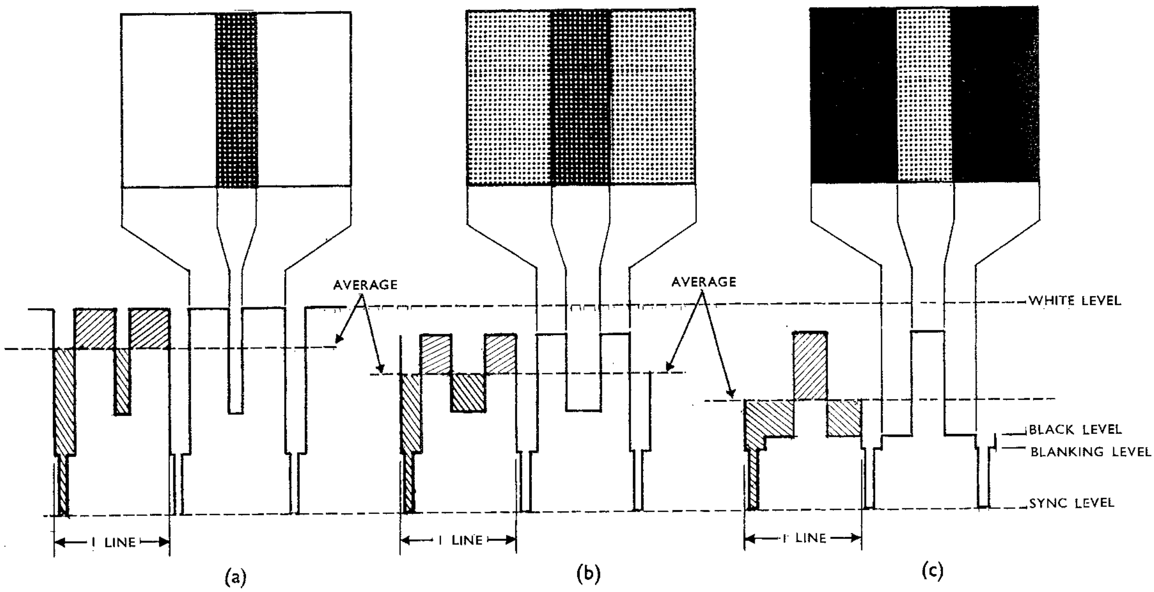


FIG. 21. VARIATION OF D.C. COMPONENT FOR VARIOUS PICTURES.

Since black level has been established as a reference level for picture tube bias adjustment, the variation of the average level relative to black level represents a D.C. signal. The complete signal is composed of a D.C. component with a superimposed A.C. component. The D.C. signal represents the average brightness of the picture.

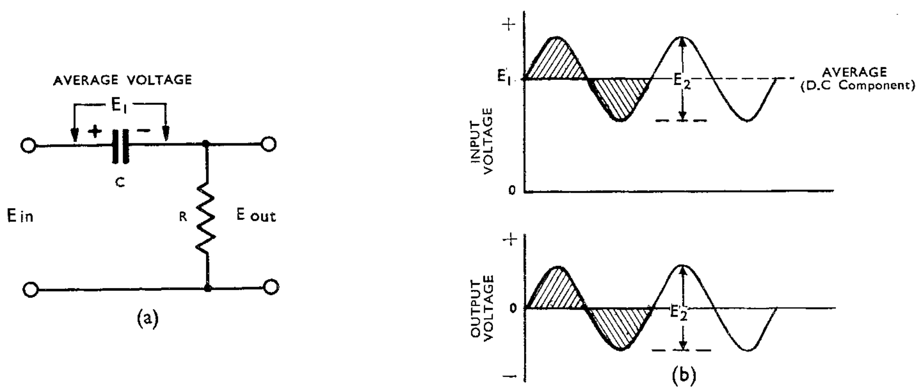


FIG. 22. LOSS OF D.C. COMPONENT IN A COUPLING CIRCUIT.

4.3 Pictures without the D.C. Component. When a signal consisting of a D.C. component plus an A.C. component is applied to an A.C. coupling circuit, e.g. a resistor-capacitor coupling circuit as in Fig. 22a, the A.C. component is the only one appearing at the output of the circuit. The D.C. component is blocked by the capacitor. The zero axis of the output waveform (Fig. 22b) establishes itself so that it is at the average of the variations of the input signal; i.e. the area of the waveform above the zero line equals the area below the zero line. The coupling capacitor is maintained with an average voltage equal to the D.C. component of the signal.

When the video signals of Fig. 21 are applied to a picture tube via a coupling circuit that passes only the A.C. component, the resulting pictures have incorrect shades. In Fig. 23, the D.C. components of the waveforms of Fig. 21 are removed so that the average levels of all of the signals line up at the same voltage. When the signals are applied as the grid-cathode voltage of the picture tube the position of the average level is set by the bias on the tube, i.e. by the brightness control. In Fig. 23 this is adjusted so that the resulting picture is correct for the signal of Fig. 23b.

With the signal of Fig. 23a applied, the signal average amplitude is such that dark grey signals cut-off the picture tube and so produce black. White signals are only reproduced as light grey. With the signal of Fig. 23c, the reverse is the case, as light grey signals are reproduced as white, and black signals as dark grey.
In addition, the blanking pulses now no longer drive the picture tube beyond cut-off, and flyback lines are seen unless special provisions to suppress them are made in the receiver circuits.

To obtain correct reproduction of the pictures, the brightness control has to be varied continually to adjust the bias on the picture tube to take into account the variation of the D.C. component and to keep the black level always at cut-off of the picture tube characteristic.

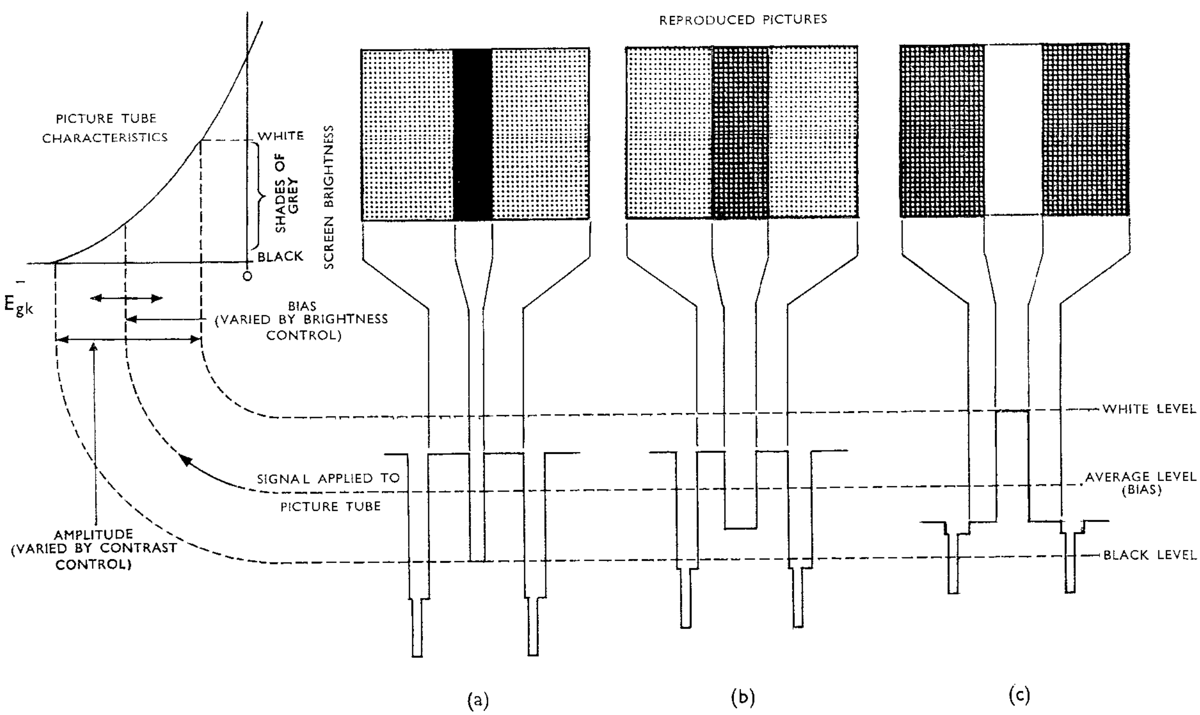


FIG. 23. PICTURES WITHOUT THE D.C. COMPONENT.

When an average scene with a practically constant D.C. component is maintained throughout a production, it is sometimes hard to visually distinguish if the D.C. component is present. But if the producer uses dramatic effects, such as a picture with lots of shadows, to create the mood of the scene, and then changes to a general scene with high overall illumination, the brightness control which was correctly set for one picture is not correct for the other.

When a change is made from one scene to another it is common practice to fade one scene to black before the other scene is faded into view. With the D.C. component present the black parts of the picture remain black and the white sections fade through grey until the complete screen of the picture tube is black. When the D.C. component is eliminated the picture tube reproduces a fading picture where the contrast is reducing but the black areas of the picture are becoming lighter and the whole screen at the completion of the fade is a mid-grey.

The response of the eye is unlike the response of the ear. We hear only variations of pressure and then only in the range of approximately 30c/s to 15kc/s. The eye however responds to variations no matter how slow, but is insensitive to variations at repetition frequencies greater than approximately 50c/s (depending on the light intensity) as we saw in the "Introduction to Television" when we discussed flicker.

The D.C. component is varying very slowly for normal pictures, but because the eye is sensitive to light intensity and slow changes in light intensity, the D.C. component must be present at the input to the picture tube for correct pictures to be reproduced. Even though the average component of the video signal may be varying at a slow rate it is still referred to as the D.C. component.

4.4 Reasons for Maintaining the D.C. Component. It is only necessary for correct picture reproduction to have the D.C. component present at the input to the picture tube. This can be achieved by transmitting the D.C. component throughout the system or by allowing the D.C. component to be removed by A.C. coupling circuits and re-introducing or "restoring" it again as required, by "clamping" black signals or some other reference level of the waveform at the required voltage. The complete system then could be A.C. coupled and some form of D.C. restoration used in receivers at the picture tube. This arrangement is not used as it is inconvenient and uneconomical.

For the transmission of video signals it is often necessary to control the amplitudes of the picture information of the signal or the sync. signals separately, or to pre-distort the amplitudes of parts of the signal to compensate for non-linearities in the amplitude characteristics of an amplifier stage. These adjustments are only convenient if the D.C. component of the video signal is present so that the reference levels of the signal are at a fixed voltage.

As another reason for the D.C. component to be present at places other than the picture tube, consider a valve used as a grid modulator with a dynamic grid characteristic as in Fig. 24. With the D.C. component restored to the signal, the black level, white level and sync. level are placed on definite parts of the characteristic. The complete relatively straight section of the valve characteristic can be used.

If the D.C. component is removed, so that only the straight section of the characteristic is used, the amplitude of the video signal on the grid of the tube has to be reduced to allow for the change in the average value for differing signals (Fig. 25) and the output power possible from the valve is correspondingly reduced. In a similar manner the capabilities of a valve used as a video amplifier are reduced by the reduction of the signal able to be applied to the grid.

In Fig. 25, as the signal is changing its position on the characteristic, the R.F. output power represented by the reference levels is changing depending on the picture content, and it is almost impossible to examine the video waveform or the R.F. waveform to make adjustments under actual working conditions without first restoring the D.C. component.

With the above points in mind, television systems transmit a fixed amplitude carrier representing the reference levels of the video signal which is equivalent to transmitting the D.C. component.

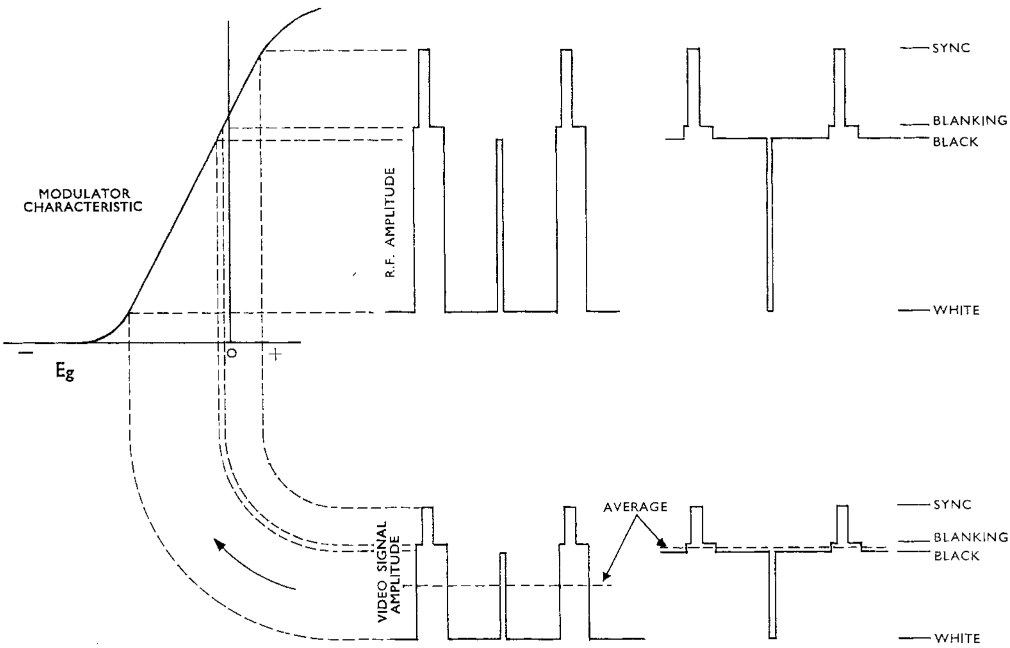


FIG. 24. SIGNAL AMPLITUDE POSSIBLE WITH D.C. COMPONENT.

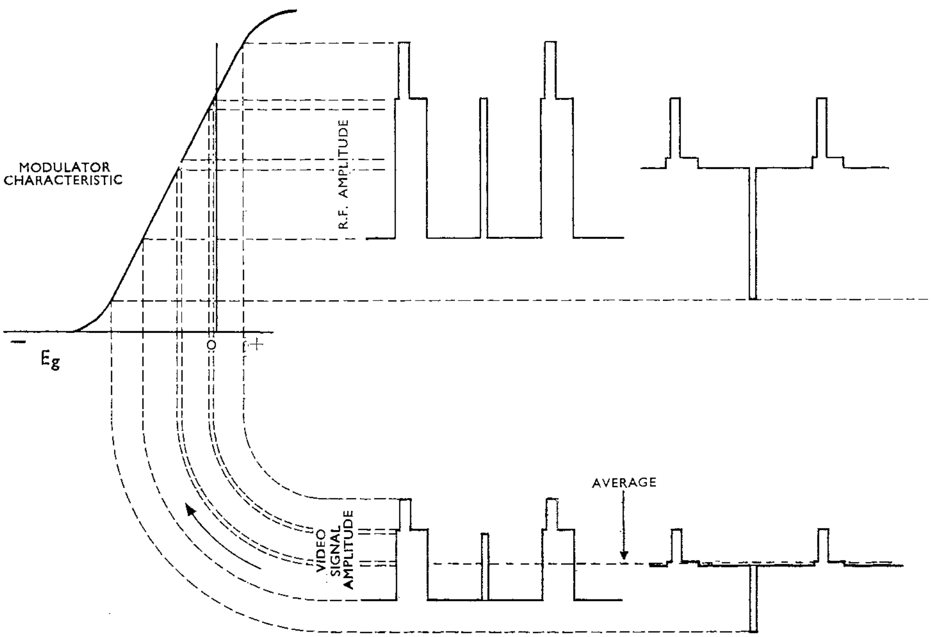


FIG. 25. SIGNAL AMPLITUDE POSSIBLE WITHOUT D.C. COMPONENT.

A further reason for maintaining or restoring the D.C. component, or more important in this case, for maintaining or clamping a reference level of the signal at a definite voltage is that it is quite often necessary to clip the video signal at various levels.

In a television transmitter installation a clipper is set so that no black picture signals extend into the sync. region and so cause possible incorrect synchronization. White picture information is clipped so that the minimum carrier amplitude never falls to zero, even if the picture amplitude is accidentally incorrectly adjusted. (Some carrier must always be present to prevent video signals interfering with sound signals in an intercarrier receiver, as is explained in other papers of the course.)

When separating the synchronizing information from the composite video signal, the peaks of the sync. pulses are clamped to a fixed level and the signal clipped to remove the picture information. An example of sync. separation is illustrated in Fig. 26, where the sync. pulses are clamped to zero voltage and the picture signals have sufficient amplitude to drive the valve into cut-off and are not present in the output. The amplitude of the sync. pulse output is then constant. Without clamping, there is a possibility of varying pulse output amplitudes and also of the picture signal not being clipped for all types of composite video signals having various values of D.C. component.

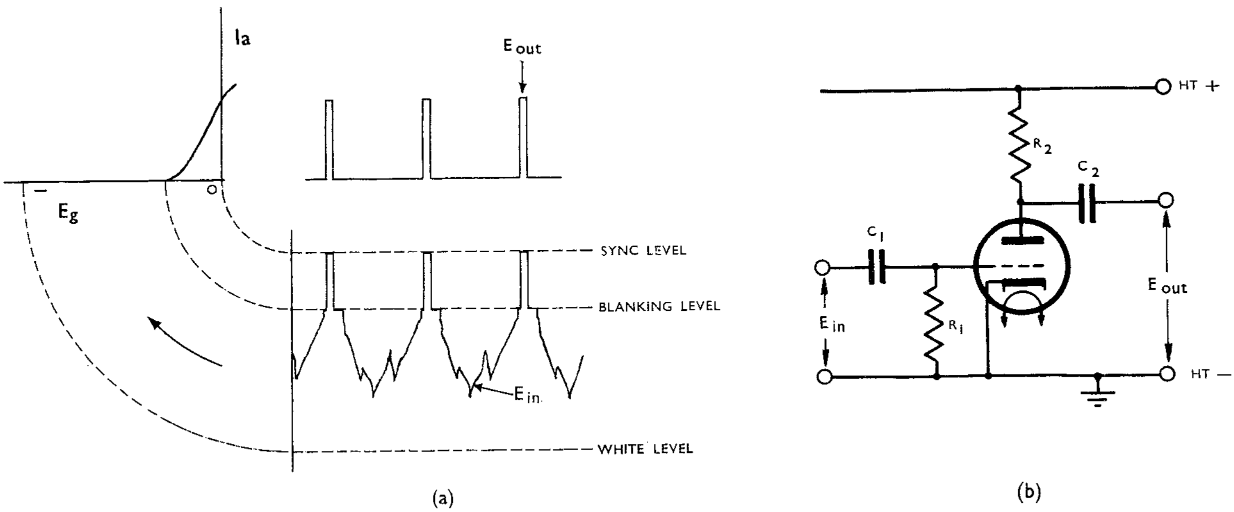


FIG. 26. SYNC. SEPARATOR OPERATION.

4.5 D.C. Amplification compared with D.C. Restoration. The D.C. component could be maintained throughout the system by using D.C. amplification in all stages (i.e. including studio, transmitter and receiver). But this cannot be economically achieved as a large number of D.C. amplifiers makes power supply requirements virtually impossible. The anode supply would be required to have a particularly high voltage with considerable power loss in voltage divider arrangements to provide correct biassing. Small variations in the supply voltage would be amplified by the complete amplifier chain to produce large variations in the operating conditions of the output stages. D.C. amplifiers are not practical for more than about three stages in cascade.

In television receivers where there is only one or perhaps two stages of video amplification, it is a relatively simple matter to provide D.C. amplification of the video signal, but manufacturers sometimes prefer to use A.C. coupling and restore the D.C. component. Other manufacturers even ignore the D.C. component or provide only part of the D.C. component.

In television transmitter and studio installation the practice is to use mainly A.C. coupling and restore the D.C. component wherever necessary to provide adjustments, remove or insert information such as sync. pulses onto the waveform, or make sure that the waveform is applied to a definite section of a valve characteristic. Direct coupling is sometimes used over two or three stages to improve the low frequency amplitude-frequency and phase-frequency responses of these stages.

A further advantage of the use of A.C. coupling and D.C. restoration is that it is possible to remove low frequency interference such as power supply interference, and to correct for amplitude versus frequency distortion at low frequencies. If a reference level of the picture signal is maintained at the correct level by making corrections during each line blanking period, i.e. at a rate of 15,625c/s, any interference or amplitude versus frequency distortion which is lower in frequency than the line frequency, is reduced.

4.6 Principles of D.C. Restoration. The methods used to restore the D.C. component of a video signal rely on the fact that fixed relationships are set between the reference levels. It is required to fix black level at a specific voltage, but as the picture information may not contain any black, this reference is not available at all times, and it is not desirable to clamp to any signal voltage in the line time occupied by the picture signal. Either sync. level or blanking level is convenient, however, and circuits that clamp these levels at a definite voltage are in effect setting black level at a definite voltage, if the sync. amplitude and the set-up are correctly adjusted.

★ 4.7 Methods of D.C. Restoration. The simplest method of obtaining D.C. restoration is by the use of a diode clamp circuit which is often referred to under the general title of "D.C. restorer" circuit. This simple circuit has many disadvantages and can only be used where a fast and accurate clamp action is not required. Among the disadvantages of the circuit are -

(i) It is a one-way clamp; that is, it can correct for changes in D.C. component in one direction more quickly than changes in the other direction.

(ii) Clamping can only be carried out on peaks and not at other levels such as blanking level during the back porch interval.

(iii) It is not immune to noise.

For these reasons "keyed" or "gated" clamps have been developed which arrange to clamp the signal to a definite voltage during a small period at regular intervals. In practice the clamping is arranged to be during the horizontal blanking period for non-composite video signals, and more specifically, during the back porch interval for composite video signals. Methods of clamping and their advantages are explained in the course paper "D.C. Restoration and Clamping".

5. FREQUENCY SPECTRUM OF VIDEO SIGNALS.

5.1 Bandwidth Required for Synchronizing Pulses. For the transmission of pulses, many harmonics of the fundamental pulse repetition frequency are required if the pulse is not to suffer significant degradation. From the discussion in the "Introduction to Pulse Techniques", we see that the frequencies required to transmit a pulse without changing its shape, depends on the rise time of the pulse, and not on the pulse duration. The highest frequency necessary for transmission of a pulse = $\frac{1}{2 \times \text{rise time}}$.
For the Australian television system, the rise time of the horizontal sync. pulses, the blanking pulses, the broad pulses and the equalizing pulses is required to be between 0.2 and 0.4µS. Therefore the highest frequency required to suit each rise time is -

$$\text{Highest frequency for rise time of } 0.2\mu S = \frac{1}{2 \times 0.2}\ \text{Mc/s} = 2.5\text{Mc/s}.$$

$$\text{Highest frequency for rise time of } 0.4\mu S = \frac{1}{2 \times 0.4}\ \text{Mc/s} = 1.25\text{Mc/s}.$$

We see that the rise time of the pulses of the composite waveform have been specified so that the components are easily contained in the bandwidth allowed for the video signal as calculated originally from the required picture detail (Section 3). Therefore, the synchronizing information should not be degraded by amplifiers that are suitable for the picture component of the video signal. The synchronizing information of the composite video signal, therefore, has a frequency spectrum with components related to the horizontal sync. frequency (15,625c/s), the equalizing pulse and broad pulse frequency (2 X 15,625c/s) and the vertical sync. frequency (50c/s), but no important components are present above the frequency limit determined by the rise time.

5.2 Frequency Components of the Picture Signal. The picture information is normally such that similar picture information re-occurs in consecutive fields. This means that the picture information contains components related to 50c/s. On rare occasions in practice, a 25c/s component is present and this is under conditions where the picture information is scanned only once per complete picture, i.e. every second field.

Motion in the picture produces components that are not multiple of the line or field frequencies (Section 3).

Much of the picture information actually re-occurs every line, at least for a few lines, e.g. the vertical lines representing the outline of a building or other picture information of this type that is not moving. The information, then, has components related to 15,625c/s, up to the limit of the bandwidth depending on the size of the detail and the sharpness of the transitions from one shade to another.

5.3 Frequency Spectrum of Composite Video Signal. The total spectrum of a composite video signal is complicated, but forms into definite bands of high amplitude components around the line frequency and multiples of this frequency, as well as a band represented by the harmonics of the field frequency. The spectrum of a typical stationary picture is shown in Fig. 27. The actual amplitudes of the frequencies depends on the picture content.

The interruption of the horizontal sync. pulses of 15,625c/s by the vertical sync. pulses of 50c/s is equivalent to modulating 15,625c/s and its harmonics with a pulse consisting of 50c/s and its harmonics. The 15,625c/s components of picture information repeated at 50c/s intervals is a similar process. The spectrum then contains frequencies which are sideband frequencies at 50c/s intervals on either side of the line frequency and its multiples.

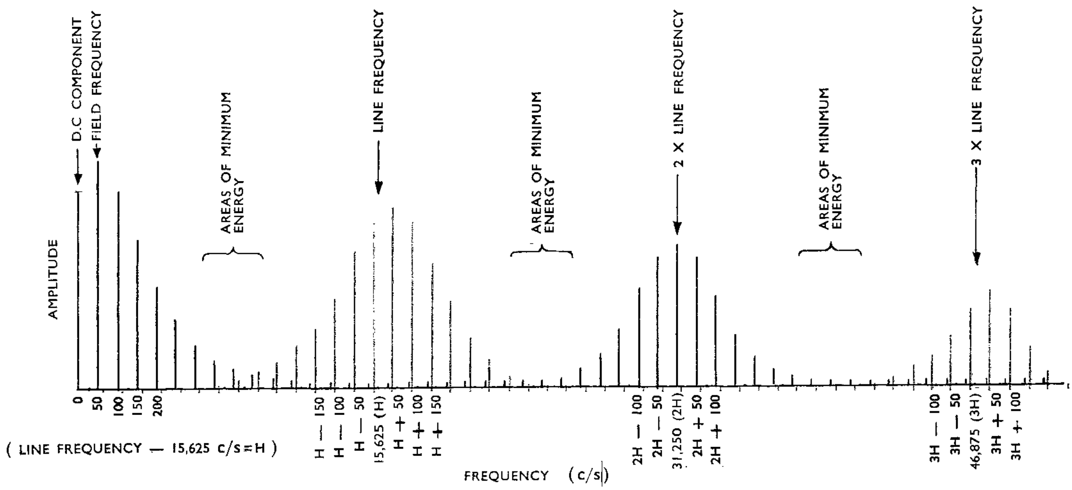


FIG. 27. FREQUENCY SPECTRUM OF THE COMPOSITE VIDEO SIGNAL.

Fig. 27 shows that the sideband components of, for example, the line frequency, interleave with the components which are harmonics of the field frequency. This is because, for an interlaced scanning system, the line frequency is not an even multiple of the field frequency but is a multiple of half the field frequency $(15,625 = 50 \times \frac{625}{2})$.

It shows also that the lowest frequency of any appreciable amplitude (neglecting the D.C. component) is 50c/s except in the special case where information is scanned only during every second field. Notice that Fig. 27 is only a representation of the frequencies and cannot conveniently be drawn to scale. The amplitude of the D.C. component of the signal is indicated at zero on the frequency scale.

For colour television systems at present in limited use in some countries, the sub-carrier frequency for the colour information is chosen so that the spectrum of frequencies produced by colour information falls in the regions of minimum energy of the frequency spectrum created by normal black and white (i.e. monochrome) signals.

6. SUMMARY.

6.1 This section summarises the major points of Sections 2, 3, 4 and 5 of this paper:-

6.2 Section 2:

(i) Blanking pulses return the signal to blacker than black to suppress spurious information occurring during the time allowed for fly-back.

(ii) Horizontal blanking time is 11.5 - 12μS.

(iii) Vertical blanking time is 18 - 22 lines.

(iv) Synchronizing pulses control the start of retrace of the deflection oscillators.

(v) Horizontal sync. pulse duration is 4.8 - 5.2μS.

(vi) The vertical sync. is composed of 5 broad pulses at 32μS intervals, with serrations of 4.8 - 5.2μS, and making a total vertical sync. pulse of 2½ lines duration.

(vii) Pre-equalizing pulses and post-equalizing pulses are included before and after the vertical sync. pulse interval to minimise the possibility of vertical synchronizing occurring at the incorrect time.

(viii) The duration of one equalizing pulse is 2.3 - 2.6μS.

(ix) The vertical sync. serrations are included to maintain horizontal sync. information during the vertical sync. period.

(x) The equalizing pulses and vertical sync. serrations are at half line spacing to provide correct horizontal sync. information for both odd and even fields.

(xi) The vertical sync. information can be segregated by an integrating circuit with a time constant of approximately two lines duration.

(xii) The horizontal sync. information can be segregated from the vertical sync. information by using a differentiating circuit.

(xiii) The set-up of black level is provided mainly to allow a tolerance for sync. stripping and is 5 - 10% of the blanking to white interval.

(xiv) The video signal is transmitted with the white level maximum positive and the sync. level maximum negative at a peak-to-peak amplitude of 1 volt.

(xv) The picture - sync. ratio is 5 : 2, for television broadcasting.

6.3 Section 3:

(i) Resolution is the number of alternate black and white lines that can be resolved in a picture over a length equal to the picture height.

i) Vertical resolution depends on the number of active lines of the system and the vertical resolution factor.

(iii) The vertical resolution factor is a factor representing the ratio of the actual vertical resolution to the maximum possible vertical resolution, and is dependant on the random positioning of the picture elements. The factor has been found experimentally to be approximately 0.75.

(iv) Horizontal resolution depends on the amplitude and phase response of the system to the high frequency components of the video signal.

(v) With a 5Mc/s bandwidth the horizontal resolution is approximately 400 lines

(vi) Increasing the scanning spot size at the camera or the receiver, reduces the resolution, particularly after the spot diameter is greater than the line spacing.

(vii) The picture signal can contain any frequency in the band from D.C. to 5Mc/s, but the majority of signals in practice are related to the line frequency and the field frequency.

(viii) Motion in the picture produces video signals that are not a multiple of the field frequency, but as the motion is normally relatively slow, no signals are found greatly removed from being related to 50c/s.

6.4 Section 4:

(i) When a receiver is correctly adjusted, black signals just cause picture tube cut-off.

(ii) Video signals are asymetrical and contain a D.C. component which represents the average brightness of the picture.

(iii) For correct picture reproduction, the D.C. component must be maintained or restored before the video signal is applied to the picture tube.

(iv) The D.C. component is required to be present at other parts of the system to allow the signal to be clipped at specific levels, to allow transmitters to be operated efficiently and to allow ease of measurement and adjustment of associated equipment.

(v) D.C. amplification is not practical throughout the entire system, so that A.C. amplification is used and the D.C. component restored as required.

(vi) D.C. restorers clamp either the sync. pulse tips, or blanking level during the back porch, to the desired level.

(vii) As a definite level of transmitted carrier represents each of the video signal reference levels, the carrier transmits the D.C. component.

6.5 Section 5:

(i) The rise time of the pulses of the video signal is 0.2 to 0.4μS, so the pulses require frequencies up to 1.25 to 2.5Mc/s to be transmitted without being degraded.

(ii) The frequency spectrum of the composite video signal for a still picture contains frequencies which are harmonics of 50c/s and 15,625c/s with bands of maximum energy formed by frequencies at 50c/s spacing on either side of the line frequency and its harmonics.

10. TEST QUESTIONS.

1. (i) What are the repetition frequencies of :-

   (a) Horizontal sync. pulses?
   (b) Vertical sync. pulses?
   (c) Vertical blanking pulses?
   (d) Equalizing pulses?

   (ii) What is the relationship between the frequencies of the above pulses and the picture frequency?

   (iii) What is the reason for the frequency of equalizing pulses?

2. (i) Drawing the waveform existing during the vertical blanking period for one field of the Australian television system, (sync. pulse negative).

   (ii) Draw under the first waveform, the same waveform, but delayed by 16 μS.

   (iii) Add the two waveforms together.

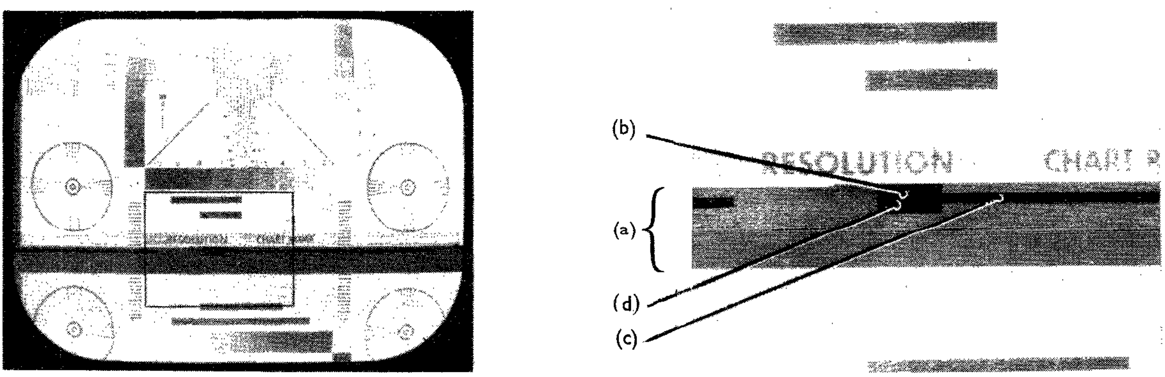
   (iv) Clip off everything above 60% of the peak amplitude.

   (v) What would be a use for the resultant waveform?

3. A fault in a receiver has caused the vertical synchronizing information to be removed from the vertical oscillator and the picture is rolling down the screen.

   (i) Is the vertical oscillator frequency higher or lower than the field frequency of the received picture?

   (ii) The picture on the screen at one instant is as in Fig. 28. What does each of the marked sections of the picture represent?



(a) Vertical Roll.   (b) Section of (a) enlarged.

FIG. 28.

4. (i) Draw sufficient composite video signals to the Australian standards, to show the signal that would reproduce as a black cross on a white background.

   (ii) Calculate the time for the signal to scan across the width of the vertical section, and the time to scan down the height of the horizontal section of the cross, if both the vertical and horizontal sections are 1" wide when reproduced on a raster 20" wide.

5. If the Australian television system had the number of lines per picture increased to 729 and all other specifications were maintained the same, which of the following statements would be correct?

   (i) The horizontal resolution would (a) increase;
   (b) decrease;
   (c) remain the same.

   (ii) The vertical resolution would (a) increase;
   (b) decrease;
   (c) remain the same.

6. A 525 line television system has the following standards :-

Time for one field	=	$\frac{1}{60}$ sec.
Vertical blanking time	=	15 lines
Horizontal blanking time	=	10 μS
Highest video frequency	=	4Mc/s.

Assuming the vertical resolution factor to be 0.75, what is the horizontal and vertical resolution of the reproduced picture?

7. If an Australian television receiver has a high frequency cut-off of 3Mc/s, what horizontal resolution could be expected?

8. Is D.C. restoration required in a receiver using a direct coupled video amplifier? Why?

9. State two reasons why the D.C. component of the video signal would be required in a transmitter installation.

10. A television receiver is directly coupled from the detector to the picture tube. The vision carrier fed into the detector is maintained by the receiver A.G.C. system so that the amplitude at the sync. pulse tips is constant. The receiver is adjusted so that the picture is correctly reproduced.

If the height of the sync. pulses at the transmitter is incorrectly increased so that the radiated carrier amplitude is as in Fig. 29.

(i) What would be the effect on the reproduced picture?

(ii) Explain how the control/controls at the receiver could be adjusted to restore the correct picture.

Illustrate the answer with suitable diagrams.

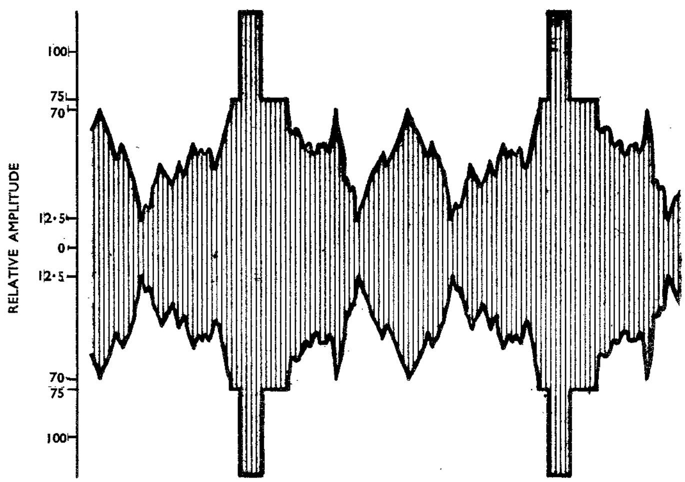


FIG. 29.

11. A C.R.O. is required to display the synchronizing information of the Australian television system without significant degrading, but is not required to show the highest frequency of the picture signal. What is the minimum band of frequencies required to be passed by the C.R.O. amplifier? (The fastest rise time of the pulses is 0.2 μS.)

END OF PAPER.