A number of different standards for black and white (or "monochromatic") television are at present in force. Several European countries (including the Netherlands and West Germany), and also one or two countries outside Europe, have adopted what is known as the Gerber standard 1), a 625-line system. Before this standard was accepted by the Comité Consultatif International des Radiocommunications (C.C.I.R.) (October 1950), an experimental transmitter designed by Philips to a standard having much in common with the American system was operated at Eindhoven. (The Philips transmitter differed in respect of the number of lines (567) and the numbers of complete pictures per second (25); the American system uses 525 lines and 30 pictures per second.)

Articles describing a TV receiver for the 567-line system 2) appeared in this Review, and in another publication, in 1948.

In Table I some characteristics of the major television standards are listed. Certain consequences of these characteristics which are of particular interest to the designer of TV receivers will now be discussed. The channel-width, method of picture-modulation, and system of sound-modulation will be discussed.

**Channel-width**

The following features are common to all the different standards.

1) Amplitude modulation and vestigial side-band transmission are employed for the video signal (fig. 1). b) The ratio between width and height of the picture is 4:3. c) Scanning is interlaced in an odd-even pattern. d) The number of complete pictures per second is 25 (except in the American system, where it is 30, so as to enable the frame frequency to be synchronized with the mains frequency, which is 60 c/s in America).

It will be seen from table I that in general the channel-width increases with the number of lines. The necessity for this may be seen as follows. The greater the number of lines employed, the higher the vertical definition of the picture. Logically, then, the horizontal definition should increase in the same proportion. Accordingly, the number of elements into which the picture is resolved during scanning increases as the square of the number of lines. The information contained in the video signal is proportional to the number of picture elements, and

1) So named after the Chairman of the C.C.I.R. sub-committee which proposed this standard; see Standards for the international 625-line black and white television system, C.C.I.R. Geneva, 10 October 1950.

the bandwidth should be proportional to this information.

However, the table shows that this general rule is not invariably followed. Whereas the French standard of 819 lines specifies a channel-width of 13.15 Mc/s, according to the Belgian standard for Walloon transmissions (likewise 819 lines) 7 Mc/s is sufficient. Thus, in this Belgian system, some of the picture information is sacrificed for the sake of economy of channel-width.

As will be seen from fig. 1, and from the table, the frequency-interval between the vision and sound carriers should increase with the bandwidth.

**Video modulation system**

In principle, the amplitude of the vision carrier can be varied by the video signal in two ways, i.e., by positive or negative modulation (figures 2a and 2b, respectively). Peak R.F. amplitude corresponds to "white" in the picture in the case of positive modulation and to "blacker-than-black" in that of negative modulation.

The direction of the modulation determines the measures by which interference from such sources as sparking commutator motors and car ignition systems may best be suppressed in the receiver. Such interference is in the form of pulses which, in unfavourable circumstances, may attain an amplitude far exceeding the peak value of the carrier. Interfering pulses of this type are shown at the points i in fig. 2a and 2b.

**Visible interference in the form of spots**

Pulse-shaped interfering signals appear on the picture as spots, which are mainly white when positive modulation is employed, and mainly black with negative modulation.

The luminance of the white spots associated with positive modulation may greatly exceed that of the brightest parts of the picture itself. If the particular interfering pulses are strong enough to drive the picture tube into grid current, the electron beam will fail to focus sharply, and the white spots will grow into bright discs. To avoid this, receivers for positive modulation are often fitted with limiters; such limiters are included in the circuit preceding the picture tube, to cut off any interference above a given level. In some cases, the cut-off level is variable.

As mentioned above, in the case of negative modulation, the spots produced by interfering pulses are mainly black. Occasional white spots also occur, but, provided that the "white" corresponds to nearly zero modulation of the carrier, they cannot become very much brighter than the brightest parts of the picture itself (fig. 2b).

**Effect of interference on synchronization**

The horizontal and vertical deflection of the electron beam is synchronized by special signals included in the envelope of the transmitted television signal. Line synchronizing signals, for example, are rectangular pulses (fig. 2), whose steep leading edges initiate the flyback of the beam.
The interfering signals are likewise steep-sided; hence, of course, they are quite capable of disorganizing the synchronization completely, and thus mutilating the picture beyond recognition. Experience has shown that this is far more likely to happen when negative, than when positive, modulation is employed, owing to the fact that in negative modulation the interference pulses are predominantly in the same direction as the sync. signals, whereas in positive modulation it is the opposite. Accordingly, measures to minimize the effect of interfering pulses in the sync. circuit are particularly necessary in receivers designed for negative modulation, where the amplitude of such pulses may greatly exceed that of the sync. pulses. Such measures include the use of:

a) a so-called “flywheel circuit” for horizontal deflection;

b) an integrating circuit for vertical deflection;

c) a noise-inverter circuit, to act upon the synchronizing signals before they are separated.

The flywheel method of synchronization has been described in detail in an earlier issue of this Review and need not be discussed here. However, it is worth mentioning that in some cases this method is also employed in conjunction with positive modulation, for the following reason. A weak incoming signal is invariably associated with a relatively high noise level, which makes the edges of the sync. pulses irregular and vague. This upsets the timing of the electron beam in the picture tube, so that it starts to scan some of the lines at the wrong moment. The result is a horizontal displacement of the scanning lines relative to one another and “tearing” at the vertical sides of the picture, and at the vertical edges of individual objects in the picture. This “frayed” effect can be avoided by employing a flywheel circuit for horizontal deflection.

For the vertical deflection, an integrating circuit inserted between the sync. pulse separator and the saw-tooth generator is recommended, because pulses of short duration contribute virtually nothing to the output voltage of such a network, and are therefore unlikely to affect the frame synchronization.

In TV transmitters with negative modulation, the framesynchronizing signal is preceded by so-called equalizing pulses, whose function is to help to maintain the interlacing when an integrating circuit is used. Equalizing pulses are not transmitted in the British system (positive modulation), but integrating networks are nevertheless used in some British-made receivers to stabilize the frame synchronization during periods of heavy interference.

As already mentioned, the synchronization of negative modulation systems is in principle more sensitive to interference than that of systems in which positive modulation is employed. However, it is possible to remove this disadvantage of negative modulation by providing the receiver with a noise-inverter circuit; this changes the sign of those interfering pulses which extend above a certain critical signal-level. After passing through the video amplifier, the signal voltage is fed both to the picture tube direct and to the sync. separator via the noise inverter. Hence the signal and the interference pulses must pass through the latter to reach the sync. separator.

The above-mentioned critical level is established as accurately as possible at a value just above the peaks of the sync. signals. As regards synchronization, the negative modulation system then has all the favourable characteristics of positive modulation.

The amplified video signal, of course, applied direct to the picture tube, by-passing the inverter circuit, so as to preserve what is really the most favourable feature of negative modulation, i.e. that the spots produced in the picture by interference pulses are mainly dark and quite small.

Effect of interference on automatic gain control

Television sets designed to receive signals on more than one channel are preferably equipped with A.G.C., that is, a system controlling the amplification of the receiver in such a way that the strength of the output signal is virtually unaffected by variations in the strength of the input signal.

The most suitable measure of signal strength is a particular level of the television signal not governed by the gradation of the picture. In the case of negative modulation, then, the peak of the synchronizing pulses is the obvious choice. In principle, a D.C. voltage extracted from the input signal of the video detector by means of a simple peak-voltage rectifier could be employed as a control voltage for the vision amplifier, but in practice this simple arrangement is rendered completely ineffective by strong interference, owing to the fact that the rectifier then responds to the relatively higher peaks of the interfering pulses rather than to those of the sync. pulses. This causes an undue decrease in amplification, which may even be sufficient to fade out the picture altogether. To avoid this, a gate valve is included in some circuits. The control grid of this valve is so biased as to pass current only during the sync. pulses. Any interference occurring in the intervals between sync. pulses is then entirely
innocuous. Provided that the rectifier has a fairly low time constant (i.e. smaller than approx. 5 x the line period), the effect on the control voltage of any interference happening to coincide with the sync. pulses will be negligible.

Fig. 3. Above: Vision signal with positive modulation, in the region of a line-synchronizing pulse (s). a black level, b blanking level. Below: Keying pulse to operate the A.G.C. valve within the period of the blanking signal.

In the case of positive modulation, the level of the blanking signal (fig. 3), that is, the signal immediately preceding and following each sync. pulse to conceal the flyback of the scanning spot in the picture tube, may be employed as a reference level independent of picture gradation. The control voltage is extracted from this level by means of a gate valve operated intermittently by the successive line-synchronizing pulses. Since these pulses precede the blanking signals, they must be displaced slightly in time by means of a delay network. As in the case of negative modulation, interference other than that coinciding with the keying pulses cannot affect the control voltage.

Sound modulation

Frequency-modulated systems

Frequency modulation of the sound signal in a television system offers certain advantages as compared with amplitude modulation. Firstly, we have the well-known advantage of frequency modulation in general, that is, the relatively small amount of noise and interference involved. To this may be added, in the case of television, that frequency modulation enables the receiver to be so designed that the tuning is relatively less critical, so that a certain amount of frequency drift in the local oscillator is allowable and that microphony of the oscillator is inaudible.

The particular television system employed to ensure these advantages is known as the "intercarrier sound" system; the principle of this system may be explained with the aid of the block diagram shown in fig. 4. As will be seen from this diagram, the sound signal in the stages up to and including the video detector (Dvid) is amplified by the same R.F. and I.F. amplifiers as the vision signal. The mixing of these two signals produces at the output of the video detector a signal — the "intercarrier signal" — whose average frequency f1 is equal to the difference between the frequencies of the sound and vision carriers, that is, 5.5 Mc/s according to the Gerber standard, and 4.5 Mc/s according to the American system (Table I).

This intercarrier signal varies in frequency with the sound modulation and in amplitude with the video modulation, since the sound and video signals applied simultaneously to the vision detector are respectively frequency-modulated, and amplitude-modulated.
The intercarrier signal passes via an amplifying stage \((MF_a)\) to a frequency detector \((D_s)\), which produces the audio signal and at the same time suppresses the (unwanted) amplitude modulation. A suitable rejection filter in the video amplifier \((A_{vid})\) prevents the intercarrier signal from reaching the picture tube and so interfering with the picture.

Television receivers are invariably tuned entirely by sound, this being far more critical than tuning to the vision signal since the sound channel covers a much narrower band. Receivers without intercarrier sound are especially critical in this respect by reason of the fact that the difference of the local oscillator frequency and the average frequency of the sound carrier must lie within the relatively narrow band (about 100 kc/s) covered by the particular I.F. amplifier in the sound channel. In receivers with intercarrier sound, on the other hand, the average frequency of the intercarrier signal \((f_i)\) is fixed (5.5 or 4.5 Mc/s), regardless of the oscillator frequency; hence it is possible to detune the oscillator appreciably (e.g. 500 kc/s) without losing the sound.

Naturally, such a receiver exhibits a similar insensitivity to deviations from the correct oscillator frequency arising from causes other than deliberate detuning, e.g. frequency drift produced by temperature variations in the local oscillator, or frequency modulation by microphony in the oscillator valve.

Against the above-mentioned advantages of intercarrier detection we must set certain disadvantages, some of which, however, can be avoided. For example, if the percentage modulation of the vision carrier is very high, the amplitude of this carrier corresponding to white in the picture will be very low; the same applies to the amplitude of the intercarrier signal. In the extreme case, i.e. 100% modulation, the intercarrier signal disappears during the scanning of white areas; hence the frequency detector has no signal to detect and the sound is temporarily interrupted. This interruption causes a highly irritating buzz (if the entire picture area be white, the television signal in the case of 100% modulation will consist solely of sync. pulses, and the frequency of the buzz will be the same as that of the frame-sync. pulses). It is prescribed, however, that the amplitude of the vision carrier may in no circumstances be less than a given fraction, e.g. 10%, of the maximum amplitude occurring during the sync. pulses (fig. 2b). Hence the above-mentioned buzzing noise can be avoided provided that the transmitting station complies with this standard, and that the receiver satisfies the two conditions which will now be defined.

Firstly, the receiver must be so designed that even at the maximum depth of modulation the intercarrier signal is strong enough to ensure proper operation of the frequency detector. Secondly, the selectivity of that part of the receiver preceding the video detector must be such as to ensure that the amplification of the sound signal will invariably remain roughly 10 times (that is, about 20 dB) lower than that of the vision signal (fig. 5). The ratio required also depends on the strength-ratio of the vision and sound signals at the aerial terminals of the receiver, and on the extent to which the amplitude modulation is suppressed by the frequency detector.)

Unlike the above-mentioned intercarrier buzz, there is another disadvantage of intercarrier sound which cannot be avoided. This is the fact that failure of the picture transmitter is invariably accompanied by the total elimination of sound, so that any announcement concerning such a failure broadcast from the transmitting station is not heard by viewers whose sets are equipped for intercarrier detection. However, this is a minor drawback as compared with the advantages of the system. The intercarrier system is therefore employed in all Philips television receivers for TV systems with frequency-modulated sound.

**Amplitude-modulated systems**

Intercarrier sound is not applicable to systems with an amplitude-modulated audio channel owing to the fact that the intercarrier signal would here vary in amplitude with the sound as well as with the vision signal, thus preventing any separation of the two modulations. Fig. 6 shows the method of detection employed in conjunction with amplitude-modulated sound. The mixer valve \((M)\) produces an I.F. vision signal and an I.F. sound signal; the sound signal is amplified by a separate
Fig. 6. Block diagram of a receiver for television systems with amplitude-modulated sound. HF radio-frequency amplifier stage, M mixer stage, O local oscillator, MF₁ first intermediate-frequency amplifier stage, for both vision and sound; MF₂ second and MF₃ third intermediate-frequency amplifier stages, for vision alone, AVid video detector, D₀ amplitude detector for sound, AF audio-frequency amplifier, L loudspeaker.

I.F. amplifier (MF₄) and detected by an amplitude detector (D₀). In most cases, however, the first I.F. valve (MF₁) can be used to amplify both signals, without interference from cross-modulation; the subsequent I.F. stages for amplification of the vision signal (MF₂ and MF₃) must then include filters to adequately suppress the I.F. sound signal. In other words, the selectivity characteristic should be such that the amplification of the sound signal is at all times a factor of 150-250 (or 44-48 dB) lower than that of the vision signal (fig. 7).

Detuning by one or two hundred kc/s is enough to eliminate the sound; hence steps must be taken to avoid frequency drift and microphony in the local oscillator.

Summary. A survey of the principal television standards at present in force is followed by an analysis of certain associated problems which are of special interest to the designer of television receivers. The points considered are: 1) Channel width; 2) Positive or negative picture modulation in relation to the visibility of interference and the effect of interfering pulses on synchronization and automatic gain control; 3) The system of sound transmission, that is to say, by frequency modulation or amplitude modulation; in connection with frequency modulation, the method of "intercarrier sound" is discussed.