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THE ESSENTIAL CHARACTERISTICS OF TELEVISION CIRCUITS

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A brief summary of the published data regarding the characteristics of various television circuits is given but no tests to determine the deteriorating effect of circuits with various known responses have yet been made. Three methods are suggested, however, whereby this problem can be analysed. The results of tests of the interfering effect of random and single frequency noise are given and values for overall gain stability are suggested. It is suggested that non-linear distortion in circuits not employing frequency translation should be defined by graphical limits to the output versus input voltage characteristics of the circuit.

INTRODUCTION.

When new systems of communication are developed the need soon arises for a knowledge of the limits which must be imposed on the characteristics of the system to achieve the desired results. For television systems it was some time before the need for a proper knowledge of such limits was fully appreciated and before it was even fully realised what a wide frequency band-width was necessary to achieve good definition.

The limits which are examined are those which must be applied to the overall circuit from the picture producing source to the received picture. The effects of aperture distortion at the transmitter and receiver are not separately considered as aperture distortion can be regarded as part of the electrical circuit distortion, the effects of aperture distortion being reproducible by electrical circuits and also capable of correction by such circuits. The final division of the overall limits between the various parts of the circuit is not considered, and is, of course, a question which must ultimately be determined largely on economic grounds.

THE ESSENTIAL CHARACTERISTICS.

The usually accepted essential characteristics of a television circuit on which limits should be imposed are:—

(*a*) The frequency band for which limits of response are to be specified.

(*b*) The attenuation-frequency response in this band.

(*c*) The phase delay frequency response over this band.

(*d*) The minimum signal-to-noise ratio with various types of noise.

(*e*) The overall gain stability.

(*f*) Non-linear distortion.

It will be noted that the first three of these characteristics are stated in terms of the steady state frequency response of the circuit. These characteristics can be replaced by a single characteristic, namely the time response of the circuit to a unit impulse voltage applied in the transmitting branch, and the use of this characteristic as an alternative to (*a*), (*b*) and (*c*) will be considered briefly.

THE EFFECTIVE FREQUENCY BAND-WIDTH NECESSARY.

In order that the average brightness of the picture may be faithfully reproduced it is necessary to transmit all lower frequencies down to and including zero. The lower frequencies can, however, be attenuated and the D.C. or zero frequency component completely removed in one part of the circuit, providing these are re-constituted later by bringing the bottoms of the synchronising pulses, or the black level in the picture signal, to a constant level by a rectifier circuit. If such re-constitution is carried out the allowable loss at low frequencies depends partly on the efficiency of the D.C. restoring circuit and partly on the maximum permissible reduction of brightness across the picture. With the most efficient D.C. restoring circuits the latter is the predominant factor. If the low frequency loss is brought about by a single resistance-capacitance coupled stage of amplification with a loss of 3 db. at 50 c/s, the change of brightness across the picture is approximately 3 per cent. in 405 line pictures with a picture frequency of 25 c/s. This change of 3 per cent. has been regarded in some quarters as the maximum tolerable.

Various methods have been suggested for estimating the maximum frequency which it is desirable to transmit. The usual method is to consider a picture consisting of alternate black and white squares, the side of each square being equal to the thickness of a line, as shown in *Fig. 1*. Such a picture has equal fineness of detail in the vertical and horizontal directions, and the detail in the vertical direction is the finest possible with the line structure employed in scanning.

Let b = width of visible picture.

h = height of visible picture.

r = aspect ratio = b/h.

n = total number of lines.

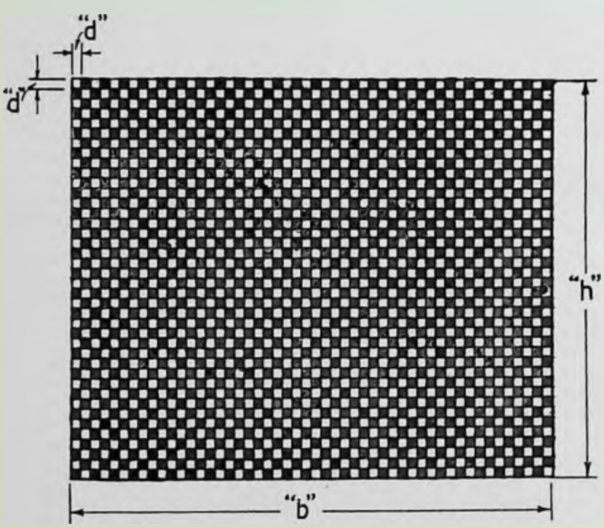


FIG. 1—Division of the Picture into Black and White Squares, with Sides equal to the Line Thickness

n_p = number of lines in the visible picture.

d = thickness of a line = h/n_p.

$\alpha = \dfrac{\text{time taken to scan visible part of line.}}{\text{total periodic time of each line.}}$

$\beta = n_p/n$.

f_p = number of pictures per second.

Then the total number of squares having sides equal to the thickness of a line, in the visible part of a line

$$= \frac{bn_p}{h}$$

The time taken to scan the visible part of the line

$$= \frac{\alpha}{f_p n} \text{ seconds}$$

and the time taken to scan two elementary squares is

$$\frac{\alpha}{f_p n} \div \frac{1}{2}\frac{bn_p}{h} = \frac{2h\alpha}{f_p b n n_p} \text{ seconds.}$$

Hence the fundamental frequency obtained by scanning the black and white squares is

$$\frac{1}{2} \cdot \frac{\beta}{\alpha} \cdot r f_p n^2 \text{ cycles per second.} \quad \ldots\ldots\ldots\ldots(1)$$

In the E.M.I. system employed at Alexandra Palace[1]

$\alpha = 0{\cdot}845$ $\quad f_p = 25$

$\beta = 0{\cdot}951$ $\quad n = 405$

$r = 1{\cdot}25$

and the frequency given by equation (1) is 2·88 Mc/s.

It has been suggested that equation (1) gives the maximum frequency necessary to ensure equal definition in the horizontal and vertical directions, but there is some doubt about this point. For example, if the spot scanning a picture of the form shown in *Fig. 1* is moved downwards by the thickness of half a line the signal obtained will be a constant level and the picture at the receiver will consist of a uniform grey surface. On the other hand if all the black squares are arranged in vertical rows, so that the picture consists of alternate black and white vertical bars, the fundamental frequency produced by scanning is given by equation (1) irrespective of any vertical displacement of the scanning spot. If the picture being scanned consists of horizontal black and white bars of thickness equal to the line thickness, the resultant picture at the receiving end may consist of a true replica of the picture being transmitted, or of a uniform grey surface, or of a result between these two extremes, depending on the vertical position of the scanning spot at the

[1] *I.E.E.J.*, Vol. 83 pp 758, 801.

transmitter relative to the horizontal lines being scanned. This suggests that, from the point of view of resolution of detail, a system having a maximum effective frequency of transmission given by equation (1) will give, on the average, a better definition in the horizontal direction than in the vertical. From the point of view of minimum transition distance on the picture from full black to full white, or vice-versa, it will be shown later that, for the maximum frequency given by equation (1), this distance is equal to the thickness of a line in the horizontal direction, while it is clear that in the vertical direction it may lie anywhere between zero and the thickness of a line, depending on the position of the scanning spot relative to the horizontal black and white edge being scanned. Thus from this point of view the definition in the vertical direction is, on the average, better than that in the horizontal direction in a system having a maximum frequency given by equation (1). It would appear that, on the whole, this frequency is a good compromise to the value required to obtain approximately equal resolution of detail and sharpness of black and white edges in the vertical and horizontal directions. It has been suggested that it may not be desirable to aim at equal definition in the two directions, but it is not proposed to discuss this in the present article.

LIMITS OBTAINED IN VARIOUS PRACTICAL TELEVISION CIRCUITS

According to data regarding the modulation amplifiers in the Marconi-E.M.I. 405 line transmitter at Alexandra Palace,[2] the overall attenuation response of these amplifiers was flat to within ± 0·05 db. at frequencies up to 1 Mc/s, and to within ± 0·1 db. at frequencies up to 2·5 Mc/s. Data regarding the output stage and aerial system of this transmitter[3] show that the input impedance at the transmitter end of the aerial transmission line with the aerial connected varied between 73 and 83 Ω over the frequency range from 43 to 47 Mc/s (i.e., 45 ± 2 Mc/s). The output impedance of the output stage of the transmitter feeding this line is fairly high compared with 78 Ω and the loss on the transmission line is only about 0·2 db. It therefore follows that the overall fidelity of the Alexandra Palace transmitter from the output of the modulator to the modulated aerial current must have been flat to within ± 0·5 db. over the modulation frequency range 0—2 Mc/s. Thus allowing for the ± 0·1 db. in the modulator the overall fidelity of the transmitter must have been flat to within ± 0·6 db. from 0 to 2 Mc/s.

[2] *Loc. cit.*
[3] *I.E.E.J.*, Vol. 84, pp. 448, 467.

The results obtained on the Marconi-E.M.I. balanced cable television system in London are also of interest in this connection. This network consists of one repeater section 7¼ miles in length, and another repeater section of variable length up to a maximum of 8 miles. When first set up with a length of 4·3 miles in the variable section, the overall attenuation of the system was constant to within ± 0·5 db. from 50 c/s to 2·0 Mc/s. The overall phase characteristic of the system was not measured but the designers stated that a phase shift linear to within ± 3° had been aimed at to as high a frequency as practicable, although this was probably not obtained up to 2 Mc/s. When this network was properly adjusted it was very difficult to detect any difference between the transmitted and received picture.

It will be seen later that it is probably undesirable to endeavour to define the limits of attenuation and phase delay in terms of single figures applicable over the whole frequency range, as in the examples quoted above. Experiments carried out by the Post Office on transmission of television signals on coaxial cables have shown that a given departure from flatness of frequency response has a much more marked effect on the picture if it occurs in the region of 10-500 kc/s than it does at the top end of the vision frequency spectrum, i.e., about 2·5 Mc/s for 405 line pictures.

DETERMINATION OF THE DESIRABLE LIMITS OF ATTENUATION AND PHASE DELAY BASED ON THE ANALYSIS OF THE CIRCUIT RESPONSE TO SQUARE WAVEFORM SIGNALS

A television signal produced by scanning a fixed picture can be analysed by Fourier analysis into single frequency components which are harmonics of the picture frequency. In general, those components which are multiples of the line frequency have the maximum amplitudes, and the amplitudes decrease with increase in frequency. If, however, the picture consists of vertical black and white bars, a large amount of energy may be concentrated at high frequencies, depending on the width of the bars. Such picture signals would, therefore, appear to be very suitable for examining the effect of variations in the high frequency response of the circuit and this method has been applied by F. Ring.[4] Ring assumed the new German standard of 441 lines, 25 pictures per second and 4 by 10^6 picture elements per second. It is interesting to note here that 4 by 10^6 picture elements per second is smaller than the number of black and white squares scanned per second

[4] *Fernsehen und Tonfilm*, May, 1938.

calculated according to *Fig. 1.* If the picture aspect ratio is to be 4/3, and β/α (see equation 1) is assumed to be unity, the latter number would be 6·48 by 10^6, and if the definition is to be the same in the horizontal direction as in the vertical direction this number is probably required. If only 4 by 10^6 picture elements per second are considered necessary the maximum frequency that must be transmitted need only be 2 Mc/s, but if 6·48 by 10^6 picture elements per second are necessary the maximum frequency must be 3·24 Mc/s. Ring then assumed that the picture consisted of alternate vertical black and white bars, each 9 picture elements in width, the type of picture being illustrated in *Fig. 2.* When a picture of this type is scanned the picture signal resulting has the form of a periodic rectangular wave as shown in *Fig. 3.* This, of course, illustrates the "picture" signal, the synchronising pulses normally placed below the black level being omitted. This rectangular periodic signal can be expanded by Fourier analysis into the following form:—

$$E = A + \frac{4A}{\pi}\left\{\sin\omega t + \frac{1}{3}\sin 3\omega t + \frac{1}{5}\sin 5\,\omega t + \ldots\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

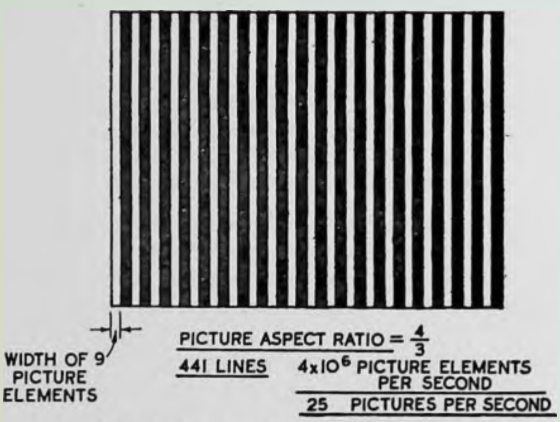


FIG. 2—Picture Considered by F. Ring.

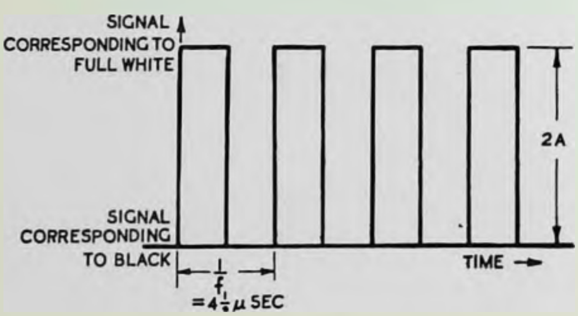
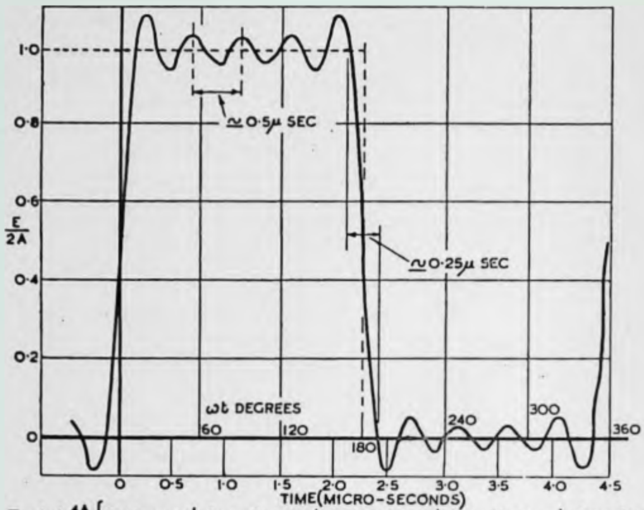


FIG. 3—Signal Produced by Scanning Fig. 2.



$$E = A + \frac{4A}{\pi}\left\{\sin\omega t + \frac{1}{3}\sin 3\omega t + \frac{1}{5}\sin 5\omega t + \frac{1}{7}\sin 7\omega t + \frac{1}{9}\sin 9\omega t\right\}$$

FIG. 4—Wave Form of Signal formed by the First Nine Harmonics of a Rectangular Wave.

where 2A = overall amplitude between black and full white, generally known as the "double amplitude peak" magnitude of the signal.

and $\omega = 2\pi \times$ the fundamental frequency.

In the example taken by Ring the fundamental frequency was 222·2 kc/s. He then assumed that all harmonics above the 9th, corresponding to the fundamental picture element frequency of 2 Mc/s (4 by 10^6 picture elements per second) were completely eliminated by the transmission path, and considered the shape of the wave received over transmission paths with various attenuation and phase characteristics in the frequency range 0 to 2 Mc/s.

The waveform of the received wave when all frequencies up to 2 Mc/s are faithfully transmitted is shown in *Fig. 4.* It will be noted from this that the received signal rises nearly to its maximum value in a time equal to the duration of a picture element, i.e., $\frac{1}{4}\mu$S. in this case. This time is, of course, half the periodic time of the maximum frequency transmitted (i.e., 2 Mc/s).

It will also be noted that the amplitude overshoots its average value (over one complete half-cycle) by 8·7 per cent., and that the amplitude oscillates about this average value with a quasi-period of about $\frac{1}{2}\,\mu S$, i.e., the periodic time of the maximum frequency transmitted. This oscillation of amplitude may be visible in a receiver with a well focused spot, and the sharp transition from white to black, or vice versa, in the received picture may be followed by a vertical striation of diminishing magnitude.

It would appear that if conclusions are to be drawn from the waveforms determined in this manner they must be based on the following considerations:—

(*a*) The minimum perceptible difference in brightness for various average brightness values, if perfect results are desired. Alternatively, the maximum permissible variation in brightness in parts of the picture which should be of even brightness, if the results are to be of an acceptable standard.

(*b*) The minimum rate of change of brightness permissible at a black and white edge.

According to Fechner's law the minimum perceptible percentage difference of brightness is nearly constant over a wide range of brightness and is equal to about 1-2 per cent. Although no separate tests have been made by the Post Office specially to confirm this, the results of tests indicate that noise is just visible with a ratio of double amplitude peak picture signal to peak noise of about 42 db. at the grid of the cathode ray tube with random noise and about 48 db. with single frequency noise. A ratio of 46 db. would indicate a minimum perceptible percentage difference of brightness of 1 per cent., and 40 db. of 2 per cent. The maximum tolerable difference of brightness in parts of the picture which should be of even brightness is probably of the order of 3 per cent. This figure is suggested by the minimum tolerable signal/noise ratios obtained in the above-mentioned tests.

With regard to the minimum rate of change of brightness at a black and white edge it is obviously desirable that the time taken to change from nearly full white to nearly full black, or vice versa, should not greatly exceed the time required to scan a distance equal to the thickness of the line. if the definition in the horizontal direction is to be as good as that in the vertical. It is interesting to note that this standard would be reached if perfect transmission were obtained up to the frequency given by equation (1).

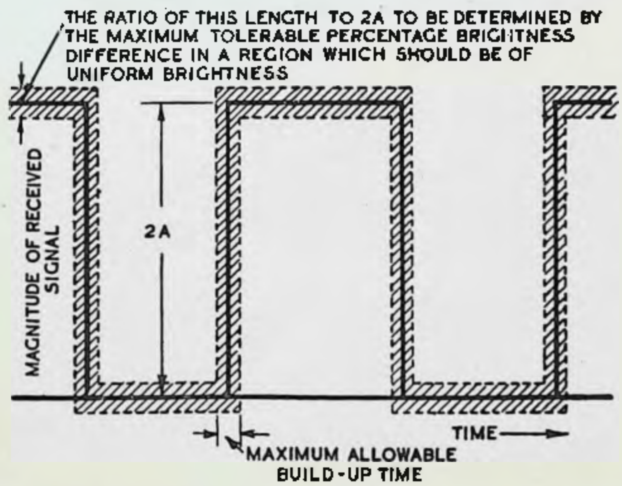


FIG. 5—Limits of the Received Waveform of a Rectangular Transmitted Wave.

If limits of this type are to be imposed on the shapes of received waveforms obtained with rectangular transmitted waveforms then the received waveforms must lie within limits such as those suggested in *Fig. 5*. It is clear that one method whereby the permissible limits of attenuation and phase distortion could be determined would consist of assuming a range of response waveforms within these limits and analysing these by Fourier analysis. By comparing the magnitudes and phases of the harmonic components of the received wave with those of the rectangular transmitted wave the limits of attenuation and phase distortion at various parts of the frequency spectrum might be determined. The process would be repeated for a range of fundamental transmitted frequencies.

DETERMINATION OF THE ALLOWABLE LIMIT OF ATTENUATION AND PHASE DELAY BASED ON THE INTERFERING EFFECT OF UNWANTED COMPONENTS INTRODUCED BY ATTENUATION AND PHASE DISTORTION

The method of analysing the response to rectangular transmitted waveforms of various frequencies obviously involves a large amount of labour, and a somewhat simpler method by which the allowable tolerances in the attenuation and phase response might be estimated will now be outlined. The method will be applicable either to the square waveform signals produced by scanning vertical black and white bars or to the signals obtained by scanning any fixed picture.

As previously mentioned, when a fixed picture is scanned the signal produced can be analysed into single frequency components which are harmonics of the picture frequency, and in general those components which are multiples of, or nearly multiples of the line frequency have the maximum amplitudes, and the amplitudes decrease with increase in frequency. In the special case where the picture consists of N black and N white vertical bars the fundamental frequency in the picture signal (omitting synchronsing pulses) obtained by scanning is Nf where f is the line frequency $(=nf_p)$.

Now suppose that the circuit transmits all frequencies perfectly except that of one of the components. It is theoretically possible for such a circuit to exist, a simple example being indicated in *Fig. 6a.* Assume that the component frequency f_1 say, which is incorrectly transmitted is represented by the vector OA in *Fig. 6b*, but that if it were transmitted perfectly (i.e., with the same attenuation and phase delay as the remaining frequencies) it would be represented by the vector OB. It is then clear that the television signal received over this circuit will consist of a perfect reproduction of the original signal together with a single frequency component at frequency f_1 represented by the vector BA. The effect of this component will be the same as if the circuit were perfect but a component of this frequency, magnitude and phase were introduced from an interfering source. Actually the interfering effect of the unwanted component is not likely, in general, to depend much on its phase, and the interfering effect will probaby be much the same for any position of the end of the vector OA on the circle with B as centre and BA as radius.

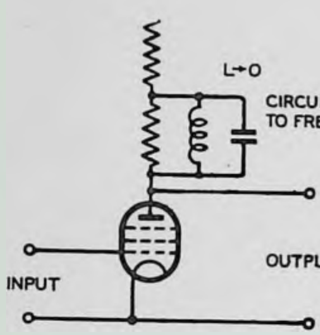


FIG. 6a—Simple Valve Circuit which will Transmit all Frequencies Perfectly except F1.

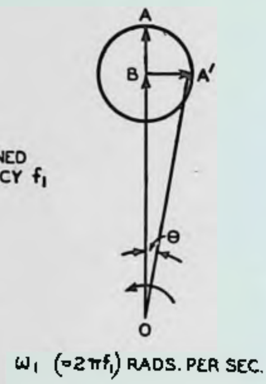


FIG. 6b—Effect of Imperfect Transmission of One Component Frequency.

The maximum ratio which can be tolerated between the magnitude of BA and the double amplitude peak magnitude of the received picture signal can be determined by tests in which a varying proportion of the frequency f_1 is superimposed on the picture signal and the visible effects noted. (This is dealt with again later in considering signal-to-noise ratio). *Fig. 7* shows the results of tests made to determine the maximum visible and the maximum tolerable values of this ratio for various interfering frequencies on the British standard transmissions, and is referred to in detail later.

The maximum ratio which can be tolerated between the magnitude of BA and the magnitude of OB will, obviously, also depend on the ratio of the magnitude of OB to the double amplitude peak magnitude of the received picture signal. This will depend on the nature of the picture and the frequency f_1. The most difficult type of picture to transmit probably consists of alternate vertical black and white bars, and the frequency spectrum of the signal produced by scanning this type of picture has already been examined. In this picture the ratio of the magnitude of the fundamental component (neglecting the synchronising pulses) to the double amplitude peak magnitude of the picture signal is $-3{\cdot}9$ db. If the fundamental frequency is less than about 500 kc/s it then appears from the results indicated in *Fig. 7* that the maximum tolerable ratio of BA to OB at this fundamental frequency will be about 0·03 or -30 db., and the maximum phase angle θ (see *Fig. 6b*) about 2°. At 2,000 kc/s, however, the ratio could be 0·45 or $-$ 7 db., and the angle θ, 24°. On this basis, therefore, it would appear that the attenuation of the circuit must be constant within $\pm$ 0·3 db. at frequencies up to about 500 kc/s, and that above this frequency the attenuation may depart from the average value below 500 kc/s by an increasing amount up to about $\pm$ 3·2 db. at 2,000 kc/s. In addition the phase angle must be linear to within $\pm$ 2° at all frequencies up to 500 kc/s, and above this frequency may show an increasing departure from linearity up to about $\pm$ 24° at 2,000 kc/s. In terms of phase delay these figures indicate the following approximate permissible variations from average phase delay at different frequencies.

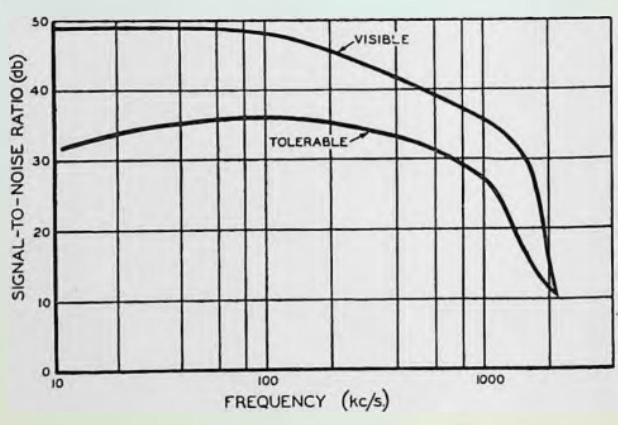


FIG. 7—Interfering Effect of Single Frequency Noise.

Frequency kc/s.	Permissible departure from average phase delay in micro-seconds
10	± 0·55
20	± 0·28
50	± 0·11
100	± 0·05
250	± 0·02
500	± 0·01
1,000	± 0·02
2,000	± 0·03

It should be noted in connection with the above figures that the tolerable limits of interference at frequencies above 1,000 kc/s were probably too high, as the focus of the monitoring receiver employed in their determination was not perfect. The above figures have been based on the maximum tolerable relative level of single frequency interference and must be reduced by about 13 db., i.e., a ratio of 4·5 if the interfering effect of the imperfect transmission at frequency f_1 is to be imperceptible (see Table No. 1).

TABLE NO. 1.
THE INTERFERING EFFECT OF SINGLE FREQUENCY INTERFERENCE.

Frequency of interference (approx.) kc/s.	Signal/Noise Ratio (db.)	
	Visible	Tolerable
20·25	49	34
101	48	36
500	40	32
1,000	36	27
1,500	31	17
2,000	17	11 (See Note 1)

Note 1.—The tolerable level was largely determined by the general increase in brightness of the picture due to the presence of the noise, which suggests that the focus of the receiving tube was not good enough to make the effects of this frequency interference fully apparent.

EXAMINATION OF THE REQUIRED TRANSMISSION LIMITS FROM THE TRANSIENT POINT OF VIEW.

The problem of determining the required transmission limits can also be examined by considering the response of a circuit to a suddenly applied unit voltage. This response may be termed the "indicial transfer admittance." It appears that the following aspects of the indicial transfer admittance will have to be specified:—

(*a*) Build-up time,
(*b*) Overswing,
(*c*) Rate of decay of overswing.

Limits to these three factors can be imposed by requiring the indicial transfer admittance to lie within a shaded area such as that shown in *Fig. 10.*

For equal definition in the horizontal and vertical directions, the build-up time should be made equal to the time taken to scan a distance equal to the thickness of a line. The factor '*a*' in *Fig. 10* represents half the maximum permissible

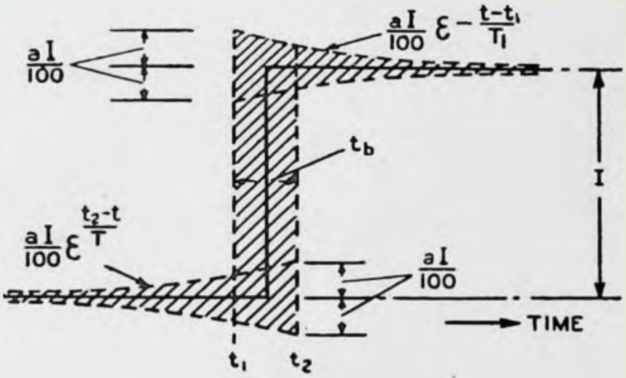


FIG. 10—Limits to the Indicial Transfer Admittance Function near the Build-up Period.

percentage change of brightness in a region of uniform brightness, and is probably of the order of 1—2. The rate of decay of overswing is expressed by the time constant T^1 in *Fig. 10.* The maximum permissible value of T^1 is difficult to specify, as it will depend on the rate of repetition of sudden changes from black to white and *vice versa.* It may be best to specify a maximum rate of repetition of these changes, and determine T^1 from that rate, but if this is necessary, it is doubtful whether the analysis of the response of the circuit to the unit impulse voltage is better than the analysis of its response to rectangular wave-form signals.

A number of methods exist whereby the amplitude and phase response of a circuit corresponding to a given time response can be determined. By analysing time responses lying within limits such as those suggested by *Fig. 10*, it may be possible to determine allowable limits for attenuation and phase response.

LIMITS REQUIRED IN THE SIGNAL-TO-NOISE RATIO.

Interfering noise usually falls in one of the following categories:—

(*a*) Thermal agitation noise or valve noise. The frequency spectrum of the former is uniform, and of the latter is also uniform above fairly low frequencies.

(*b*) Single frequency interference.

(*c*) Noise from impulse excitation, in which the duration of the pulses is small compared with their time separation.

The last form of noise will not normally be encountered in well-shielded line circuits, and it is not proposed to consider it here.

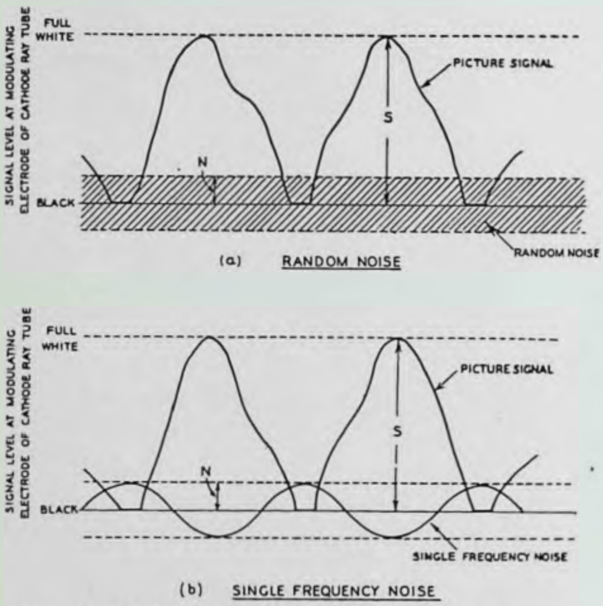


FIG. 13—Method of Expressing Signal Noise Ratio.

The signal/noise ratio is expressed as the ratiio of the double amplitude peak (D.A.P.) vision signal voltage to peak noise voltage. Referring to *Fig. 13*, the D.A.P. vision signal voltage is the magnitude S of the vision signal between black and full white, synchronising pulses being excluded. The peak noise level is the single amplitude peak value N.

The average results of a considerable number of tests made by several observers on a variety of different pictures were as follows:—

Visible signal/noise ratio = 35 db.
Tolerable signal/noise ratio = 28 db.

Tests were also made to determine the lowest level of noise visible on a uniformly illuminated raster[5] in the absence of a vision signal, the masking effect of the noise inherent in the vision signals previously employed being thus obviated. In order that the results should be comparable with those of the preceding tests, the noise level was expressed in relation to the level of the vision signal required to give a good picture on the particular cathode-ray tube used. The average value obtained for the signal/noise ratio at which the noise was just visible was 42 db.

Tests were carried out on the lines described above to determine the "visible" and "tolerable" signal/noise ratios for single frequency interference at frequencies from 20 kc/s to 2 Mc/s. The interference was found to be most objectionable at frequencies equal to, or close to, multiples of the line frequency. The pattern then consisted of vertical bars, alternately black and white, the number of pairs of bars in the width of the picture being equal to the ratio of the interfering frequency to the line frequency. The bar pattern was either stationary or drifting slowly across the picture.

The results for a series of such frequencies are given in Table No. 1 and *Fig. 7*. It will be seen that the signal/noise ratio at which the noise just became visible decreased from 49 db. to 17 db., and the tolerable signal/noise ratio from 34 db. to 11 db. as the frequency of the noise was increased from 20·25 kc/s to 2,000 kc/s. This reduction may have been partly due to imperfection of focus in the tube of the receiver used, partly to the greater masking effect of the existing random noise at the higher frequencies, and partly to the fact that the finer grain of the interference pattern at the higher frequencies makes it less visible at the normal viewing distance.

No tests were made to determine the level at which the single frequency interference became visible on a uniformly illuminated raster in the absence of signal. In view of the regular nature of the interference patterns, however, it is probable that the noise inherent in the vision signals had little masking effect at the lower frequencies.

Fechner's law states that the minimum perceptible percentage difference of brightness is nearly constant and equal to about 1—2 per cent. over a wide range of brightness. A minimum perceptible percentage difference of brightness of 1 per cent. would mean that the ratio of the double amplitude peak magnitude of the signal

[5] The series of illuminated lines produced on a screen when scanning with an electron beam.

to the peak magnitude of the noise at which the noise was just visible would be 46 db. This figure is in good agreement with the average figure of 46 db. obtained experimentally with single frequency interference having a frequency up to 500 kc/s.

OVERALL GAIN STABILITY.

As already stated, the minimum perceptible percentage change of brightness is nearly constant over a wide range of brightness and equal to about 1-2 per cent., corresponding to a db. ratio of 0·1—0·2 db. The maximum tolerable change of brightness is probably of the order of $\pm$ 1 db., but it is thought that a brightness stability of $\pm$ 0·5 db. is desirable and perhaps closer than this if the gain changes are fairly rapid. The permissible figures of gain stability will depend on whether the black level is fixed in the receiver (e.g., by D.C. restoration from the black level), or whether the bottom of the synchronising pulses is the fixed level, as is normal at present, when a gain stability better than $\pm$ 0·5 db. is probably essential for a good service. Experiments to determine these limits more definitely are obviously desirable.

NON-LINEAR DISTORTION.

A fair amount of effective non-linear distortion occurs in the normal cathode-ray television receiver due to the non-linear relation between spot brightness and modulator grid bias. This distortion is usually such as to increase the light parts of the picture relative to the darker parts, and it has been stated that this is desirable with small pictures owing to the fact that the contrast sensitivity of the eye is reduced by a reduction in the size of the field of vision.

In a line transmission circuit non-linear distortion would generally be opposite to this, i.e., such as to decrease the relative brightness of the light part of the picture. If the synchronising signals are transmitted with the picture signal, and D.C. modulation is not employed, then the necessary limits of non-linear distortion will be much closer than they would be if D.C. modulation were employed, because non-linear distortion would result in changing amplitude of the synchronising pulses and also changing brightness in fixed parts of moving pictures. Changing amplitude of synchronising pulses is very undesirable if the bottoms of the pulses are to be employed for D.C. restoration in the receiver, although this difficulty could be overcome in a line circuit by D.C. restoration at the receiving end of the line from the black portion of the signal following the line synchronising pulse, the lengths of the synchronising pulses being levelled in a subsequent correcting circuit.

No definite figures are known for the non-linear distortion permissible in the overall circuit. It would probably be best to define limits for this overall non-linear distortion of the system by defining graphically limits to the output versus input voltage characteristic.

So far only the non-linear distortion of a direct transmission circuit has been considered, in which the input video signals occupy the same position in the frequency spectrum throughout the transmission. In a coaxial cable system, however, the input video frequency band is raised, and sometimes inverted. The line transmiission and the modulating and demodulating processes at the transmitting and receiving ends of the line may result in components appearing in the final output video signal with frequencies which were not present in the original signal and which do not bear a harmonic relation to the latter frequencies. These unwanted products will have the same effect as noise on the picture and they must be considered as part of the total noise in the circuit. The limitations which must be applied to them are therefore the same as those outlined in connection with other types of noise, taking into account noise already existing from other sources.

CONCLUSIONS.

The conclusions arrived at so far regarding the desirable limitations to be imposed on the characteristics of television circuits will now be briefly summarised.

First, it is now clear that to obtain the same definition in the horizontal direction as in the vertical all frequencies must be transmitted without appreciable loss up to the frequency given by equation (1).

In the Marconi-E.M.I. system transmissions from Alexandra Palace this frequency was 2·88 Mc/s. A sharp cut-off at this frequency will lead to striæ following a black and whitei edge which may be visible at a distance where the lines can be distinguished, and a gradual cut-off above this frequency may be desirable in the ideal case.

Practical experience suggests that an attenuation response flat to within $\pm$ 0·5 db. up to at least 500 kc/s is desirable, although satisfaction appears to have been expressed with the results of line tests in other countries where the variation was of the order of twice this value. A great deal depends on the type of picture employed in testing, pictures containing sharply-defined black and white edges needing much better transmission conditions, particularly at higher frequencies, than pictures containing only gradual changes.

Apart from the direct experimental determination of the effect of various transmission conditions on picture quality, three indirect methods of assessing the allowable limits of the attenuation and phase response of the circuit have been examined.

A preliminary examination of a method based on the interfering effect of unwanted components introduced by attenuation and phase distortion suggests that the attenuation should be kept flat to within ± 0·3 db. at frequencies up to 500 kc/s, and above this frequency may be allowed to depart by an increasing amount up to about ± 3·2 db. at 2,000 kc/s. On the same basis the phase shift must be kept linear to within ± 2° at all frequencies up to 500 kc/s, and above this frequency may show an increasing departure from linearity up to about ± 24° at 2,000 kc/s. These limits must be divided by about 4 if the circuit is to show no perceptible picture distortion for any type of picture.

A preliminary examination of a second method of determining the necessary limits of attenuation and phase response has also been made depending on the response of the circuit to signals of rectangular waveform. Limits to the shape of the received waveform should be based on build-up time at black and white edges and the maximum tolerable percentage brightness difference in regions which should be of uniform brightness. It is suggested that in order to obtain equivalent definition in the horizontal and vertical directions the build-up time must not exceed the time taken to scan a distance equal to the thickness of a line. The maximum tolerable percentage brightness difference in regions which should be of uniform brightness is probably about 3-5 per cent., this figure being based on the interfering effect of single frequency interference.

By harmonic analysis of received waveforms lying within these limits it may be possible to prescribe limits of attenuation and phase response of the circuit, but difficulties may arise here as mentioned below.

The subject has also been studied from the point of view of the transient response of the circuit to a suddenly applied voltage, and it has been shown how limits can be applied to the response characteristic, based, as in the second method, on build-up time and maximum tolerable percentage brightness difference in regions which should be of uniform brightness. Unfortunately, a third limit must be placed on the transient response characteristic, namely, the rate of decay of overswing. It appears that this can only be determined from a knowledge of the rate of repetition of black and white edges in the picture.

It has been shown how the limits of attenuation and phase response might be determined from the limits of the transient response characteristic, but difficulties may arise here. It appears that limitations in simple form may only be applicable strictly to the response to square waveform signals, or the transient response, and that it may not be possible to apply them strictly to attenuation and phase response.

In all these methods of determining the permissible limits in the attenuation and phase response of the circuit, pictures have been considered involving sharp black and white edges, and on this account the limits derived from them may be closer than those which are necessary in pictures involving few sharp changes in brightness.

Limits to the minimum signal to noise ratio permissible with either random noise or single frequency noise have been determined experimentally. The ratio of the double amplitude peak signal level (excluding synchronising pulses) to the peak noise level at which the noise is just perceptible in the absence of other noise is about 42 db. for random noise and about 49 db. for single frequency noise of frequencies below 500 kc/s, and decreasing for higher frequencies. Both types of noise can be raised about 14 db. above these respective levels before becoming intolerable.

It is suggested that overall gain stability of at least ± 0·5 db. is necessary, and better than this if D.C. modulation is not employed, or D.C. restoration carried out from the black level.

Limits of non-linear distortion in circuits not employing any frequency translation should be defined graphically. Where frequency translation occurs, components at frequencies not present in the original signal may be produced, and these must be regarded as additional noise in the picture.

It is now clear that the limitations which must be applied to a television circuit are much closer than those necessary in a telephony or music circuit. In transmission of music the first essential is that the output frequencies shall be the same as the input frequencies, and that no additional frequencies of appreciable magnitude shall be introduced. Providing these limitations are met no discords are possible, and fairly wide variations (of the order of ± 3 db.) in the attenuation response of the system are permissible without appreciable effect on the results. Considerable variations may occur, for instance, due to room reflections in the room when the music is reproduced. In addition, the phase response of the system is of little importance for music transmission. For television signals, however, not only must the output frequencies be exactly equal to the input frequencies, but the variation of the amplitude of the output signal with time must be closely proportional to the variation of the input signal with time, as the eye is able to perceive brightness differences as low as 1 per cent. The result of this is that very close limits of both attenuation and phase response are necessary in a television circuit, in addition to the fact that the frequency band-width required for reasonable definition is about 250 times as great as that required in a good music circuit. Even from the present rather scanty data on this subject it is now clear that very close transmission limits are essential in a television circuit if the result is to be comparable with present cinema standards.

The difficulties in obtaining such close limits with existing components and technique, especially on long circuits, will mean that the future development of television will depend to a considerable extent on the development of new types of valves and, perhaps, also on the development of the technique of the use of the very high radio frequencies.

THE EFFECT OF NOISE AND INTERFERING SIGNALS ON TELEVISION TRANSMISSION

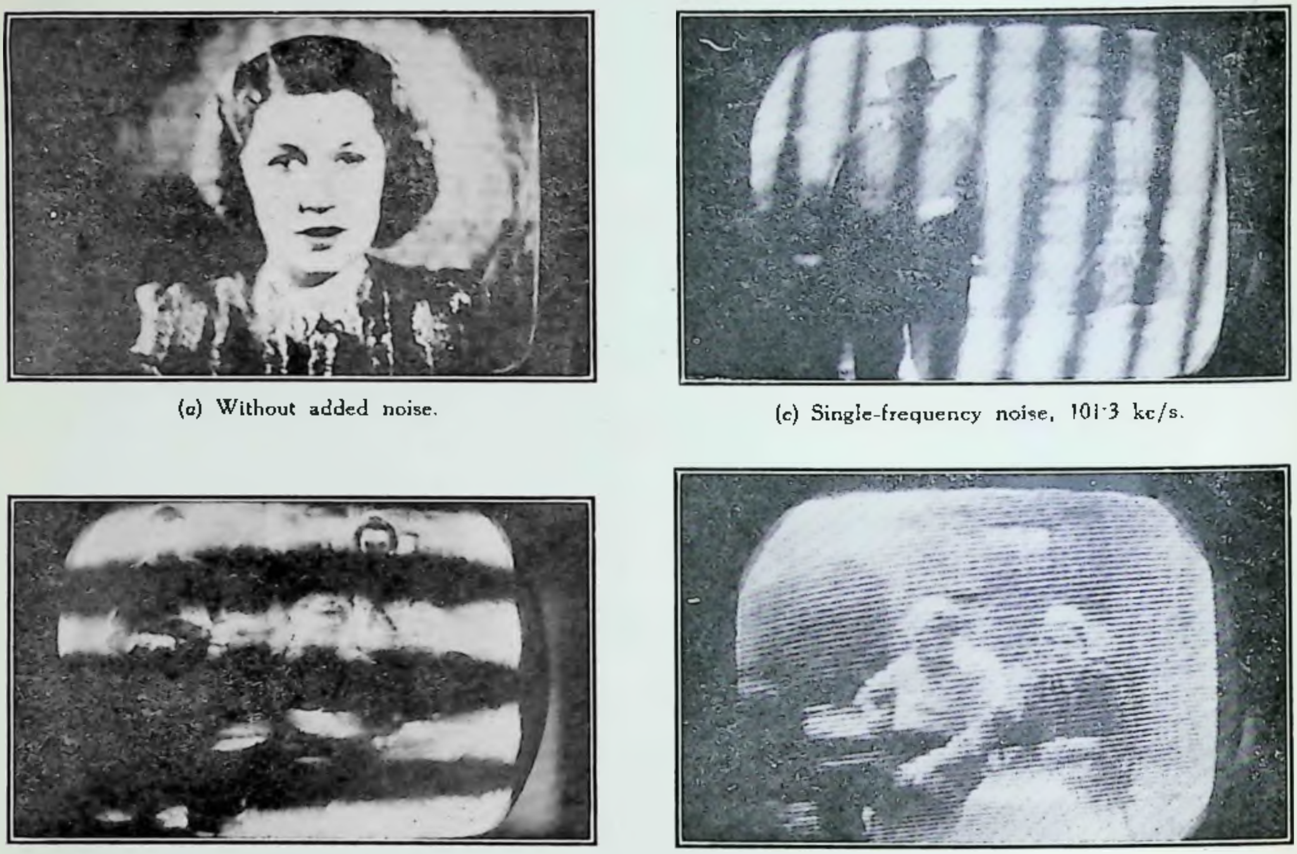
Reprinted, by permission, in abstract from The Post Office Electrical Engineers' Journal, Vol. 32, Part 3, 1939.

By R. F. J. JARVIS, Ph.D. and E. C. H. SEAMAN, B.Sc.

This article indicates the effects of various types of electrical "noise" on television reproduction, and describes tests to determine the minimum satisfactory signal/noise ratio for television transmission.

INTRODUCTION.

A stationary flat picture, or scene projected on a flat surface, may be regarded as a variation of brightness in two dimensions. If the picture is scanned by a spot of light moving in such a manner as to cover all points in the picture at regular intervals, the light reflected or transmitted by the picture being scanned can be converted into an electrical current proportional to the instantaneous magnitude of the reflected or transmitted light. Then if a spot of light at the receiving end is moved in synchronism with the transmitting spot, and the intensity of this light at any instant is varied proportionally to the value of the transmitted current at that instant, the picture will be reproduced at the receiving end, providing the rate of scanning is fast enough to enable the eye to see the receiving spot at all positions simultaneously by reason of the effect of persistence of vision. The picture is usually scanned in horizontal lines and it is more usual now to scan an electrical image of the transmitted picture with an electron beam, rather than scan the actual picture with a light beam, but the connection between the brightness in the picture and the electrical current transmitted remains the same. It is necessary to keep the scanning spot at the receiver in synchronism with that at the transmitter by suitable synchronising signals transmitted on the same path as the vision signal or on an independent path.



(*a*) Without added noise.

(*c*) Single-frequency noise, 101·3 kc/s.

(*b*) Single-frequency noise, 200 c/s.

(*d*) Single-frequency noise, 100·5 kc/s.

FIG. 1—Photographs of Screen of Television Receiver, showing Effects of Noise.

It is necessary to appreciate this fundamental connection between the brightness in the different parts of the transmitted and received pictures and the variation of transmitted current with time, in order to understand the effects of interfering signals on the received picture. Such interfering signals may be produced in the transmission path, or be picked up from outside. The instantaneous value of the total interfering current adds to the instantaneous value of the television signal current so that the brightness of the receiver spot at this instant is modified in accordance with this addition. The interfering current by itself, if of sufficient magnitude, produces a variation of brightness over the area of the received picture which appears as a series of spots or pattern, as described later, and when the television signal is added the desired picture is seen with this interference superimposed.

With sound transmission the disturbing signals are termed "noise," and the same term is generally used for disturbances present in television signals, although their effect is, of course, visual. The most important types of noise are:

(*a*) Random noise, having a uniform energy frequency spectrum. This is produced by thermal agitation and valve noise.

(*b*) Noise consisting of sharp transients produced at regular or irregular intervals. The most important type of this noise is that due to ignition systems.

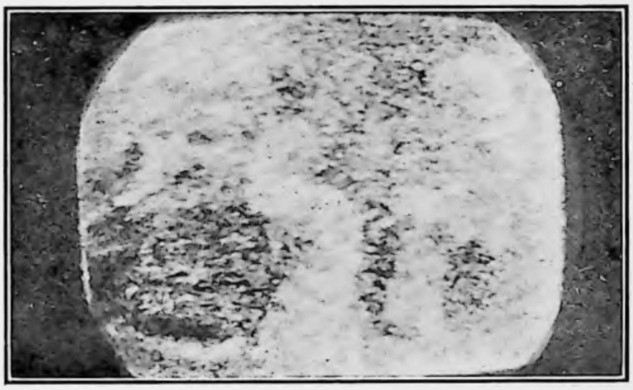
(*c*) Single frequency noise produced by interference from outside transmitters or set up in frequency translation processes.

It is proposed only to deal with the first and third types in this article, although the general conclusions will apply also to the second.

(e) Single-frequency noise, 500 kc/s approximately, bar pattern.

(f) Single-frequency noise, 500 kc/s approximately mash pattern.

(g) Random noise, low level.



(h) Random noise, high level.

FIG. 1—Photographs of Screen of Television Receiver, showing Effects of Noise.

EFFECTS OF NOISE ON TELEVISION REPRODUCTION.

As explained above, noise superimposed on a television signal causes an unwanted variation in brightness of the light-spot in the receiver, and if the noise level is sufficiently high the reproduced picture is marred by an irregular background, random white spots, or a superimposed pattern, the effect depending on the nature of the noise. The presence of noise also alters the shape of the synchonising pulses, so that relative displacement of successive lines in the picture occurs and the picture detail is distorted; interlacing is also impaired. If the noise level is very high the receiver may lose synchronism entirely, but noise which is just sufficient to produce an objectionable effect on the appearance of the picture is not generally sufficient to cause complete loss of synchronism.

The effects of different types of noise are more fully described below, and are illustrated by photographs of the screen of a television receiver taken during the reception of a B.B.C. programme, with noise superimposed on the received signal.

Effect of Random Noise.—When random noise is present at such a level that it is just visible on the picture, its effect is to produce a fine irregularity of the background illumination. (*Fig. 1 (g)*). At higher levels it results in the appearance of numerous white spots, occurring irregularly in position and time, which may entirely obscure the picture detail. (*Fig. 1 (h)*).

Effect of Single-frequency Noise.—When single-frequency noise is present, a sinusoidal voltage variation is superimposed on the signal which controls the brightness of the light-spot in the receiver. The brightness of the spot is increased during the positive half-cycles of the noise and decreased during the negative half-cycles, and a pattern appears superimposed on the reproduced picture. The nature of this pattern depends on the relation of the noise frequency to the line, frame, and picture scanning frequencies, i.e., the number of lines, frames, and complete pictures respectively scanned per second. It is convenient to consider two cases:

(*a*) Noise frequency lower than line frequency.

(*b*) Noise frequency higher than line frequency.

If the noise frequency is much lower than the line frequency, so that a number of lines are scanned in the duration of one cycle of noise, there is no appreciable variation of brightness in the horizontal direction. The noise causes a variation of brightness in the vertical direction, and if the noise frequency is an integral multiple of the frame frequency, a stationary pattern consisting of horizontal bars alternately dark and light is produced, the number of pairs of bars being equal to the ratio of noise frequency to the frame frequency. (*Fig. 1* (*b*)). If the noise frequency is not an integral multiple of the frame frequency, there is a horizontal bar pattern which appears to move vertically, or a general flicker effect.

If the noise frequency is lower than the line frequency but not very low compared with the latter, the patterns are more complicated on account of variation of brightness across individual lines; the effect is generally one of sloping dark and light bars. When the noise frequency is higher than the line frequency, if the noise frequency is an integral multiple of the line frequency, a stationary pattern consisting of vertical bars alternately dark and light is produced, the number of pairs of bars being equal to the ratio of noise frequency to line frequency. (*Figs. 1* (*c*) and *1* (*e*)). If this relation does not hold, but the noise frequency is an integral multiple of the frame frequency, a stationary pattern consisting of sloping bars is produced. (*Fig. 1* (*d*)). With a noise frequency not an integral multiple of the frame frequency, there is a bar pattern which appears to move across the picture, or a general flicker or mesh effect. (*Fig. 1* (*f*)).

SIGNAL/NOISE RATIOS.

In the reception of the B.B.C. television transmissions from the studio at Alexandra Palace, even under conditions of freedom from interference, the picture has a slight irregularity of background illumination. This is due to random noise which arises in the cameras and circuits at the transmitting station and in the receiver. For the design of a complete television system it is necessary to consider how far noise from these sources reduces the picture quality obtainable with a given number of scanning lines and frequency band-width; this question is, however, outside the scope of the present article, in which such noise will be regarded as "inherent" in the television signals.

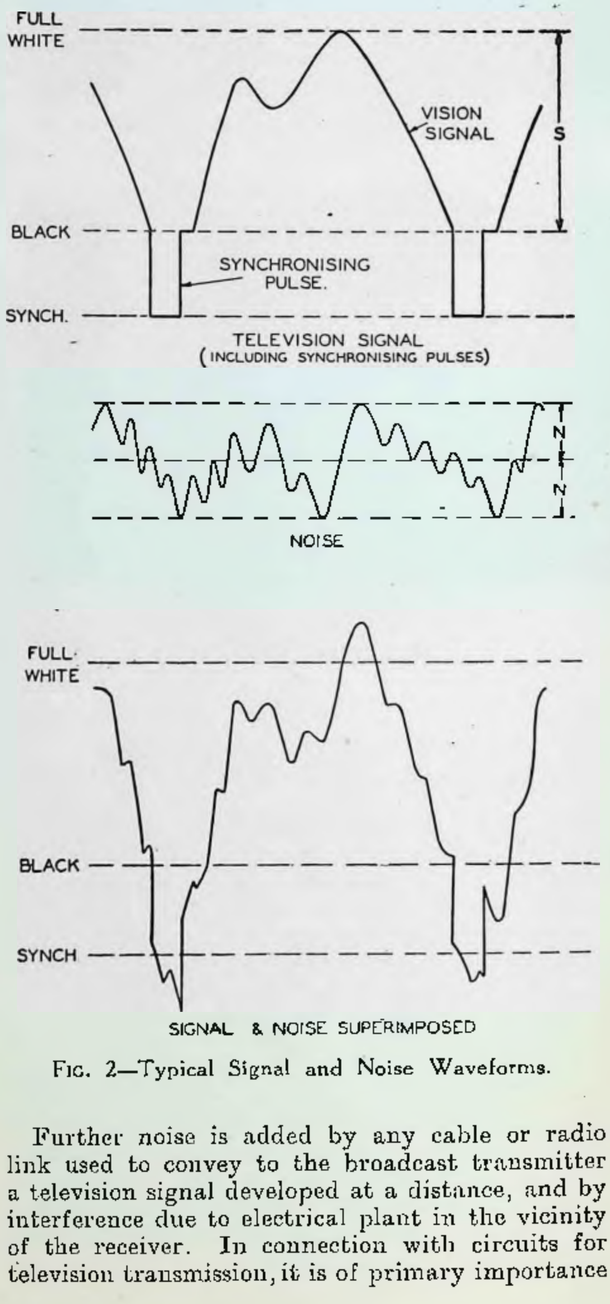


FIG. 2—Typical Signal and Noise Waveforms.

Further noise is added by any cable or radio link used to convey to the broadcast transmitter a television signal developed at a distance, and by interference due to electrical plant in the vicinity of the receiver. In connection with circuits for television transmission, it is of primary importance to decide the highest permissible level, relative to the signal, of such additional noise; to this end a series of tests has been carried out in the Post Office Television Laboratory. The tests consisted in mixing additional noise with a vision signal having a normal amount of inherent noise, and determining by observation of the picture:

(a) the level relative to the signal at which the added noise just became visible against the background of inherent noise, giving the "Visible Signal/Noise Ratio";

(b) the highest level of noise relative to signal that could be tolerated without serious deterioration of the quality of the received picture, or undue irritation to the observer, giving the "Tolerable Signal/Noise Ratio";

As these relations are subjective, readings were taken by a number of different observers, and the average calculated.

The signal/noise ratio is expressed as the ratio of the double amplitude peak (D.A.P.) vision signal voltage to the peak noise voltage. Referring to *Fig. 2*, the D.A.P. vision signal voltage is the magnitude S of the vision signal between black and full white, synchronising pulses being excluded. The peak noise voltage is the single amplitude peak value N.

CONCLUSIONS.

As was to be anticipated from the nature of the observations, there was a large variation between the signal/noise ratios assessed by different observers, but the averages for all observers did not vary greatly on different pictures, and there was good agreement between the average results of tests on pictures obtained from a film-scanning transmitter and from the B.B.C. transmissions.

On the basis of the average results, it is concluded that added random noise is just visible on the picture at a signal/noise ratio of the order of 35 db., and that a signal/noise ratio lower than about 28 db. cannot be tolerated. It appears that, on a picture having no inherent noise, random noise would be just visible at a signal/noise ratio of about 40 db.; further investigation of this aspect would, however, be desirable before definite conclusions were drawn.

The effect of single-frequency noise was found to vary considerably according to the type of pattern produced, and for frequencies of the same order was much more serious when the frequency was an exact multiple of the line frequency, so that a stationary vertical bar pattern was produced. With a given type of pattern, the interfering effect decreased as the noise frequency was raised; the very low values of signal/noise ratio obtained at the highest frequencies may, however, have been partly due to lack of definition in the monitor employed. It is concluded that, for single-frequency noise in the range 20 kc/s to 2 Mc/s, the interfering effect is greatest when the noise frequency is a small integral multiple of the line frequency. For such noise frequencies, added single-frequency noise is just visible on the picture at a signal/noise ratio of the order of 50 db., and a signal/noise ratio lower than about 35 db. cannot be tolerated. No tests were made at frequencies lower than 20 kc/s, but as the visual effects would be similar, it appears reasonable to assume that the same figures would apply with lower frequencies such as to give distinct bar patterns.

It will be appreciated from these results that single-frequency interference is, in general, more objectionable than random interference, as the bar pattern produced by the former is more noticeable than the moving spots produced by the latter, for a given intensity.

The level at which interfering signals first become visible is clearly directly related to the minimum perceptible percentage difference of brightness. It has previously been found that this is nearly independent of brightness over a wide range of brightness, and is of the order of 1-2 per cent. For a figure of 1 per cent. the interfering signal would just become visible at a signal/noise ratio, as measured in the experiments described in this article, of 46 db., which corresponds approximately with the level at which single-frequency interference just became visible in these tests.

Another important feature which these results indicate is the comparatively small difference of only about 12-14 db. in the level of noise which is just visible in the absence of all other noise, and the level of noise which is intolerable. Although this is, in some respects, a useful feature, the importance of it must not be overlooked when connecting a number of links of a television circuit in tandem, for while the noise in each individual link may just be invisible, the noise on the overall circuit may become intolerable.

CATHODOLUMINESCENCE AS APPLIED TO TELEVISION

By H. W. LEVERENZ (R.C.A. Mfg. Co., U.S.A.)

Abstracted from the R.C.A. Review, Vol. 5, No. 2, October, 1940.

SUMMARY—A review including some hitherto unpublished data from the R.C.A. Laboratories. The constitutions and syntheses of the better known phosphors are outlined and a simplified theoretical mechanism of phosphor luminescence is discusssed. There are eight important qualities which should be possessed by phosphors for kinescope use.

These are: Ease of application; Ease of degassing; Secondary emission ratio at least unity; stability; quality of emission spectra; brilliancy and efficiency; phosphoresence.

Restriction or over-emphasis of any one phosphor quality, e.g. phosphorescence, would automatically eliminate most of the phosphors which are excellent in all eight qualities. The choice of 30 pictures per second for the repetition rate is shown to be a minimum below which serious disadvantages occur.

With the inception of electronic television, approximately eleven years ago, an urgent need was felt for greatly increasing the capabilities of luminescent materials used in television cathode ray tubes. The first researchers had but two phosphors sufficienty efficient for television purposes: (1) zinc sulphide, and (2) willemite, a zinc silicate mineral containing about 1% of manganese silicate. Willemite was first discovered in 1830 and named after King Willem I of the Netherlands. Both phosphors emitted preponderantly green light, giving early television viewers considerably æsthetic dissatisfaction with the reproduced images.

There were many more objectionable features about the phosphors known at the outset of electronic television; serious disadvantages such as poor secondary emission, further reduction of initially low efficiencies when the materials were ground and processed for kinescope application, and a restricted choice of green colours. However, since better phosphors were vital to electronic television, which has the inherent advantage of practically inertialess picture scanning, extensive research was instigated in the R.C.A. Manufacturing Co., Inc., under the sponsorship of Dr. V. K. Zworykin, to determine the possibilities of improving phosphors for use in kinescopes.

Since sulphides have been originally discovered and developed abroad, European luminescent researchers concentrated mainly on sulphide phosphors. American researchers, because of their use of the naturally-occurring mineral phosphor, willemite, followed by use of the improved synthetic willemite, favoured the oxygen-containing phosphors, especially since oxide phosphors are inherently more rugged than sulphides or selenides.

An important product of R.C.A.'s television-luminescence research is the zinc beryllium silicate phosphor system, which is a major component of the light-emitting coatings used in the new highly-efficient tubular luminescent lamps (usually called "fluorescent" lamps, despite the need for a considerable phosphorescence in order to minimise flicker). The luminescent art is commencing to expand into the ultra-violet and infra-red regions of the spectrum and should employ the unique advantages of the high efficiencies of the phosphors, and their easily controllable emission spectra in those invisible radiation ranges.

It should be mentioned that, despite unusually favourable conditions for synthesising luminescent materials, exact reproduction of phosphors is still difficult. Phosphors are both impurity- and structure-sensitive materials. The addition or subtraction of as little as 0·0001% (one part in a million) of a foreign substance can alter some phosphors' properties by 50-100%. Maintaining identical chemical composition, but changing crystal structure by polymorphic transitions also produces equally pronounced changes in some phosphors' characteristics. In general, the best phosphors have a relatively colourless bulk crystal, which is of the excess-cation type of a high-temperature semi-conductor and contains a very small concentration of a salt of some easily polarisable multivalent element.

Synthesis of phosphors is chiefly chemical work. Obviously, the best available analytical reagent chemicals are much too impure for use in phosphors. Therefore, the chemist must further purify the substances used, add the tiny quantities of activator and perhaps a flux to assist in crystallising the phosphor. The intimate mixture must then be skilfully heated to produce the crystal size and modification having greatest efficiency and ease of application in cathode ray tubes. It is especially remarkable and, from the chemist's standpoint, aggravating, that the limits of chemical purification processes coincide with the order of magnitude of activator impurity usually necessary in efficient phosphors or the magnitude of the "poisoning element" detrimental to phosphors. The coincidence occurs in the range of 10^{-3} to 10^{-8} part of activator, or impurity, to one part of bulk crystal. The syntheses of phosphors are typified by the two following examples:

A — Synthesis of blue-emitting zinc sulphide phosphor.

Purify zinc sulphate ($ZnSO_4$) by conventional chemical methods until no spectrographically detectable impurities remain. Electrolyse the aqueous zinc sulphate solution to remove any copper, manganese, and lead which the spectrograph may not have indicated. Precipitate pure zinc sulphide with well-washed hydrogen suphide, and wash the precipitate. $ZnSO_4 + H_2S = ZnS + H_2SO_4$. Add sufficient solution of a silver salt to equal a silver concentration of 0·01% of the weight of the zinc sulphide and further add sufficient sodium or potassium chlorides (in aqueous solution) to equal 2% of the weight of the zinc sulphide. Stir well, while evaporating to dryness and heat in a quartz crucible at 800-1500°C. The time and temperature of heating may be adjusted to determine the phosphor's particle size and form. The resultant phosphor is symbolised by $ZnS{:}Ag$; since the alkali halide reacts with the zinc sulphide to form volatile zinc chloride and soluble alkali sulphide which are moved during heating and subsequent elutriation. Cadmium sulphide may be substituted in part for the zinc sulphide to alter the phosphor's spectral emission over the entire visible spectrum and into the infra red.

B — Synthesis of yellow-green emitting zinc beryllium silicate phosphor.

Zinc and beryllium nitrates ($Zn(NO_3)_2$) and $Be(NO_3)_2$) are purified and mixed in aqueous solution such that the ratio of zinc to beryllium is approximately nine to one on a gram-molecular-weight (mole, or molar) basis. Approximately 0·006 mole of pure manganese nitrate ($Mn(NO_3)_2$) is added per mole of zinc plus beryllium. Very pure, finely divided silica (SiO_2), such as collodial silica or a substance such as an organic silicate is added to the nitrate solution and the carbonates of zinc, beryllium and manganese precipitated around the silica by adding ammonium carbonate. The amount of silica added may be exactly ortho-proportion or up to several hundred per cent. over ortho-proportion. "Ortho-proportion" is two moles of (zinc plus beryllium) to one mole of silica. Stir and evaporate to dryness and heat in a clean platinum crucible at 900-1600°C, depending on the degree of chemical combination, crystal type and size required. A shorthand notation for the finished phosphor is $ZiO_u{:}BeO_v{:}SiO_{2w}{:}Mn$. In this example, $u/v \doteqdot 9$ and $w \geq (u+v)/2$, but u, v, w, and the Mn concentration may be varied to produce a wide variety of emission colours and other phosphor characteristics. Mechanical mixtures of certain blue-emitting and yellow-emitting phosphors, prepared as described in *A* and *B* will give a resultant white light under cathode-ray excitation.[1]

THEORIES OF PHOSPHOR LUMINESCENCE.

There is no theory of luminescence adequate to explain quantitatively all the properties of known phosphors or to predict the properties of new phosphors.

A crude description of the modus operandi of a phosphor is the following: Imagine a three-dimensional lattice-work of elastic bands joining together a regular array of identical bells. This corresponds to the basic crystal of a phosphor. Dispersed at regular intervals throughout the ordered structure, in a concentration of one to a thousand, there are much smaller bells substituted for, or suspended between, bells of the main bell network. These smaller bells are the activator centres. It is apparent that considerably less force will be required to cause the smaller bells to sound than the larger bells. It is also apparent that the smaller bells may be rung by either direct application of energy or by receiving energy which has been trans-shipped through the elastic bands after being absorbed by some larger unit. The reason for the greater luminescent efficiency of the crystalline state versus the amorphous state is deducible from the model. Energy transfer through elastic bands having widely varied degrees of tension would be short-lived because the different bands would not pass the same frequencies.

The absorption of energy and re-emission of sound entirely by a single small bell represents fluorescence. Absorption of energy by any unit of the lattice-work with subsequent transmittal to a small bell, possibly far removed, which emits the eventual sound represents phosphorescence. The distinction between the two luminescence acts is

1 H. W. Leverenz, *J. Opt. Soc., Am.*, 30, 7, 1940, p. 309,

seen to be primarily one of localisation versus decentralisation and of time required for energy transport. Vigorous jangling of the entire structure would cause the main lattice bells to sound and disturb the more sensitive efficiencies of the smaller bells. The model thus portrays the effect of incandescence in phosphors. Unfortunately, the bell model fails in several respects in simulating the operation of an actual phosphor. For example, it allows high-amplitude, low-frequency vibration to ring the small bells, which emit higher frequencies than were possessed by the exciting energy. This is opposite to phosphor action as expressed in Stoke's law, "The emitted light is of a longer wave-length than the exciting radiation." Since frequency v, wavelength λ, and speed of propagation c are related by $c=\lambda v$, it is seen that the bell model violates Stoke's law by absorbing low frequency long wave-length energy and emitting high-frequency, short wavelength sound. Exceptions to Stoke's law are unimportantly rare.

Foreign elements, such as iron, nickel, etc., previously classified as phosphor poisons are deleterious by virtue of: (1) occupying positions which might otherwise be advantageously occupied by the luminescence activator units, (2) absorbing energy and then emitting radiation in an invisible (viz.: ultra-violet or infra-red) region of the spectrum, and (3) decreasing phosphorescence by absorbing trans-shipped energy more readily than the luminescence centres and thus destructively diminishing the amount of potential energy stored in the phosphor crystal. Use of more than one activator in a phosphor fails to increase efficiency, since each activator is ocupying position which might be used by the other.

Pure, presumably unactivated, crystals also luminesce. In fact, under cathode ray bombardment all materials luminesce. The luminescence emission spectra of several pure crystallised sulphides and silicates are shown in *Fig. 1* contrasted with activated phosphors of the same substances. The ordinate scales of the various curves, including those of the same phosphor (activated and unactivated) are not drawn to relative scale.

Hitherto unpublished results, obtained in the R.C.A. laboratories, show the spectrum emission of pure SiO_2 (crystallised at 1300°C) to be located at approximately the same ultra violet region as that of the pure silicate (crystallised at 1100-1300°C) of zinc, magnesium, calcium, cadmium, strontium and barium. In the foregoing pure-substance phosphors the emission mechanism is thus determined by the SiO bond in the crystal lattice while the metal cation (*Zn, Mg, Ca, Cd, Sr* or *Ba*) has very little effect. This result is interesting, in that it is quite the opposite of the case for the same silicates activated with manganese. The manganese activator is therefore associated with the cation lattice positions whereas the pure crystal's emission centres are located in the Si-O_x radicals or chains.

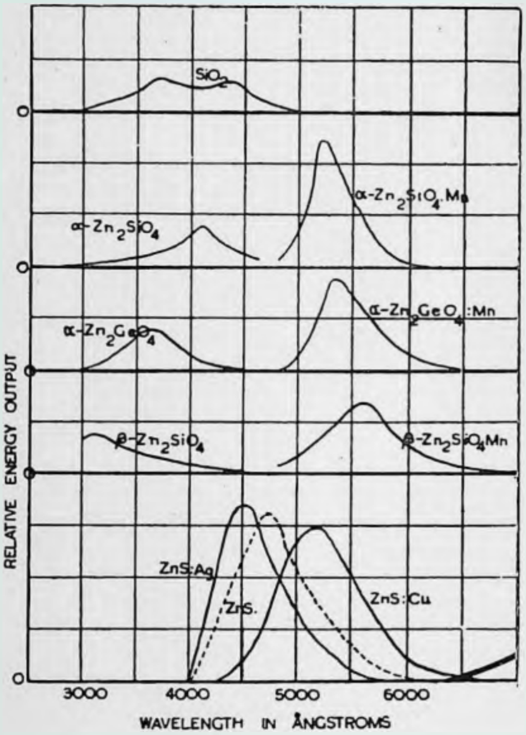


FIG. 1—Emission spectra of activated and unactivated phosphors.

Pure, unactivated β-zinc silicate, which is formed by quenching molten zinc silicate, has its emission spectrum located at shorter wavelengths than that of the normal unactivated α-zinc silicate. Similarly, the emission spectrum of unactivated α-zinc germanate is at shorter wavelengths than that of a pure α-zinc silicate. However, the emission spectra of manganese-activated β-zinc silicate and α-zinc germanate are located at longer wave-lengths than that of α-zinc silicate. The spectrum shifts of the activated compared with the unactivated materials are seen to be in opposite directions. Evidently the binding forces of the luminescent-active optical electrons associated with the SiO_x groups are increased by expanding the lattice from α- to β-zinc silicate and similarly by expanding the lattice through substitution of germanium for silicon. It appears from these results that valuable information regarding strengths of crystal lattice bonds and their directivities may be gained by further studies of the emission spectra of cathode ray excited substances.

PHOSPHOR PROPERTIES and APPLICATION OF PHOSPHORS IN T.C.R. TUBES.

Good phosphors must meet numerous requirements for use in T.C.R. tubes. The necessary qualifications may be divided into two groups according to whether they are: (1) objective (independent of the seeing act), or (2) subjective (directly related to the processes of seeing).

A—Objective Qualities.

(1) Ease of applying phosphors to form T.C.R. tube screens. This subject has been given considerable discussion elsewhere.[2] The chief objective from the phosphor standpoint is to produce a non-aggregated, smooth-flowing phosphor powder having a narrowly limited crystal size whose average magnitude is best suited for the method of screen application, provides good screen adherence and gives sufficient screen contrast. The crystal size is best controlled by the crystallisation process, since grinding of phosphors seriously reduces their efficiencies and stabilities. The table shows the effect of grinding an α-zinc silicate phosphor:—

Effect of grinding upon performance of α-Zn_2SiO_4:Mn.

Hours grinding.	Original efficiency.
0	100%
16	80%
24	66%
64	36%

Crystal size control is especially important in mix-phosphor screens, such as white-emitting Kinescope screens composed of the blue zinc sulphide and yellow zinc beryllium silicate phosphors described in the section on syntheses. If the particle sizes of the two phosphors are not substantially matched, the efficiency data on the two measured separately will not allow accurate computation of the relative proportions required for a good white screen. Instead, the resultant screen will emit a preponderant amount of light from the phosphor having the smaller particle size. This effect is illustrated by showing that most of the larger particles are deposited first in the settling method of screen application and that even if all the particles were deposited together, the impinging beam would encounter more small particles per unit volume on first entering the screen structure. Since the beam's energy is dissipated exponentially through the thickness of the screen, the light output per unit distance is greatest in the layers on the size of the impingement. Deviations of the composition of the entire layer will thus change the screen's emission colour.

The most efficient phosphors are materials which are also excellent catalysts in that they exhibit abnormally large absorbing surfaces. As an example, the quantities of copper ion absorbed by sphalerite ZnS from a dilute copper sulphate solution are equivalent to surface films many molecules thick. Since only monomolecular films have been found, the sphalerite crystals must have many crevasses or other irregularities providing inordinately large absorption area.

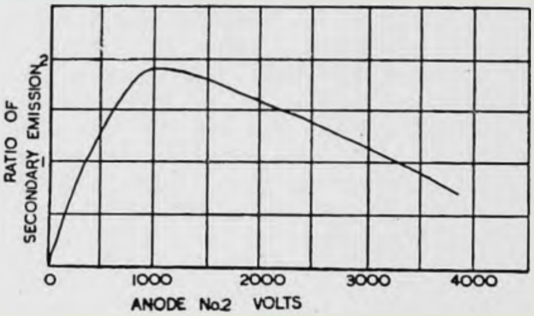


Fig. 2—Secondary emission characteristics of insulators.

In general, it is most advantageous to use phosphors synthesised from exceptionally pure ingredients which have been heated to very high temperatures in order to crystallise sufficiently to preclude the active, highly catalytic state prevalent at lower temperature heatings.

Phosphors are good insulators, usually having resistivities greater than most glasses (10^{12}–10^{16} ohm. cm. at room temperature). The negative charge imparted to the screen by the exciting electron beam cannot be dissipated effectively by conduction through the crystals to the accelerating-anode coating A_2 in the Kinescope, but must be maintained at a low value by emission of secondary electrons from the phosphor, S. The secondary electrons are attracted to the anode coating as long as the collector voltage is positive with respect to the phosphor crystals, or only slightly negative, within the voltage range corresponding to the emission velocities of the secondary electrons (0 to approximately $-10V$).

2 H. W. Leverenz, *Jour. Opt. Soc., Am.*, 27, 1, 1937, p. 25.

It is very important that a phosphor's secondary-emission ratio (ratio of emitted secondary electrons to incident primary electrons), be unity or greater for the particular voltage applied to the Kinescope. Should the ratio be less than unity, the potential on the screen will decrease with respect to the applied voltage until unity ratio is established or, failing to attain a ratio of unity or greater, the screen potential will fall to cathode potential so that no further current can reach the luminescent screen. *Fig. 2* shows a secondary emission curve representative of phosphors and insulators in general.

Both V^1, the applied voltage corresponding to the second unity-crossover of *Fig. 2*, and θ, the degree of departure from linearity of the screen potential beyond the limiting potential V^1, are greatly affected by extraneous influences such as Kinescope screen composition and thickness, residual gas, evaporated material from heated tube parts or getters, and deleterious effects of continued electron bombardment during tube life.

The quantitative influences of structure variations and changes in compositions of phosphors as affecting V^1 and θ, have yet to be investigated. With the use of higher voltages, over 20 kilovolts for projection Kinescopes, it becomes important to know more about possible means of increasing V^1 and decreasing θ without resorting to extraneous devices such as supplying a conducting coating under the phosphor screen.

B—Subjective qualities.

Emission spectra of phosphors. The eye is a very selective receiver of radiation, sensitive only in the narrow band of 38000–7200 Å (approximately one octave) with a maximum of 5560 Å. Phosphors intended for Kinescope use must have their emissions located well within the visible region and preferably near the wavelength of maximum visual response (5560 Å) if optimum efficiency is desired. Thus, many phosphors having very high efficiencies in the visually ineffective spectral regions are unsuitable for direct use in Kinescopes.

Decades of acquaintance with printed matter, photographic reproductions and the early motion pictures have installed a taste for black and white, or black versus some very pale colour, rather than black versus a strong hue such as yellow or green. Through centuries of experience the human eye has associated blue-white, viz., daylight, with high illumination levels (200–5000 foot lamberts) and yellow-white, viz., candlelight or incandescent lamps with considerably lower brightnesses (1–200 foot lamberts).[3] An ideal white light would probably comprise equal energy continuously spread over the entire visible spectrum, but the sensation of white may be produced by but two monochromatic emission lines paired in wavelength and relative energies.

Kinescope screens emitting white light are usually composed of mixtures of complementary blue-emitting and yellow-emitting phosphors, as shown in Figure. The blue-emitting zinc sulphide phosphor is very susceptible to contamination and easily acquires a green-emission band at the expense of, and in addition to its normal blue-emission if subjected to careless handling or abuse in tube processing. The resultant screens then luminesce very green instead of white. Thus Kinescope manufacturers sporadically rediscover and are plagued by green zinc sulphide, a phosphor first synthesised in 1886.

The occurrence of more than one band of emission from a material is indicative of the presence of more than one type of activating centre or else of more than one crystal form or chemical combining proportion.

Emission spectra of phosphors allow exceptional control and degree of variation and may, therefore, be practically "made to order." Characteristics of invariant optical media (viz., absorption filters) and spectral responses of photoelectric devices may be matched by phosphor spectral emission distributions for interesting applications such as in colour television.

BRILLIANCY AND EFFICIENCY OF PHOSPHORS.

Theoretically, enormous brilliancies could be produced with present type, fine crystal phosphor screens. The following general equation represents the maximum magnitude of luminescence energy output (E_{max}) disregarding the phosphor material, but assuming unlimited rate of energy input,

$$E_{max} = \frac{ZPE}{t} \quad \frac{ergs}{cm^2\ sec}$$

Z = optimum concentration of activator centres cm^3 ($\geq 10^{21}$)

P = penetration distance of the exiciting radiation into the phosphor (cm)

$E = h\nu$ = the energy value of the quanta of emitted radiation ($ergs$)

t = the length of time required by the phosphor to convert the exciting energy into the emitted energy (seconds)

3 Bouma, *Philips' Rev.*, 2, 1, 1937. p. 1.

If it is assumed that every luminescent centre is "loading and firing" without interruption and that the time of the fluorescent act is 10^{-8} second, and if any loss of emitted light by absorption or scattering is disregarded, the substitution of values for 10,000 volt electrons ($P = 0{\cdot}00025$ cm)[33] exciting light at 5560 Å ($E = h\nu = 3{\cdot}54 \times 10^{-12}$ *erg*) yields

$$E_{max} = \frac{10^{21}(2{\cdot}5 \times 10^{-5})3{\cdot}54 \times 10^{-12}}{10^{-8}} = 9 \times 10^{12} \frac{ergs}{cm^2 \; secs}$$

$$= 9 \times 10^{5} \text{ watts/cm}^2$$

$$= 6 \times 10^{8} \text{ lumens/cm}^2$$

$$= 6 \times 10^{11} \text{ foot lamberts.}$$

The foregoing analysis is mainly of academic interest, but serves to give an upper limit for light output of conventional phosphor screens. Attainment of such great brilliancy requires practically 100% conversion of excitation energy into light in order to avoid overheating of the phosphor and requires tiny crystals in which the phosphorescence action is negligible compared with fluorescence.

PHOSPHORESCENCE.

Modern investigators have increased the exactness of phosphorescent measurements, but have not discovered any phosphor exhibiting a decay curve contrary to the normal initially rapid decrease in light output, followed by a "tapering-off" of decay rate. According to Johnson and Davis, "It appears that the older phosphors differed chiefly in efficiency, not in any essentials of behaviour, from the materials recently developed for television and fluorescent lighting."

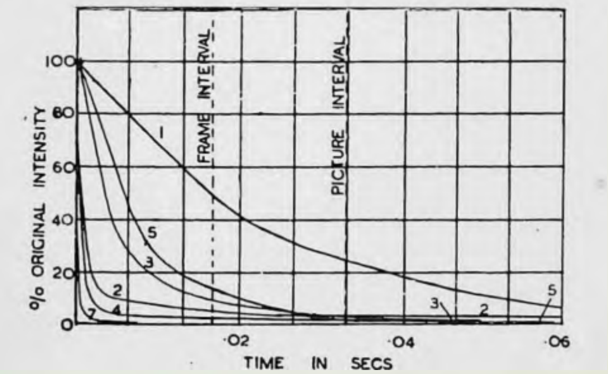


FIG. 3—Typical phosphor decay curves (persistence).

Fig. 3 shows typical phosphorescence curves for silicate phosphors (exponential monomolecular) and for sulphide phosphors (hyperbolic or bimolecular).

Pure tungstate phosphors have very short decays, lasting about 10^{-5} second. The decay curve of β-zinc silicate : *Mn* is practically identical with the α-form.

Fig. 4 shows results published by P. W. Cobb[4] demonstrating the reduction of critical flicker frequency by increasing the amount of time the light was on in relation to the total time between light-dark intervals. It is seen that filling 59/60 (98·3%) of the field time with light reduced the critical frequency to only 20–26 cycles/second, and that filling 45/60 (75%) reduces the critical frequency to 39–47 fields per second, the exact values being dependent on illumination levels. It follows, from Cobb's data, that the use of phosphors such as long-persistence orange-emitting calcium- or cadmium silicate would decrease the critical frequency to only about 40 fields per second at low brightness levels.

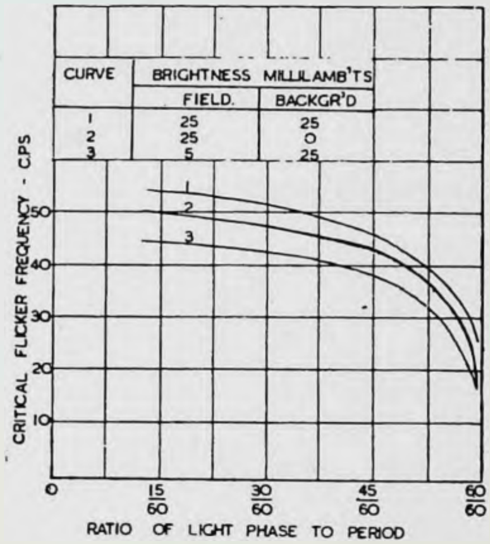


FIG. 4—Critical flicker frequency as a function of illuminated portion of the frame frequency interval.

At the brightness levels ordinarily demanded for television pictures, the critical frequency for these materials would be about 44 to 48 fields per second. Because it is desirable to use the most efficient light-producing phosphors, shorter persistence characteristics with still higher critical frequencies must be accepted. Thus, a mixture of blue-emitting zinc sulphide and yellow-emitting zinc beryllium silicate—which provides a brilliant white screen—fills less than 45 per cent. of the field interval and has a critical frequency of 44 to 52 fields per second for a brilliancy range of 5 to 25 millilamberts.

4 *Jour. Opt. Soc., Am.*, 24, 109, 1934.

The flicker sensitivity of the human eye as a function of colour is directly proportional to the eye's photopic sensitivity to that colour. Thus, the critical flicker frequency for coloured lights of equal intensity decreases in the order: yellow, 5800 Å; orange, 6100 Å; green, 5100 Å; red, 6500 Å; blue, 4800 Å.

The general average illumination level has been increasing rapidly in the past few decades. In 1896, 0·4 footcandle was deemed sufficient; in 1914, the average was 1-3 footcandles; while in 1931 the standard was 11 footcandles. The brilliancies of television images will undoubtedly tend to increase with the trend of increasing illumination levels.

There is a definite increase in visual acuity up to 15–20 footcandles and increased illumination directly improves the ability of the eye to see quickly. There is an increase in "speed of vision" between 0·4 footcandle and 12·0 footcandles amounting to approximately 600% for visual detail of size 1·15′ and 331% for a detail of double this size (Ferrie and Rand as quoted in Hardy). Accordingly, utilisation of finer detail in television images (such as by increasing the number of lines) would require increasing picture brilliancy and correspondingly increasing the eye's susceptibility to flicker.

It is well understood that a frame repetition rate of less than 30 per second is inadequate to avoid loss of continuity in rapidly moving objects, since even 30 frames per second is insufficient for some television scenes of rapid motion. A thorough study by R. Thun[5] has resulted in the graph which shows the degree of satisfactoriness of average pictures (either motion pictures or television) as a function of frame frequency, while keeping all other variables at optimum values. An extensive investigation by E. W. Engstrom[6] gives the essentials involved in choosing frame and field frequencies. The study showed it to be illogical to expect that the flicker problem could be solved by using phosphor screens of longer persistence.

5 *Die Kinotechnik*, Apr., 1935, p. 117. *Ibid*, Nov. 5, 1935, p. 358 and Nov. 20, p. 374.
6 *Proc. I.R.E.*, 21, 1933, p. 1631. *Ibid.*, 23, p. 295, 1935.

ABSTRACTS

The Inverted Amplifier. (Strong, Electrical Comm., Vol. 19, No. 3, p. 32).

By applying the input excitation in series with the cathode of a power amplifier, with the grid earthed, important advantages for H.F. operation are gained, since the grid acts as a shield and the output capacitance is reduced.

Quality in Television Pictures. (Goldmark and Dyer, Proc. I.R.E., 28, p. 343, 1940).

A photographic method of producing television pictures which enables factors such as contrast, gradation, brilliance, and spot shape to be varied has been developed. Pictures are shown which are obtained by this means and which approach ideal quality within a given set of standards.

Subjective sharpness of simulated television images. (Baldwin, Proc. I.R.E. 28, p. 458, 1940).

Sharpness, in the subjective sense, is found to increase more and more slowly as the physical resolution of an image is increased. Images of present television grade are shown to be within a region of diminishing return with respect to resolution. Equality of vertical and horizotal resolutions is found to be very uncritical in the sharpness of an image, especially if it is already fairly sharp.

Portable equipment for observing transient response of television apparatus. (Kallman, Proc. I.R.E., 28, p. 351, 1940).

Apparatus for supplying a perfect transient, either directly or as the modulation of an H.F. carrier to a television amplifier and recording its transient response.

Design details described, with description of a carbon-disk attenuator for U.H.F.

Factors affecting the choice of Lenses for Television Cameras. (DeVore and Iams, Proc. I.R.E., 28, p. 369, 1940).

The specification of a camera lens for television can be computed by knowing the size and sensitivity characteristics of the pick-up tube and V.F. ampifier, the required signal-noise ratio and the angle of view of the camera.

The focal length F of the lens $= \frac{1}{2} W \cot\frac{1}{2}a$ inches, where W is the width of the sensitive surface, a is the horizontal angle of view.

The N.A. is $f = \cdot 064 W\sqrt{(TBs)} \div \sqrt{(10^6 I_n N)}$, where T is the light transmission factor of the lens, I_n is the equivalent r.m.s. noise current in the input of the ampifier, and N is the required signal-noise ratio. s is the operating sensitivity in μA/lumen and B the surface brightness in c./ft.^{2}.

The derivation of the formulae, with charts, is given.

VIDEO OUTPUT SYSTEMS

By D. E. FOSTER and J. A. RANKIN

Abstracted from the R.C.A. Review, Vol. 5, No. 4, 1941.

VIDEO OUTPUT SYSTEMS.

The output stage of the video frequency amplifier of a television receiver is required to modulate the grid of the picture C.R. tube over the range of optimum contrast.

To accomplish this, a relatively large output is necessary over the entire video frequency range and in addition the output stage must re-insert the D.C. component.

In this paper the advantages of direct coupling, grid rectification, and diode rectification as a means of D.C. insertion are discussed, together with the characteristics of circuits to obtain uniform high frequency response. The characteristics of these circuits are shown in the attached figure, and the authors' comments are as follows:

Three current type of valve have characteristics suitable for the video output stage requirements. These are the 6AC7, 6AG7 and 6V6. The 6V6 has the greatest output, but the 6AC7 has the greatest sensitivity. Typical operating conditions are:—

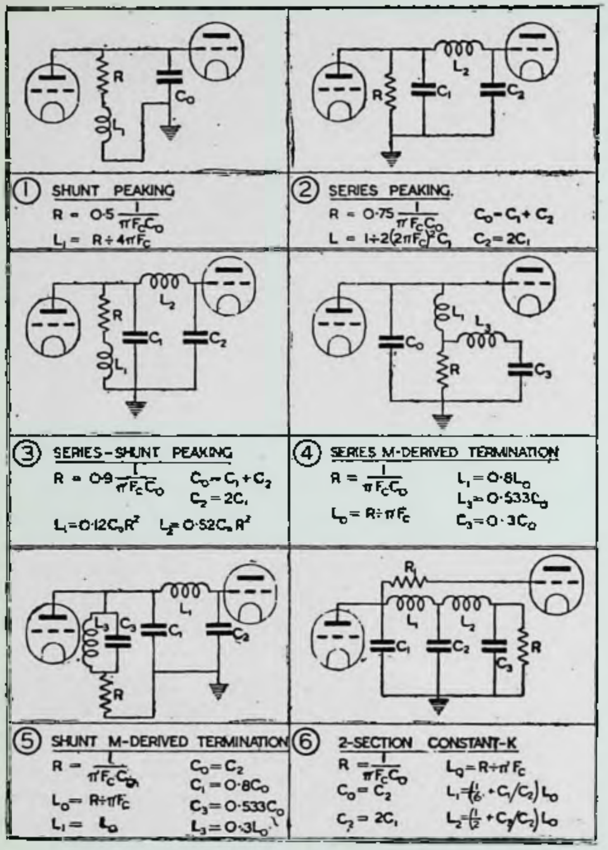
Valve Type	6AC7	6AG7	6V6
Anode Volts	250	250	250
Screen Volts	150	140	250
Grid Bias	2·0	2·0	12·5
Anode Current ...	10	33	45
Mutual Conductance	9·0	10·2	4·1
Output Capacity ...	5	7	12

The six basic circuits are shown diagrammatically in the figure, with their design parameters. The d.c. connexions are not given, and the capacitances are those of the input and output of the tubes. F_c is the maximum frequency of response (cut-off frequency) and the nominal or determining value of capacitance C_o.

Eight cases are given below, illustrating the merits of the various types of output circuit.

The reference number of the C.R. Tubes are those of the R.C.A. C_a is the output capacitance of video valve plus wiring, C_g the input capacitance plus wiring. Mc/sec. refers to the maximum frequency transmitted without loss in fidelity. P-P volts is the maximum voltage output.

Case No.	Type of Circuit	Valve	C.R. Tube	D. C. Restoring	Ca	Cg	Mc/sec	P-P Volts	Gain
1	2	6AC7	1802	Grid	7	16	2·5	55	40·7
2	6	6AC7	1804	Grid	7	20	3·8	38	28·1
3	1	6AG7	1802	Grid	14	16	2·5	53	20·9
4	4	6AG7	1804	Grid	14	20	3·8	56	22·0
5	6	6AC7	1802	Diode	7	16	2·5	166	60·0
6	6	6AC7	1804	Diode	7	20	3·8	95	34·2
7	3	6AG7	1802	Diode	14	16	2·5	180	27·9
8	5	6AG7	1804	Diode	14	20	3·8	190	29·4



Case 1.—The load resistance is approximately 40% greater than in the conventional circuit and the series inductance is correspondingly increased. The gain is good, but the output is only 40% greater than the minimum required for satisfactory working.

Case 2.—The maximum output is not sufficient to modulate the C.R. tube grid satisfactorily.

Case 3.—The use of circuit No. 1 with the 6AG7 results in a low value of load resistance, but when using the valve the gain is fair and the output more than the minimum required.

Case 4.—The maximum output is adequate with fair gain, but the circuit requires close tolerances on all the components of uniform gain over the band is to be obtained.

Case 5.—The gain and output for this are excellent. A diode-type d.c. restorer is required, which may not be justifiable with a small receiver.

Case 6.—Both circuits 5 and 6 result in the same value of load resistance and as the gain and output are good the choice lies between the circuits, Circuit 5 requiring the closer tolerance.

Case 7.—The maximum output in this is more than required and the gain is reasonably good. The combination of tube and diode d.c. restorer is expensive and the tolerances on the end capacities are narrow.

Case 8.—The gain is lower than in *Case 6* but the output is ample.

AMERICAN TELEVISION STANDARDS.

In the last issue of the *Journal** it was noted that a National Television Systems Committee had been formed in America to determine basic standards for television transmission. A brief summary of their recommendations is as follows:

1. The width of the vision broadcast channel shall be 6 mC./sec., with the picture carrier 4·5 mC./sec. lower in frequency than the sound carrier (unmodulated).

The unmodulated sound carrier shall be 0·25 mC./sec. lower than the upper frequency limit of the channel.

2. The standard number of lines per frame† shall be 441 lines, interlaced 2–1. The frame frequency shall be 30 p.sec., and the field‡ frequency 60 per sec. The aspect ratio shall be 4:3 and the scanning direction left to right horizontally and top to bottom.

3. Amplitude modulation shall be standard for picture and sync. signals with black level at 75% ± 2½% of the peak carrier amplitude.

4. The sound transmission shall be frequency modulated.

5. The picture transmitter shall be rated in terms of the peak power when transmitting a standard picture signal. Maximum white shall be 15% or less of the peak amplitude.

The maximum deviation in the sound transmitter shall be 75 kC./sec. in modulation.

6. A horizontally polarised wave shall be standard.

It is of particular interest to note that the sound transmitter is to employ frequency modulation. It is expected that the foregoing recommendations will be adopted in the near future.

* *Jour. Television Soc.*, Vol. 3, No. 5, 1940, p. 140.

† U.S. Frame = British "Picture."
‡ U.S. Field = British "Frame."—Ed.

LIBRARY.

LITERATURE OF THE PHOTO CELL.

Examination of the Journal of the Physical Society for the past ten years shows a complete series of papers on the theory and applications of the photo-cell. They have been contributed from various quarters — U.S.A., the Research Laboratories of the G.E.C., the N.P.L., etc., and together they form a complete record which will be of assistance to research workers who may require special applications of the cell.

Reprints have been collected and bound in one volume for the Society's Library, and the following is a list of titles:—

"Early History of Photo-electric Cells"	H. S. Allen
"The Thalofide Cell" ...	T. W. Case
"Barium Cells"	T. W. Case
"Manufacture of Selenium Cells"	Major C. S. Phillips
"Photo-cells and some Applications"	J. Kunz
"Manufacture and Properties of Sodium Cells"	P. Selényi
"Use of Photo-cells in Sound Reproduction"	D. H. Loughridge
"Theory of Selective Photoelectric Emission"	N. R. Campbell
"Time Lag in Gas-filled Photo-cells"	N. R. Campbell
"Standardisation of Photo-cells"	N. R. Campbell
"Theory of Use of a Photo-cell with Amplifier" ...	N. Yates-Fish
"Theory of Amplification of Photoelectric Currents"	H. A. Thomas
"Distortion in Photo-cell Amplification"	H. Geffcken
"Electrostatic Measurement of P.E. Current" ...	F. B. Moss
"Comparing Small Amounts of Light"	G. M. Dobson
"Measurement of Daylight"	W. R. Atkins
"P.E. Cell as a Precision Photometric Instrument"	T. H. Harrison
"Notes on Photoelectric Photometry"	C. H. Sharp
"Photo-cells in Biological Work"	V. E. Shelford
"Photo-cell in Spectro-Photometry"	K. S. Gibson
"The Koch Micro-photometer"	E. A. Baker
"Spectro-photometric Absorption"	D. S. Perfect
"Photoelectric Photometry and Phototherapy"	H. D. Griffith

REVIEWS.

TELEVISION RECEIVING EQUIPMENT: W. T. Cocking. (Iliffe and Sons, 297 pp. with numerous diagrams and three circuit diagrams in text, 7/6 net).

Mr. Cocking's articles on the design of television receivers appeared in the *Wireless World* during 1938 and 1939 and were written in his usual careful and accurate style. This book, which is published in uniformity with the other *W.W.* handbooks, contains the subject matter of the articles together with much additional information based on the experience of the *W.W.* laboratory.

In order to make the book complete, the opening chapters are devoted to just so much theory of the subject to make the book intelligible to the beginner in television, but a certain standard of radio knowledge is required.

The technical description begins with a review of the electrostatic and magnetic C.R. tubes, H.T. supplies and deflecting circuits. The circuits illustrating electrostatic deflection are those of the original home-construction receiver published in the *W.W.*, on which excellent results were obtained. Electromagnetic deflection is dealt with more fully both as regards scanning, coil design and amplification of the deflecting impulse. Saw-tooth oscillators complete the section on the tube and its circuits.

The various sections of the receiver—video frequency and intermediate frequency amplification are then discussed with a short chapter on detection. Various types of sync. separating circuit are given from the early "saturated pentode" to the more elaborate diode separators with differentiating and integrating circuits. This is a valuable portion of the book, as so many home constructors pay little attention to obtaining efficient synchronising, and the commercial circuits are not available for reference.

Apart from one or two articles which have appeared, the subject of synchronisation has not been given the prominence it merits, and there is scope for a monograph when some of our television designers take up their work again.

An interesting chapter in the book is that on "Special Television Circuits"—principally resistance networks, but the cathode follower circuit and its special advantages is outlined. Readers requiring more information on this should consult the I.E.E. paper by Blumlein on the E.M.I. system.

Complete circuit diagrams of the magnetic receiver with full component values are inserted in the book, which concludes with brief notes on faults and their remedies and servicing. The diagrams throughout are drawn in the characteristic excellent style adopted by the *Wireless World*, and nothing is taken for granted. Those who consider that the circuits centre round one particular maker's valves should remember that at the time when the design was under consideration there was not the wide variety of types which are now available.

Mr. Cocking's book is a worthy addition to the Society's collection of television literature and will be frequently consulted by professional engineers as well as the home constructor. G.P.

RADIO FREQUENCY MEASUREMENTS by Bridge, and Resonance Methods: L. Hartshorn, D.Sc. 266 pp., 99 figs. (Chapman and Hall, 21/- net).

Dr. Hartshorn is Principal Scientific Officer at the N.P.L., and writes with the knowledge of many years practical experience in the field of measurement. The reader must not expect to find detailed information on all the measurement circuits used in the N.P.L., but, what is perhaps more important, he will find numerous suggestions on points of detail such as screening, earthing, stray capacities and various other bugbears of the science of radio measurements.

The opening chapters on Impedance and general principles of impedance measurement are followed by one on screening as applied to r.f. bridges.

The second section of the book, headed "Apparatus," deals with Generators, Detectors and standards of capacitance and inductance (the author uses the word "inductor" in accordance with the B.S.I. recommendation, to denote apparatus possessing the property of inductance).

Under "Methods," an outline is given of the various methods of resistance, capacitance and inductance measurement including ultra-short-wave technique. This last chapter is of particular interest in view of the amount of work which is being done at the present time in the ultra-high frequencies.

In the chapter on detection the author does not mention the "magic eye" null indicator, although under certain conditions this can be made to give results almost as sensitive as the telephone and with less fatigue to the user. Nor, curiously enough, is the cathode ray oscillograph mentioned either as a phase indicator or null indicator.

The author urges the importance of experimental work in preference to reading up the subject from various sources, and as a guide to the student undertaking r.f. measurements this book can be recommended, particularly from the theoretical aspect.

Under the heading "Bibliography" is the quotation from Belloc: "Read less, good people, and observe more; and above all, leave us in peace." It is just as well that the author put it at the end of the book and not the beginning! G.P.

TELEVISION—The Electronics of Image Transmission: V. K. Zworykin and G. A. Morton. (John Wiley and Sons Inc. (New York), Chapman and Hall (London), 630 pp., with numerous figures and diagrams in text, 36/-).

This may be considered as the first authoritative textbook on television published in America. Dr. Zworykin's work is so well known that his name on the title page of a book is sufficient guarantee of its excellence, and readers who expect a complete account of modern television practice will not be disappointed.

The book follows somewhat different lines from those which have appeared in this country, such as J. C. Wilson's *Television Engineering*. The historical side of television is only mentioned where necessary to introduce a particular section of the subject and the greater portion of the book is naturally concerned with the author's specialities—the iconoscope and the kinescope.

The opening section covers the fundamental physical principles of electron emission, fluorescence, electron optics and vacuum practice. A separate book on this subject from Dr. Zworykin would be welcome as very little has appeared since Dushman's monograph was written.

The second portion deals with the factors affecting picture transmission—brightness, flicker, resolution, etc., leading to the various pick-up devices and reproducers. Systems other than the electronic are given cursory mention, although a concise account of the Scophony system is included. Over a hundred pages are then devoted to the theory and practice of the iconoscope and kinescope, followed by a discussion of the components of the receiver and transmitter. Under scanning and synchronisation the American standard signal is analysed and a full description of the separation of sync. impulses given. The section on the practical details of reception is accompanied by a complete circuit diagram for an experimental receiver for the R.M.A. system with component values.

The R.M.A. television project is outlined with illustrations of the studio equipment and the Empire State transmitter. Each chapter is followed by a bibliography of the principal references which are not exclusively confined to papers in the I.R.E. Proceedings, as is common in American books.

Dr. Zworykin's book will be the standard television textbook in America for some time to come and will be equally useful to British engineers. G.P.

RADIO AT ULTRA-HIGH FREQUENCIES: R.C.A. Institute's Technical Press, N.Y. 448 pp. and figs. (*Not for public sale*).

This booklet is a collection of papers which have appeared in the R.C.A. Review and I.R.E. Proceedings, written by R.C.A. engineers. They have been classified into two main groups—above 300 mC/sec., and below 300, each group being sub-divided into Transmitting Methods and Equipment, Propagation, Measurements and Reception.

In addition to over twenty papers which are given in full, there is a section which summarises thirty odd papers in addition.

Space does not permit of a full list of the subjects dealt with, but the following are of particular interest to television engineers:

- Television Antennas (P. S. Carter).
- The Empire State Building Television Antenna (Lindenblad).
- Frequency Assignments for Television (Engstrom and Burrill).
- High Power and U.H.F. Television Transmitters (Conklin and Girhing).
- R.F. Generator for Television Receiver Testing (Turner).

The latter equipment was originally described in the R.C.A. Engineer, 1939, and consists of a push-pull r.f. oscillator and push-pull modulated ampifier with a frequency range of 40—100 mC./sec. The modulation can be varied from 30 to 3,000,000 cycles and the output is constant at any level from 0·5—25 volts.

The R.C.A. Technical Press have rendered an important service to radio and television engineers by the issue of this book. The contents have been chosen to present the most useful reference papers in a handy form, and this saves an immense amount of time and trouble in hunting through bound volumes or card indexes for the required information.

The book is not available for sale, but is issued free to subscribers to the R.C.A. Review, and forms a companion volume to those on "Television" (2) and "Radio Facsimile" issued a short time ago.

Particulars of the subscription rate to the R.C.A. Review can be obtained from the R.C.A. Institute's Technical Press, 75, Varick Street, N.Y. City, U.S.A., but members are reminded that it is not at present possible to send subscriptions out of the country except through authorised channels. A library copy is available for loan on request.

BAIRD HIGH DEFINITION COLOUR TELEVISION

Members will be interested to note that Mr. J. L. Baird has resumed active work in television development at his laboratory at Sydenham. The following brief account of his high definition colour television system was issued after a demonstration had been given on January 14th, 1941, at which the Lecture Secretary was present.

The *inset* (page 173) is kindly presented by the Editor of *Electronic Engineering* and appeared in *Electronics and Engineering and Short Wave World* (as its title was then) April, 1941. The coloured reproduction in the inset will allow members to appreciate all the more the practical achievements outlined in this article.

THE WAR AND TELEVISION.

Statements have appeared recently to the effect that Hitler's activities have stopped all television progress in this country. Such statements encourage the enemy and the demonstration given to-day will, it is hoped, disprove them. The television industry will give employment to thousands when television broadcasting is re-started at the very critical period which will arise at the conclusion of hostilities. Television was first achieved in Britain and this country has ever since held the leadership. It is felt to be of national importance that this leadership should be maintained.

TELEVISION ABROAD.

Reports have appeared recently of colour television demonstrations in the U.S.A. These appear to be of an experimental nature, only coloured lantern slides and coloured films have been sent, the difficulty of sending studio scenes not having been overcome in that country. The pictures also are of a relatively low number of lines (343). The system they use appears to be on the same principle as that demonstrated to the Press by Mr. Baird eighteen months ago.

THE DEMONSTRATION.

Mr. Baird's new 600 line colour television system was shown in operation. Artists in an outdoor studio were transmitted to a receiving set in an adjoining house.

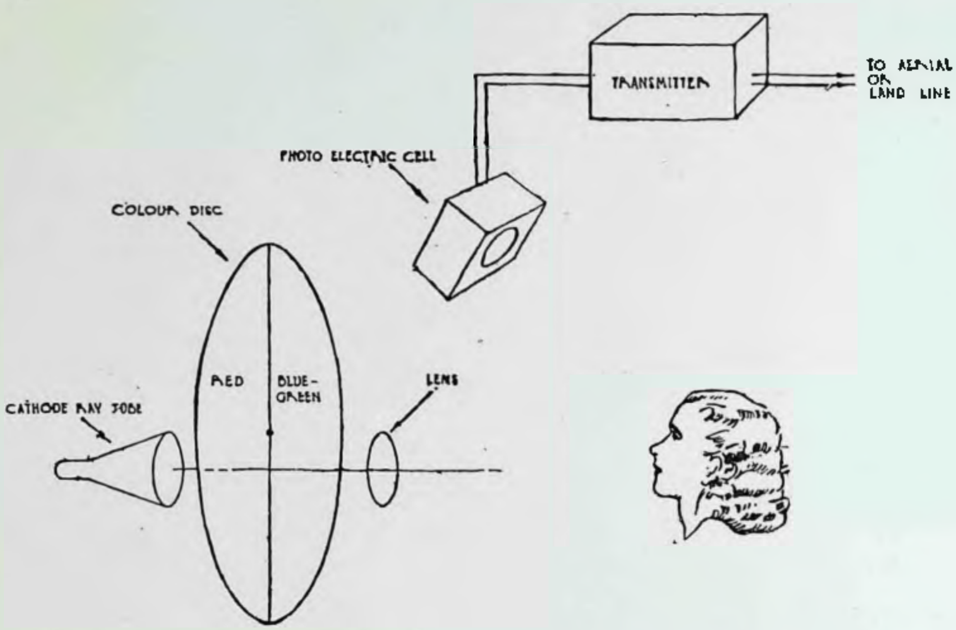
THE TRANSMITTER.

The transmitter is based on Mr. Baird's original spot-light system. It consists of a cathode ray tube in front of which revolves a disc fitted with blue-green and red filters. After passing through the disc the light spot on the cathode ray tube is projected on to the scene to be transmitted by means of a lens. The person being transmitted is thus scanned by blue-green and red light beams in succession. The light from the coloured light spots traversing the scene operates three large photo-electric cells. The current from these is amplified and sent by land line or wireless to the receiver (in this demonstration a land line was used as, owing to the war, the use of wireless was prohibited by the Government).

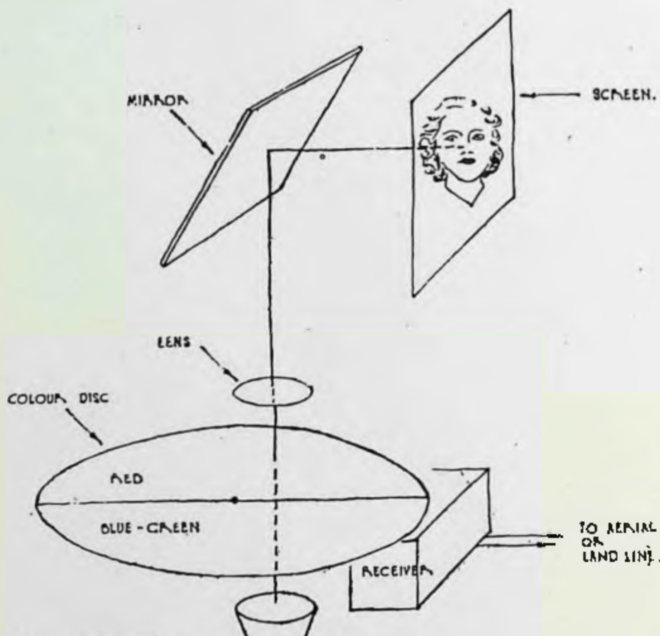
THE LARGE SCREEN COLOUR TELE-RADIOGRAM.

At the receiver, the transmitted pictures corresponding to blue, green and red are superimposed, as in the familiar colour printing process, to form a complete television picture in colour. Similar apparatus is used to that employed at the transmitter, the picture is first produced in black and white on a cathode ray tube. In front of this is a colour disc similar to that at the transmitter and revolving exactly in step with it (this is achieved by controlling the motor driving the disc from an impulse incorporated in the transmitted picture). The black and white pictures, by passing through the colour disc, are coloured blue-green and red and then projected on the screen by means of a lens. At the screen they blend to give a television picture in colours. The screen is 2ft. 6in. by 2ft. 0in. (the largest screen ever produced for the home) and shows 600 line pictures (50% more lines than used by the B.B.C.). In addition to colour, the new televisor will receive the B.B.C. black and white pictures on the same screen by merely pressing a button. Four push buttons are provided and these bring into action:

(a) An all-wave radio set.
(b) An automatic record changing radiogram.
(c) B.B.C. television.
(d) Colour television.



TRANSMITTER



ILLUSTRATING
BAIRD'S
SYSTEM OF
HIGH DEFINITION
COLOUR
TELEVISION

TELEVISION IN COLOUR

J. L. BAIRD'S NEW ADVANCE

The first photograph of a television image ever published, the image on the screen of Mr. Baird's first televisor in 1926

While the theory of television was well-known long before 1926, no practical success had been achieved in transmitting television images. It had only been possible to send shadows of shapes ; in other words, the televised image was then nothing more than a transmitted shadowgraph. On January 27th, 1926, however, for the first time, true living pictures—that is, images modelled by light and shade—were shown by a system of television invented by John Logie Baird, a demonstration being given to members of the Royal Institution and other scientists on that date. This achievement created a sensation which most of us remember, and much appeared in the Press at that time, a good deal of it greatly exaggerated. What was actually shown in that year is simply and authoritatively described in an article by Dr. Alexander Russell, F.R.S. a past president of the I.E.E. and of the Physical Society, writing in "Nature" of 3rd July, 1926. He states :—

"We saw the transmission by television of living human faces, the proper

(Miss Paddy Naismith, the well-known Airwoman)
The first photograph of a colour television image ever published, the image on the screen of Mr. Baird's 600 line colour televisor.

gradation of light and shade, and all movements of the head, of the lips and mouth, and of a cigarette, and its smoke were faithfully portrayed on a screen in a theatre, the transmitter being in a room at the top of the building. Naturally, the results are far from perfect. The image cannot be compared with that produced by a good kinematograph film. The likeness, however, was unmistakable, and all the motions are reproduced with absolute fidelity. This is the first time we have seen real television, and, so far as we know, *Mr. Baird is the first to have accomplished this marvellous feat*".

The "marvellous feat" in 1926 is a common-place today. A photograph taken of the television image of 1926 is reproduced in the illustration at the head of the preceding page. The original apparatus itself is preserved in the Science Museum, South Kensington.

Baird's first apparatus

was named by him a "Televisor", which word was for some time a commercial trade mark but has now come into general use for any television receiver.

The actual televised image was considerably clearer than either the photograph or the illustration here given. Authentic photographs of television images are difficult to take and are invariably much inferior to the real picture. Any variations of the televised image causes blurring in the photograph, and of course, the realism of the moving image is largely lost in the photograph.

Television had a chequered early history. Baird had a struggle to obtain the co-operation of the B.B.C. which looked with some scepticism on his claims to be able to transmit television by wireless. Finally, the matter was settled by a Government Committee under the Chairmanship of the late Lord Selsdon (then Sir Mitchell Thompson, Postmaster General) advised by the experts of the Post Office and the B.B.C. This committee was given a demonstration, the transmission being made from 2LO (the B.B.C.'s station in Savoy Hill), while the receivers were placed at the General Post Office in St. Martin's-le-Grand, and also at the B.B.C. Headquarters at Savoy Hill. This demonstration so convinced the Committee that in due course they reported the result as

a "Noteworthy Scientific Achievement"

and recommended that the B.B.C. should provide broadcasting facilities for the Baird system.

Following this report, television transmissions by the Baird process started in 1929, not only in London through the B.B.C. but also in Berlin, Baird apparatus being installed in the Berlin Broadcasting Station by the German Post Office.

The great electrical combines, inspired without doubt in great measure by Baird's pioneer work, saw the possibilities of the new art. They applied their gigantic resources to its development and television as we know it to-day represents the pooled results of a great number of research workers. The little flickering images which caused such a sensation in 1926 have become pictures of a size and clarity which rivals the cinema itself,—and now colour is being added.

Colour television was shown for the first time as far back as 1928 when Baird demonstrated a colour television image a few inches square to the British Association. It is gratifying therefore to find that in 1941 he still maintains leadership in its development.

In spite of manifold difficulties caused by the war and working entirely independently in his private laboratory he has developed a 600 line television system for

televising in natural colours.

We present on the preceding page a reproduction of the colour television image, *the first photograph of such an image ever reproduced.* It is obvious that any loss sustained in photographing the monochrome image is multiplied when the image is in colour, but the Dufay untouched colour photograph, here reproduced as faithfully as mechanical processes permit, will give an idea, but only a very inadequate one, of Baird's new achievement.

It is encouraging to know that, in spite of all the great difficulties of the time, television research still continues in this country and we can be assured that when the war ceases Great Britain will once again hold the leading position in the television field.

Mr. Baird's 600 line colour televisor. The screen receives either 600 line colour pictures or by pressing a button the B.B.C. 405 line monochrome pictures. It measures 2′ 6″× 2′ 0″. The set includes an automatic record-changing radiogram and an all-wave wireless receiver.

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