Beginner's Guide to Television

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PREFACE

THE first edition of this Beginner's Guide was written and edited by the late Mr. F. J. Camm and published in 1958. The book sold many thousands of copies in three editions until the many changes in the world of television made a completely rewritten edition necessary in 1968. In writing the new text, I endeavoured to follow the down-to-earth approach of Mr. Camm which was so much liked by the many readers more interested in practice than in theory. There must be some theory, of course, and where it was necessary to introduce this I tried to present it as simply as possible yet without detracting from the value of the work from the point of view of the student and technician studying the subject for examinations.

I also endeavoured to give the book appeal to the man-in-the-street, who while not reading for examinations, is nevertheless curious to know how television works and desirous of keeping up to date with new developments.

The sections dealing with receiver adjustments and fault conditions, and the off-the-screen symptom photographs have proved useful to the enthusiastic amateur and skilled engineer alike.

In revising the text for this new fifth edition I have taken the opportunity to include information on the transistor circuits being used in contemporary receivers and on the new breed of single-standard receivers. Test Card F is also described and the u.h.f. station list is brought up to date.

In conclusion, I should like to record my sincere thanks to the various manufacturers, companies and organisations who have supplied information and photographs, without which the book could never have been written.

Gordon J. King

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BASIC PRINCIPLES

WE see television pictures because our eyes are incapable of registering in its true form a bright, fast-moving pin-point of light on the screen of the picture tube. Instead of following the light as an actual spot, our eyes discern its movement on the screen as a sequence of thin, closely spaced horizontal lines. This stems from a subjective process called *persistence of vision.* Human vision is essentially an optical–chemical–nervous process in which our eyes translate the energy of light radiation focused within them into a chemical activity which in turn sends impulses to our brain informing it about the scene upon which they are focused.

The prime optical organs associated with this translation are called *rods* and *cones*, and these work via the retina, which is a photosensitive film upon which the image of the scene is focused by the eye lens. The rods deal with the brightness sensations of the scene, while the cones add the colour sensations.

Because of the relatively slow decay time (about 80 milliseconds) of the eye/brain activity when the light stimulus is removed, fast, repetitive movement of a light or an object conveys the impression of continuity. This is what is meant by the term persistence of vision. A spot of light moving back and forth recurrently along the same horizontal path on the screen of a picture tube appears as a continuous horizontal line when the repetition frequency exceeds about 15 Hz (1 Hertz—Hz—equals one cycle per second). Flicker is apparent at low frequencies, but this almost completely disappears at about 50 Hz.

Scanning

The design of a television picture tube is such that an intensely bright pin-point of light is produced in the centre of the screen. This is called the *scanning spot*, and arises as a result of the electron beam in the tube striking the fluorescent coating of the screen. Two coil sets arranged at right-angles to each other on the picture-tube neck are energised by currents of almost sawtooth waveform. The magnetic fields that accompany these currents in the coils subject the electron beam passing along the tube neck to vertical and horizontal forces. The beam is thus deflected; and since the electron beam is responsible for the creation of the scanning spot, this is also deflected both vertically and horizontally on the screen.

The tube-neck coils are called *scanning coils.* There are two pairs of them, one pair for vertical deflection and the other pair for horizontal deflection.

Vertical deflection of the scanning spot is from the top to the bottom of the screen, and the British repetition rate is 50 Hz or thereabouts to match the a.c. mains frequency. In America and other countries with a 60-Hz mains system the vertical deflection rate is 60 Hz.

Horizontal deflection of the spot is from the left to the right of the screen (looking at it from the front of the tube) at a rate of 10,125 Hz on the British 405-line standard and at 15,625 Hz on the 625-line standard.

Because the spot is deflected horizontally more swiftly than

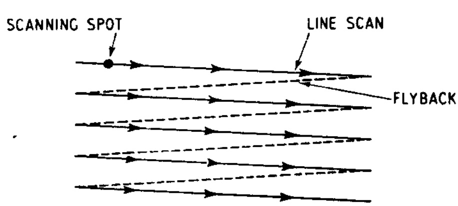


Fig. 1.1. The basic principles of scanning. Scanning coils deflect the spot horizontally more swiftly than vertically to give the effect of a succession of horizontal scanning lines.

vertically, it traces on the screen a succession of horizontal lines as shown in Fig. 1.1. These are called *scanning lines*, while the resulting rectangle of screen illumination, comprising all the lines, is called the *raster*; and it is upon this that the television picture is built.

The sawtooth nature of currents in the scanning coils causes the scanning spot linearly to deflect from top to bottom and from left to right on the screen, and after each full deflection the spot is made to return very rapidly to its starting position because of the rapid change in scanning coil current at the end of each full deflection. A full deflection is called a *scanning stroke*, while the rapid return of the spot is called the *retrace stroke* or, more popularly, the *flyback*.

Line standards

A television raster is composed of a certain number of scanning lines, according to the line standard. The original 405-line raster standard adopted in Great Britain on a permanent basis in 1937 is still in use. However, it is now partnered by a standard of 625 lines, and these two standards are likely to be in use side by side for some years to come. The plan is ultimately to drop the 405 standard and change to exclusive use of the 625 standard, but at the time of writing the exact plan for this changeover has not been finally determined.

The 625-line standard is used for U.K. colour transmissions, and three out of the four u.h.f. channels of each local group accommodate the programmes of B.B.C. 1, B.B.C. 2 and I.T.V., all in colour. At the time of writing no final decision has been made regarding the deployment of the fourth channel.

The two line standards have tended to complicate the receivers in the past, but now with the rapid development of the 625-line service over the country the need for dual-standard receivers is diminishing, and by the time this edition is in print—or a little afterwards—most manufacturers will be making 625-line models only, both for monochrome only and colour.

Previously, dual-standard switching techniques have been used in both monochrome and colour receivers. Dual-standard colour models receive black-and-white only on the 405-line standard, and both colour *and* monochrome on the 625-line standard. However, since the need for dual-standard colour models was short-lived, all colour models now being manufactured are single standard.

Now, although a picture is said to have 405 or 625 lines, this is not strictly true. If it were possible to count the number of lines it would be discovered that the number is slightly less than the line standard. This is because some of the lines occur during periods when there is no picture information transmitted, and at these times the lines are blacked out. A 405-line picture has about 377 active lines and a 625-line picture about 585 active lines. We shall see later that a synchronising signal occurs during the time of the blacked-out lines.

Frames and fields

Because the vertical repetition frequency is 50 Hz, it follows that a complete set of lines, forming the raster, must appear on the screen every fiftieth of a second. However, we have seen that the line-repetition frequency is 10,125 Hz on 405 lines and 15,625 Hz on 625 lines. Now, if we divide 10,125 and 15,625 each by the vertical frequency of 50 Hz we get answers of $202\frac{1}{2}$ and $312\frac{1}{2}$ and not 405 and 625 as might well be expected. This little arithmetic proves that for each vertical scan there are only half the number of lines of a complete picture. How, then, are the 405 and 625 standards created?

The answer is that each complete television picture is made up of two vertical scans, each scan yielding half the number of lines of a complete picture. This means that a complete picture is produced every twenty-fifth of a second.

Each vertical scan of half the number of total picture lines is called a *field*, while each full-line picture, *consisting of two fields*, is called a *frame*. We thus get the term *field frequency*, which is the same as the vertical deflection frequency already considered. The British field frequency is therefore 50 Hz, and that in America and some other countries 60 Hz.

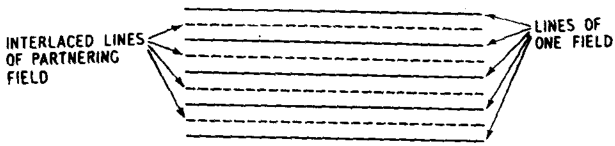


Fig. 1.2. The scanning lines of the two vertical fields interlace.

It will be understood, of course, that not all the lines of a field are active lines. About 20 per field are blacked out on 625 lines and about 14 per field on 405 lines.

Our persistence of vision is such that each field is sustained for a small period of time before totally decaying, and in this manner we discern the two fields on the screen simultaneously in spite of the fact that they occur at intervals of fiftieths of a second.

Interlacing

Now, the complete full-line picture or frame is seen because the scanning lines of one field interlace in the spaces between the lines of the partnering field, as shown in Fig. 1.2.

The question now arises as to why go to all the trouble of interlacing the lines of two fields to develop a whole picture when a full-line picture could surely be produced by a single vertical scan simply by doubling the line frequency. It is certainly true that a raster of 405 or 625 lines could be obtained by stepping up the line frequency to 20,250 or 31,250 Hz, while retaining the original 50 Hz vertical frequency. The problem, however, is concerned with the horizontal definition of the picture which is influenced by the speed at which the spot traces out the scanning lines.

The more swiftly the spot moves on the horizontal scanning stroke, the greater the speed at which its brightness needs to change to 'shade in' picture detail on the screen. The brightness change is controlled by the speed at which the level of the vision signals can change in the television system as a whole. Since this in turn is a factor of the system bandwidth, any increase in horizontal scanning speed demands an increase in bandwidth. Decreasing the bandwidth slows down the brightness change of the spot, and the reason for this is considered later. As there is already a shortage of 'radio space' in the television bands, any scheme that increases the bandwidth requirements could never be used.

An alternative is to reduce the vertical frequency to 25 Hz and retain the original line speeds. True, this would eliminate the bandwidth demands of increased line speed, but the slowing down of the vertical scan would produce bad picture flicker, which is troublesome up to about 48 Hz.

Clearly, interlacing solves both of these problems and allows the transmission and reception of good quality pictures within a practical bandwidth at an effectively flicker-free vertical scanning frequency. Although only half the picture information is portrayed at a rate of 50 Hz by interlacing, this represents the flicker frequency in spite of the fact that full-line pictures are produced at the lower rate of 25 Hz.

Camera scanning

The image of a televised scene focused by a television camera is scanned by a focused electron beam in the same way as the screen of the picture tube is scanned. The camera beam, however, does not result in a spot of light, but instead causes the camera to deliver information on that part of the image upon which it is impinging at any instant in time.

This information is given in the form of electrical impulses, and since the camera electron beam is being deflected both vertically and horizontally in exact synchronism with the picture-tube electron beam, the brightness of the scanning spot on the screen of the picture tube changes from instant to instant to match the brightness of that part of the image upon which the camera beam is impinging.

It will be recalled that a microphone translates sound waves into electrical impulses. A television camera does likewise to light waves, but it is impossible to translate vision, as a complete scene, into one signal pattern. This can be done with sound because the signal waveform takes on the exact electrical character of the sound at any moment while it is being translated by the microphone. With vision it is necessary to break down the scene into *elements* and to translate these by the camera to electrical impulses. Each picture element is translated sequentially in time so that a series or train of impulses makes up one line of picture information. On each line scan, therefore, there occurs a series of impulses which are electrically equivalent to the brightness and detail of the scene along each line.

This is where the scanning process comes in. The whole of the image of the scene is scanned at the camera, and electrical impulses are produced during the whole process of scanning. These impulses eventually arrive at the receiver, where they are used to change the brightness of the scanning spot on the picture-tube screen, and since this spot is always in the same relative position on the screen as the focused electron beam in the camera, the image as 'seen' by the camera is unfolded on the picture-tube screen.

Definition

While the vertical definition of a television picture is governed by the number of scanning lines (i.e. the line standard), the horizontal definition is governed by the speed at which the brightness of the scanning spot can change and hence, as we have seen, by system bandwidth. It is possible to secure a very high vertical definition, therefore, simply by increasing the number of lines, while the horizontal definition may be very poor. Apart from deleting the 'line effect', there is little point in increasing the vertical definition of a picture, by increasing the number of lines, beyond the value as fixed by the horizontal definition and available bandwidth. Indeed, if the number of lines is increased without a corresponding increase in bandwidth, the overall definition of the picture will suffer.

Optimum overall definition occurs when the vertical and horizontal definitions are equal.

Picture elements

This can be better appreciated in terms of picture elements. Let us suppose that we have a 405-line picture geared to a raster whose height equals its width. We have seen that there are about 377 active lines in a 405-line picture, so if we multiply 377 by 377 we shall see how many picture elements exist in this square picture. The answer is 142,129.

In this simple illustration it is assumed that the scanning spot has a diameter equal to the width of a scanning line, the latter being based on the height of the screen divided into 377 equal-width strips. Of course, in practice it is the diameter of the scanning spot which determines the width of the lines. A spot a bit too large would cause overlapping of the lines, while one too small would cause gaps between them. It is the job of the picture-tube maker to ensure that the spot produced by his tubes will give an optimum-width scanning line when the tubes are properly applied. Bad circuit design or a set fault can make the spot size too small or too large.

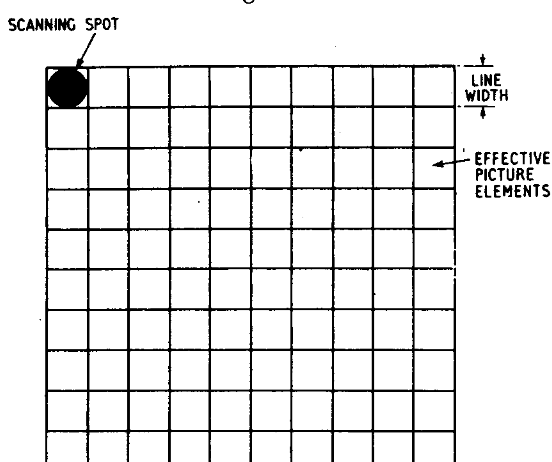


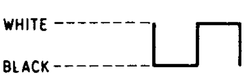
Fig. 1.3. A picture composed of 100 elements. In ideal situations, the scanning spot is the exact size of each element used.

Fig. 1.4. A television line of minimum band-width.

To recapitulate on this picture element business, let us look at Fig. 1.3. Here is represented a very-low-definition 10-line, square picture. It is easier to appreciate the principles involved when the lines are only few, and to get the real results it is necessary only to scale-up the example.

The scanning spot just fills the line width and since there are 10 units vertically (given by the number of lines), balanced horizontal definition calls for a like number of units horizontally. In this example we have a hundred elements in all. It will be understood, of course, that 10 lines on a 17-in. picture tube would call for a mighty large scanning spot, and since the spot cannot define picture detail of smaller size than itself, the resulting picture would, for this reason alone, be of very poor definition!

Anyway, the exercise is now to see what decides the horizontal definition which is established initially by the number of lines (for the horizontal definition should desirably match the vertical definition). This is best done by considering the worst possible picture or pattern to reproduce, which is alternate black and white elements (Fig. 1.4). Now, the controlling signal for the scanning spot brightness to display this pattern over, say, one line is called upon to change from maximum (say, corresponding to white) to minimum (black) five times. The signal waveform could be represented by that in Fig. 1.5. This is a squarewave. One positive-to-negative waveform, as shown in Fig. 1.6, would



(Above) *Fig. 1.5. Line of corresponding signal.*

(Left) *Fig. 1.6. A single black and white element.*

thus handle a black *and* a white element. Thus, our 100-element picture would need 50 such signal cycles to deal with alternate black and white elements over the entire picture.

Bandwidth

Let us suppose that this 100-element picture is geared to a frame frequency of 25 Hz. The total number of black-to-white (Fig. 1.6) waveforms per second would then be equal to 50 times 25, giving 1,250. This represents a squarewave repetition frequency of 1,250 Hz. The bandwidth of the vision channel would thus need to be of such a frequency to pass these 1,250-Hz squarewaves without distortion. In theory, the bandwidth would need to be about 10 times 1,250 Hz, or 12,500 Hz, to secure perfect transitions from black to white and from white to black, as in Fig. 1.4, but in practice a smaller bandwidth is considered adequate, for one would rarely, if ever, wish to transmit a chequerboard pattern over the whole of the screen for sheer entertainment!

A vision bandwidth ten times the squarewave repetition frequency is theoretically required because a squarewave is composed of a fundamental frequency sinewave plus a series of sinewaves equal to the successive odd harmonics of the fundamental. When these harmonics are added to the fundamental sinewave in correct amplitude and phase relationships a squarewave signal results, and the greater the number of harmonics added, the better the squarewave shape. If a squarewave signal is passed through a channel whose bandwidth is below that required to carry all the harmonics, distortion results and the corners of the squarewave are rounded. If the bandwidth is equal only to the squarewave's fundamental frequency, the output signal is of sinewave character. This, of course, is because all the higher-order odd harmonics are suppressed in the channel.

Now, let us get back to a 405-line picture displayed on an ordinary picture tube. Such a picture is not square. Its width is greater than its height. The width-to-height ratio is called the *aspect ratio*, and this ratio is currently 4-to-3 (meaning that