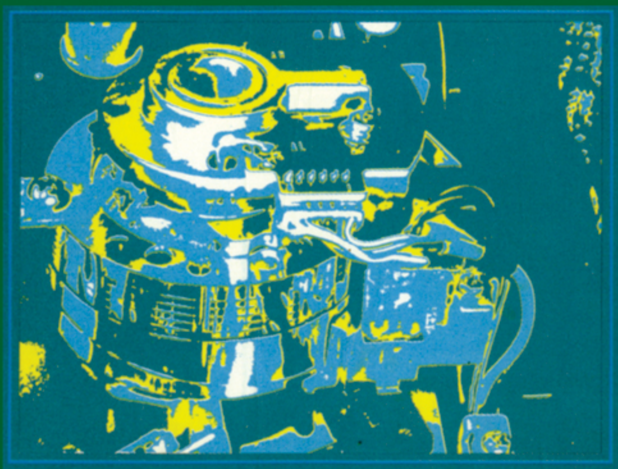
NEWNES GUIDE TO TV & VIDEO TECHNOLOGY



Eugene Trundle

Newnes Guide to

TV and Video Technology

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Preface

This book is a combination of two *Beginner's Guides*: *Colour Television*; and *Videocassette Recorders*. Both books have been overhauled, revised and updated for this single-volume presentation.

Much use is made throughout the book of block diagrams. Since integrated circuits – silicon chips – are now so widespread, much service data are now presented in block diagram form; to explain principles and techniques I have used early 'discrete' circuits, in which the separate functions and circuit elements can be clearly recognised.

This book is aimed at interested laymen, students and technicians and those in allied fields seeking an insight into the technicalities of TV and VTR practice. I have assumed that the reader has a basic knowledge of electrics and mechanics. Although the book addresses itself to domestic products, the line between these and professional gear is now very blurred and ill-defined – the same techniques and even components are used in both these days! Similarly, the various VTR formats are amazingly similar in essence.

For further reading I can recommend my *Television and Video Engineer's Pocket Book* and Steve Beeching's *Videocassette Recorders – A Servicing Guide (3ed)*, both published by Heinemann Newnes. Manufacturers' service manuals and technical training courses are a mine of product-specific information.

My thanks are due to several setmakers for their help and for supplying pictures, individually acknowledged in the captions; and to the Engineering Information Departments of the BBC and IBA.

E. Trundle

1

Basic television

For a reasonable understanding of colour television, it is essential that the basic principles of monochrome TV are known. As we shall see, all colour systems are firmly based on the original 'electronic-image dissection' idea which goes back to EMI in the 1930s, and is merely an extension (albeit an elaborate one) of that system.

Although there are few black and white TVs or systems now left in use, the compatible colour TV system used today by all terrestrial transmitters grew out of the earlier monochrome formats. In the early days it was essential that existing receivers showed a good black and white picture from the new colour transmissions, and the scanning standards, *luminance* signal, and modulation system are the same. What follows is a brief recap of *basic* television as a building block of the colour TV system to be described in later chapters.

Image analysis

Because a picture has two dimensions it is only possible to transmit all the information contained within it in *serial* form, if we are to use but one wire or RF channel to carry the signal. This implies a *dissection* process, and requires a timing element to define the rate of analysis; this timing element must be present at both sending and receiving ends so that the analysis of the image at the sending end, and the simultaneous build-up of the picture at the receiver, occur in synchronism. Thus a television picture may be dissected in any manner, provided that the receiver assembles its picture in precisely the same way; but the path link between sender and viewer must contain *two* distinct information streams: video signal, which is an electrical analogy of the light pattern being sent, and timing signals, or synchronisation pulses, to define the steps in the dissection process. The presence of a timing element suggests that each picture will take a certain period to be built up; how long will depend on how quickly we can serialise the picture *elements*, and this in turn depends on the bandwidth available in the transmission system – more of this later.

Scanning

If we focus the image to be televised on a light-sensitive surface we are ready for the next stage in the dissection process – the division of the pattern into picture elements, or

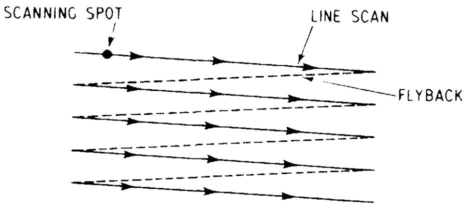

Figure 1.1. The scanning process. Horizontal lines are drawn from left to right of the screen by horizontal deflection, and 'stacked' vertically by the slower-moving vertical deflection field

pixels. Each pixel is rather like the individual dots that go to make up a newspaper photograph in that each can only convey one level of shading. Thus the detail, or definition, in the reproduced picture is proportional to the number of pixels. In 625-line television we have approximately 450 000 pixels, adequate for a 67 cm-diagonal picture, but barely sufficient for much larger screens. These individual pixels are arranged in horizontal lines; there are 625 lines in the British TV system. Figure 1.1 shows how the image is scanned, line by line, to read out in serial form the pattern of light and shade which forms the picture. When half the lines have been traced out the scanning spot has reached the bottom of the picture and traced one *field*. It now flies back to the top of the screen to trace out the rest of the 625 lines in the spaces between those of its first descent. This is known as interlacing, and confers the advantages of a 50 Hz (Hz, Hertz, one cycle per second) flicker rate with the lower scanning speed and lesser bandwidth requirement of a 25 Hz *frame* rate. All TV systems use this 2:1 interlaced field technique; its success depends only on accurate triggering of the field scan.

The camera tube

In practice the image is focused on the internal *target* behind the faceplate of a camera tube, which is usually a variant of the *vidicon* type, illustrated in Figure 1.2. The vidicon has a

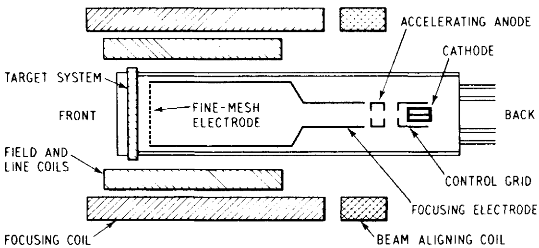

Figure 1.2. Primary elements of photoconductive vidicon camera tube

heated cathode at its back end, in similar style to a picture tube, and this emits a beam of electrons forward towards the target area. A system of electrodes within the tube performs the functions of beam accelerator and electron-lens, so that the beam is brought to pinpoint focus at the target surface.

The scanning action is achieved by suitably-shaped waveforms in the line- and field-scanning coils surrounding the tube. These magnetically deflect the electron beam on its way along the tube so that the interlaced scanning pattern of Figure 1.1 is traced out on the target. To achieve the very small spot size and precise geometry required of the tiny scanning field, a magnetic focusing system is used in conjunction with the electrostatic lens within the tube, and beam focus optimised by adjusting the DC current in the large cylindrical focus coil. Having set up our image-scanning system, we must now see how the image is read out as an electrical waveform.

Target operation

Figure 1.3 represents the equivalent electrical circuit of the target of a photoconductive camera tube. The target consists of a rectangular plate coated with a photoconductive material

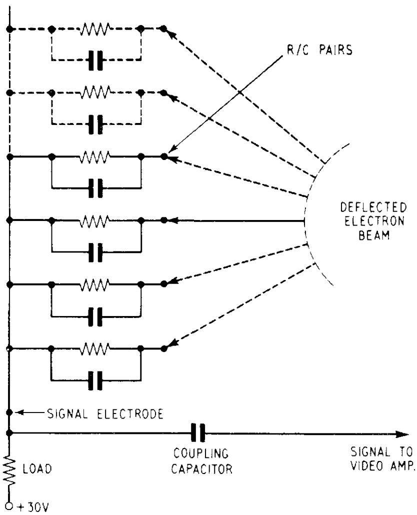

Figure 1.3. Equivalent circuit of photoconductive camera tube, showing the effective RC elements (see text)

such as lead oxide whose electrical resistance in the dark is very high, falling to a low level when light is present on its surface. When a complex pattern of light and shade is present, in sharp focus, each picture element will effectively form a parallel RC pair, as in Figure 1.3, and the charge on the capacitor (formed between the front and back layers of the target coating) will be proportional to the light intensity at

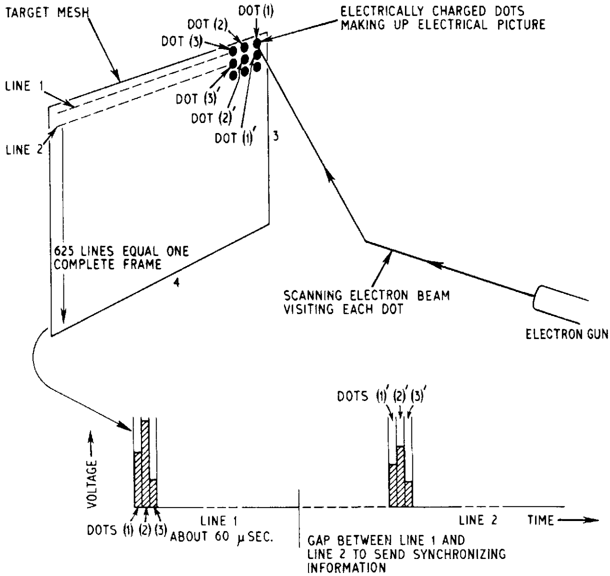

Figure 1.4. Basic principle of scanning at the camera tube

that point. The scanning beam is in effect a conductor, and as it periodically and momentarily picks out each pixel, the capacitor will charge to tube-cathode potential via the electron beam which acts as a conductor. Current for this charging process must come from the target voltage source, so that if we interpose a resistor in series with the positive target potential, we shall develop across it a signal voltage proportional to target current. This is our output signal, an electrical facsimile of the picture element brightness along each line as scanned by the beam. The principle is illustrated in Figure 1.4.

Scanning waveforms

The beam in the camera tube is deflected from right to left of the target (as viewed from within) and its passage takes just 52 μs (μs, microsecond, 0.000001 second) during which it passes across the target at a constant velocity. Having reached the left-hand side, the beam flies back to its starting

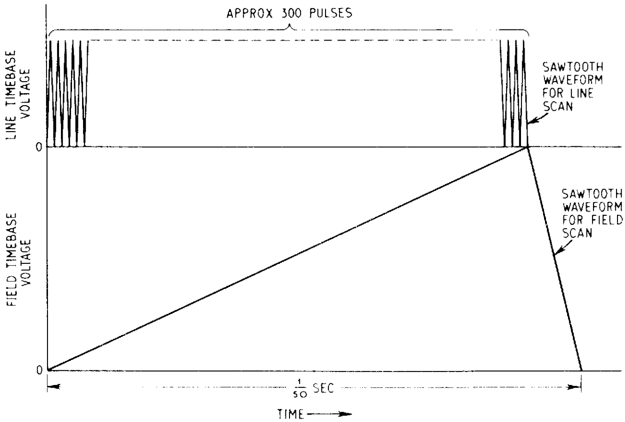

Figure 1.5. Comparison between the time scales of line and field scanning

point on the right, taking about 12 μs to do so. While this horizontal scanning process is taking place, the beam is simultaneously being slowly drawn downwards (by the action of the field deflection coil) until it reaches the bottom of the target after 20 ms (ms, millisecond, 0.001 second) whereupon it is suddenly deflected back to the top (field flyback or retrace) to begin the next sweep. Thus the current waveforms in the deflection coils need to be ramp- or sawtooth-shaped with very linear characteristics, and there needs to be 312½ horizontal sweeps (half the total) to each vertical sweep, as in Figure 1.5.

The video signal

The waveform coming from the vidicon target will be similar to that shown in Figure 1.6, consisting of an *analogue* signal representing the picture pattern, with 'blanks' at 64 μs and

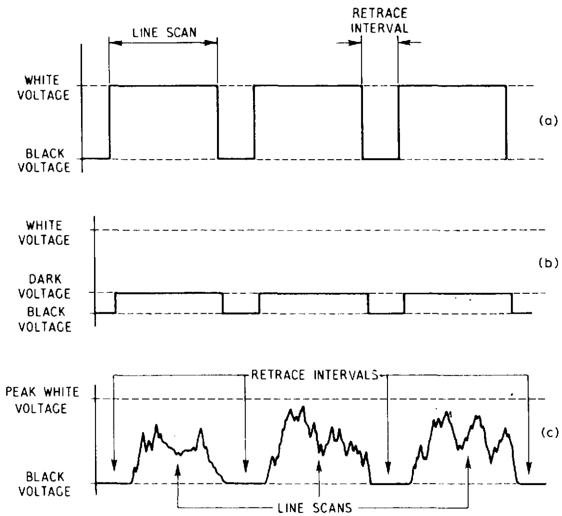

Figure 1.6. Lines of video signal. (a) high brightness. (b) low brightness. (c) picture content

20 ms intervals, during which flyback or *retrace* is taking place. In practice there will be spurious signals during these *blanking* intervals, and these are suppressed in the camera circuit.

Change-coupled devices (CCDs)

An alternative method of televising an image is now commonly used, using a semiconductor pickup device (sometimes called a solid-state image sensor) in place of the traditional thermionic tube. A very small (typically 8×10 mm) sensor 'chip' contains a matrix of many thousands of tiny silicon photodiodes, each of which effectively forms a capacitor whose charge is proportional to the brightness of light falling on it. These capacitors are represented by C1, C2, C3 and C4 in Figure 1.7, which portrays the first four pixels in one television line. C1 will have a charge proportional to the light level on the first pixel, and this will appear as a voltage at the output of the first amplifier A1. If all the switches S1 to S3 are now momentarily closed, the charge on C1 will be passed into C2, whose charge will be transferred into C3 and so on, all the way to the last in the line, at the right-hand side of the

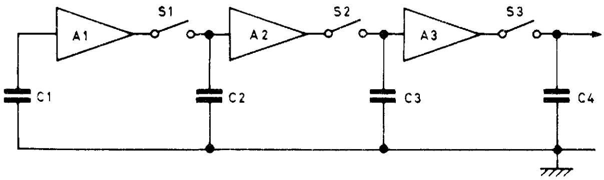

Figure 1.7. The concept of a CCD image sensor. Light patterns are held as charges in the capacitors, one for each pixel

diagram. Thus, by momentarily closing all the switches in synchronism, the brightness level charge for each pixel can be made to 'march' like a column of soldiers to the right where an orderly sequential readout of the light pattern along that line can be picked up, at a rate dependent on the switching frequency. This will form the video signal, with each TV line being read-out in sequence, in similar fashion to a computer's *shift-register.* This is the basis of the operation of a CCD, whose 'scanning' function can be seen to be a *digital* rather than analogue process.

We now have one of our information streams (the video signal), and it's time to insert the second stream (timing pulses) to synchronise the TV receiver. For simplicity, we shall assume that our signal source is a vidicon tube.

Synchronisation pulses

The receiver or monitor which we shall use to display the picture has scanning waveform generators too, and these must run in perfect synchronism with those at work in the camera. This will ensure that each picture element picked up from the vidicon target is reproduced in the right place on the display. Plainly, if the camera sees a spot of light in the top right-hand corner of the picture, and the monitor's scanning spot is in the middle of the screen when it reproduces the light, the picture is going to be jumbled up!

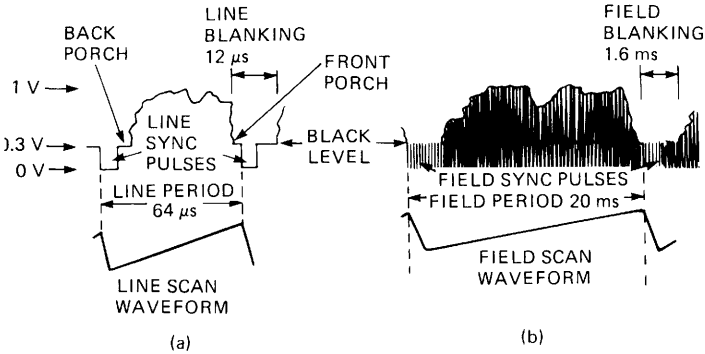

Figure 1.8. The basic analogue TV signal – arrangement of video and sync information and the relationship between signal timing and scanning waveforms

This is prevented by inserting synchronising pulses (sync pulses for short) into the video waveform at regular intervals, and with some distinguishing feature to enable the TV monitor to pick them out. To signal the beginning of a new line scan, we insert a 4.7 μs negative-going pulse into each line blanking period, and to initiate field flyback a *series* of similar, closely-spaced pulses are inserted into each field blanking period. These are shown in Figure 1.8, which represents what is called a VBS (video, black-level and sync) or *composite* video signal. Black level is established at 0.3 V (300 mV) from which the signal rises to 1 V for peak white with lesser brightness levels giving correspondingly lower voltage. Each time a sync pulse occurs, the signal voltage drops to zero for its duration. The timing of the field sync-pulse trains is very critical for good interlace in the displayed picture, and the sync pulse generator is carefully designed to achieve this. The short period preceding the line sync pulse is called the *front porch*, and the rather longer ($5.8\,\mu s$) post sync-pulse period is termed the *back porch*. The time spent on porches and sync pulse is known as the *blanking period*, and it's $12\,\mu s$ between lines, and 1.6 ms between fields, as shown in Figure 1.8. The lower section of the diagram indicates the relationship between sync pulses and scanning current for both camera tube and picture tube.

Picture reproduction

We have now obtained a composite video signal, in a form which conveys both video and timing information. Let us now see how it is used to recreate an image on the screen of a picture-tube. For simplicity, we will assume we have a closed-circuit set-up, and that the camera and monitor are linked by a single coaxial cable. Figure 1.9 shows the arrangement. Here we have, at the sending end, a vidicon tube with the necessary lenses, scan coils and power supplies.

Attendant on it is a master sync pulse generator which triggers the sawtooth generators in the camera and also provides a blanking signal for use in the video processing amplifier. A second pair of outputs from its sync-pulse section is taken to an *adder* stage for insertion into the video waveform, and the composite video signal is passed into the transmission cable.

On arrival at the monitor, the signal is first amplified, then passed to the cathode or grid of the picture tube. A second path is to the *sync separator* stage which works on an amplitude-discriminating basis to strip off the sync pulses for application to the timebase generators. They work in just the same fashion as those in the camera to generate sawtooth

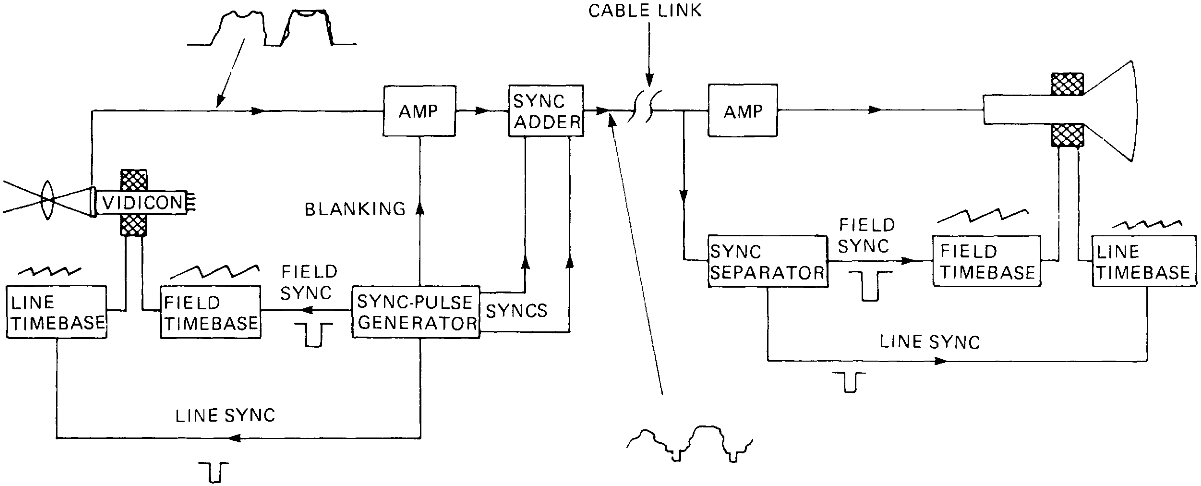

Figure 1.9. A closed-circuit set-up showing derivation and use of the waveforms in Figure 1.8

currents in the scanning coils with which to deflect the scanning beam, but this time in the display tube. Thus we have the two electron beams – one at the sender and one at the receiver – swinging to and fro and up and down in perfect synchronism; and a flow of constantly-changing voltage in the form of the video signal conveying the pattern of light and shade from the vidicon target to the picture-tube screen.

The picture tube

In Chapter 7, we shall study the operation of colour tubes, and as an introduction to these, we need to examine the workings of monochrome tubes – they have much in common! Figure 1.10 shows the basics of a picture tube, which shares many features with the vidicon already described.

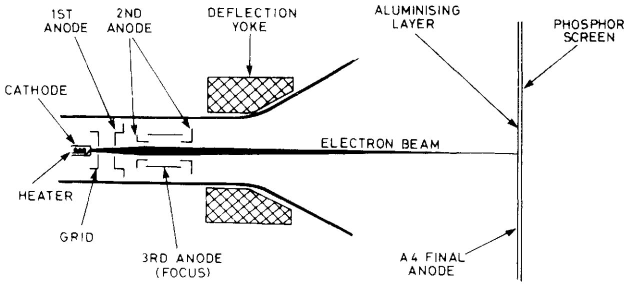

Figure 1.10. The working principle of a monochrome picture tube

The process starts with a heated cathode, from which electrons are 'boiled off' by thermal agitation, to form a *space charge* around the cathode. Depending on the negative potential we choose for the 'grid' (in practice a cylinder surrounding the cathode, with a tiny hole in its otherwise-closed outer face), some of these electrons are attracted away down the tube neck towards the screen by the highly-positive anode cylinders, some of which are shaped and arranged to form an electron-lens whose focal point is the inner surface of the display screen. As the electron beam passes into the 'bowl' of the picture tube it comes under the influence of the scanning coils which deflect the scanning spot, at line and field rate, to trace out a rectangle of light, known as a *raster*, on the inner face of the tube. The screen is *aluminised*, and the thin aluminium layer is held at a potential of several thousand volts with respect to the cathode – this gives an accelerating 'boost' to the electrons in the beam, so that they collide with the phosphor screen surface at very high velocity indeed.

How is the light produced? The inner surface of the faceplate is coated with a continuous layer of *phosphor* which has the property of emitting white light when a high-velocity electron beam impinges on it. The aluminised screen backing reflects the light forward, and forms a barrier to prevent harmful ions burning the screen. The light output is regulated by varying the beam current, and as we have seen, this is the primary function of the 'grid' cylinder. We can arrange a fixed bias on this electrode to set the overall raster brightness, then feed a video signal to it (normally about 80 V peak-to-peak is required) to instantaneously vary the beam current to trace out, and faithfully copy, the brightness of each individual pixel as it is positioned on the screen by the scanning system.

Bandwidth

The scheme outlined so far describes the stages in capturing, relaying and reproducing the picture. We have given little thought as yet to the requirements of the transmission medium, be it a cable, space or a glass fibre!

Mention has already been made of pixels, and the more we have, the faster the rate of change of the video facsimile signal. Much depends on the scanning rate, and this has to be faster that a certain minimum to avoid a disturbing flicker effect in the picture. By using the interlace technique we achieve 50 'flashes' per second, and this is just sufficient to accommodate the human eye's 'time-constant', known as *persistence of vision*. To capture reasonable detail we need all of 625 lines (in fact only about 575 of them are used for the picture itself) and this means that if the 450 000 or so picture elements are each different from their neighbours, the rate of change of the video signal needs to be in the region of 5.5 MHz (MHz, megahertz, one million cycles per second).

Let us look more closely into the reasons for this. If we are televising a picture of a black cat on a white carpet, the rate of change of the video signal will be very low except at the point of the scanning spot's transitions from carpet to cat and back again, each of which will give rise to a sudden *transient*. At the other extreme, if the camera is looking at a pattern of fine vertical lines the video signal will be much 'busier' and contain a great deal of HF energy. In practice the frequencies in the video signal are mostly related to line and field scanning rates, and much of the energy in a video signal is concentrated into 'packets' centred on multiples of line and field frequency. This is an important point, and one to which we shall return.

Modulation

The word modulation, in our context, means the impressing of a signal waveform (usually video, sound or digital pulses) onto a *carrier* wave. The nature of the carrier wave is dependent on the medium to be traversed – space, cable, optical fibre; the distance required to be covered; and to a lesser extent, the nature of the information to be carried. Thus the medium-wave sound broadcast band (MF, medium frequency) is suitable for long-distance broadcasts of rather indifferent-quality sound signals, but quite useless for television; at the other extreme, the SHF (super-high frequency) band is well-suited to a 'beamed' television broadcast service from an orbiting satellite, but one wouldn't expect to find Radio Brighton up there as well! So far as the studio and viewer are concerned, the carrier is irrelevant, because it acts purely as a vehicle on which the wanted signal travels, being discarded at the receiving end once its usefulness has been realised.

Types of modulation

The four types of modulation used in communications to attach information to a carrier wave are (a) amplitude modulation, (b) frequency modulation, (c) phase modulation (which is a variant of *b*), and (d) pulse-code modulation. In ordinary sound broadcasting (a) or (b) is normally adopted, the former at LF, MF and HF, and the latter at VHF (very high frequency, around 100 MHz). In *terrestrial* TV broadcasts, (a) is used for vision and (b) for sound. In fact, television uses all four modulation modes, because a form of phase modulation is used for the colouring signal, as we shall see in later chapters, and some modern TV links also make use of PCM.

Amplitude modulation

AM is amongst the earliest forms of modulation to be used, and probably the easiest to understand. It is perhaps surprising that this was pre-dated, however, by PCM (*d* above) in that the very first crude spark transmitters used this mode, conveying the message by simply interrupting the transmitter's operation by means of a morse key! We use AM for the vision signal in terrestrial TV broadcasts; let's see how it is arranged.

For AM, we start with a stable oscillator to generate the carrier wave. For TV broadcasts, the crystal oscillator runs at a sub-multiple of the station frequency, and its output is multiplied up to the required frequency (corresponding to the specified channel number). The information to be sent is made to vary the *amplitude* of the carrier wave, so that in our example of a TV broadcast, the waveform of Figure 1.8 is fed to a *modulator* which may control the *gain* of an RF amplifier which is handling the carrier wave. Thus the video signal is impressed onto the carrier, and the polarity of the video signal is arranged to give *negative modulation*. This means that the tips of the sync pulses give rise to maximum carrier power, and whites in the vision modulating signal raise only about one-fifth of that level. This is illustrated in Figure 1.11 which represents the waveform fed to the UHF broadcasting aerial, and present in the tuner and IF sections of a conventional TV receiver.

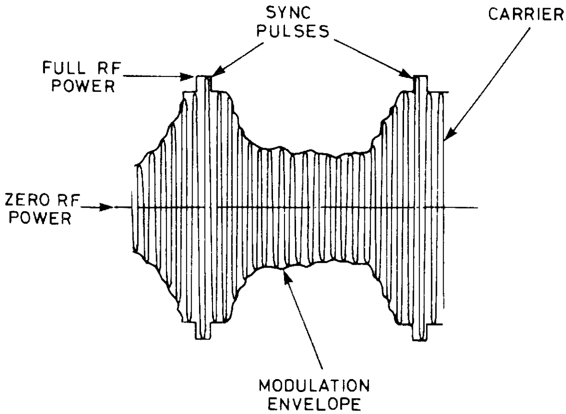

Figure 1.11. AM modulation of the video signal onto an RF carrier for transmission

One of the advantages of AM is the simplicity of the detection or *demodulation* process, which in its original form requires only a rectifier and filter to recover the modulating information.

Frequency modulation

This is the second most popular mode for broadcast use, and is used for high-fidelity (hi-fi) sound transmissions in VHF Band II. Most of these radio transmissions are multiplex-stereo-encoded. So far as we are concerned here, the most significant use of FM modulation is for the TV sound transmissions which accompany 625-line UHF picture broadcasts, and for vision broadcasts from satellites. In this type of modulation the carrier amplitude is kept constant and the frequency of the wave is varied at a *rate* dependent on the frequency of the modulating signal and by an *amount* (deviation) dependent on the strength of the modulating signal (see Figure 1.12). Thus the 'louder' the signal the greater the deviation, while the higher its frequency, the greater the rate at which the carrier frequency is varied either side of its nominal frequency.

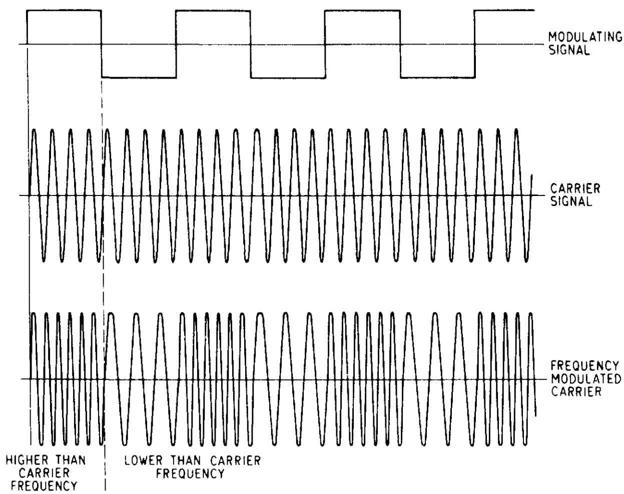

Figure 1.12. Illustrating frequency modulation

Maximum deviation of the TV sound carrier is about ±50 kHz (kHz, kilohertz, one thousand cycles per second) corresponding to maximum modulation depth of this particular system, commonly described as 100 per cent modulation. 100 per cent amplitude modulation is when the troughs of the modulated waveform fall to the zero datum line. This is the absolute physical limit for AM.