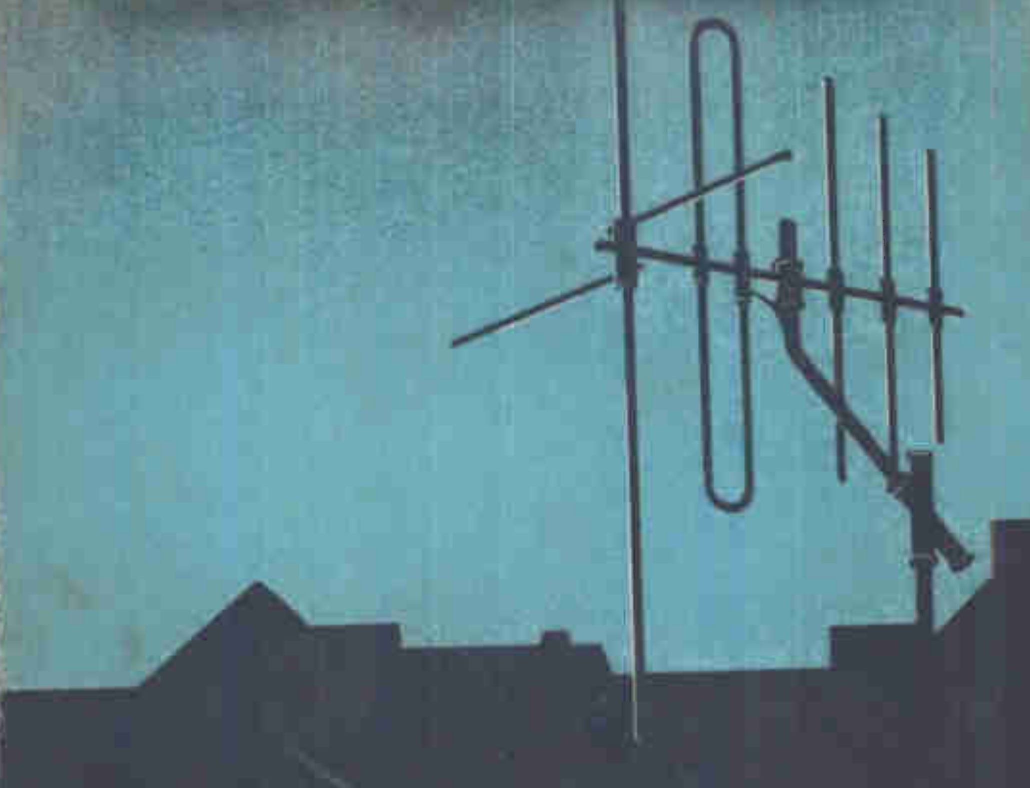
TELEVISION EXPLAINED



By W. E. MILLER M.A. (Cantab) M. Brit. I.R.E.

Revised by

E. A. W. SPREADBURY M. Brit. I.R.E.

Associate Editor "Wireless & Electrical Trader"

ABOUT THIS BOOK . . .

THIS is the seventh edition of a book specially designed for those requiring technical information on domestic television presented in a simple, straightforward manner. The main difference between this edition and the previous one is that a chapter has been included on combined television and F.M. receivers; though the opportunity has been taken to revise the rest of the book where necessary to bring it up to date, and thus keep pace with the constantly changing pattern of the services available to the television viewer.

The book was first published in 1947 under the authorship of Mr. W. E. Miller, the Managing Editor of "The Wireless Trader", who took it through five editions. Because of his increasingly heavy commitments he was unable to continue with the work of revision, so Mr. Spreadbury, an Associate Editor of the same Journal, and well known to a wide circle of readers, was invited to produce the sixth edition. This was a major task because of the number of important changes that had taken place since the publication of the previous edition. That he succeeded is borne out by the fact that the new edition sold out so quickly, necessitating the present one, which is also due to Mr. Spreadbury. He has made every endeavour to maintain the original style, which has made successive editions so deservedly popular.

This book assumes a knowledge of the ordinary sound radio receiver, but no previous knowledge of television circuits. It is non-mathematical, written in simple language, and comprehensively illustrated by many diagrams and photographs. It will prove of great assistance to all students of television, to radio service engineers who wish to embark upon television work and want to understand the principles and circuits involved, and to knowledgeable owners of television receivers who would like to understand the working of their sets.

Contents: Aerials, The Signal, The Receiver Outlined, Single-Channel Receivers, 5-Channel Tuning in Band I, Multi-Channel Tuners, The Vision I.F. Amplifier, Video and Sound Circuits, The Cathode-ray Tube, Time-base Oscillators, Time-base Output Circuits, Synchronization, Automatic Gain Control, TV F.M. Receivers, Receiver Installation and Operation, Test Card "C", Fixed Attenuators.

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TELEVISION EXPLAINED

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RADIO CIRCUITS

W. E. Miller

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E. A. W. Spreadbury

F.M. EXPLAINED

E. A. W. Spreadbury

TELEVISION RECEIVER SERVICING

Volumes 1 & 2

E. A. W. Spreadbury

TELEVISION EXPLAINED

W. E. MILLER
M.A. (CANTAB.), M.BRIT.I.R.E.

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Associate Editor of "Wireless and Electrical Trader"

LONDON: ILIFFE & SONS LTD.

First Published 1947

*Published for "Wireless & Electrical Trader" (Trader Publishing Co. Ltd.) by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.*1.
Made and Printed in England at The Chapel River Press, Andover, Hants
BKS 3578

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PREFACE TO THE SEVENTH EDITION

GREAT CHANGES HAVE TAKEN PLACE in the design of television receivers since the publication of the early editions of this book, owing mainly to the introduction of an alternative television programme and the consequent necessity for design features that enable the non-technical user to tune his receiver from one transmission to another. This involves switched tuning, automatic gain control, an increased use of flywheel synchronization, and dual aerial systems, and the differences in technique are accentuated by the location of the alternative programme in the very high transmission frequency region of Band III.

In addition, in this seventh edition, there is a new chapter on combined television and F.M. radio receivers, while other parts of the book have been brought up-to-date to keep pace with the constantly changing pattern of the services available to the television viewer.

As in previous editions, in explaining the principles of television receiver circuits, a knowledge of ordinary sound radio receivers is assumed, but no previous knowledge of television circuits is necessary for an understanding of the text. The complete receiver is described stage by stage, and it is hoped that the method adopted of splitting this up into a number of more or less self-contained separate units will help the reader to understand the complete receiver more easily.

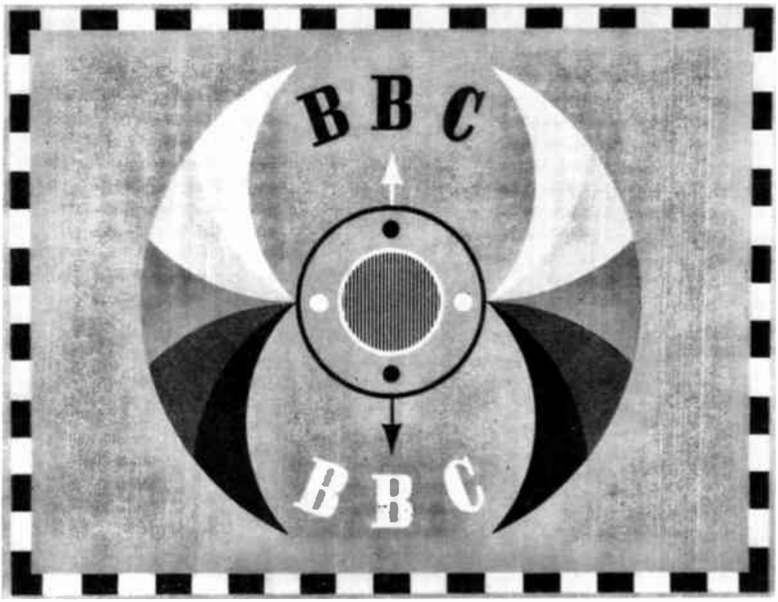
The book is intended to be of assistance to students of television, to radio service engineers who wish to embark upon television service work and want to understand the principles and circuits involved, and to the knowledgeable owners of television receivers who would like to find out how their sets work.

E. A. W. S.

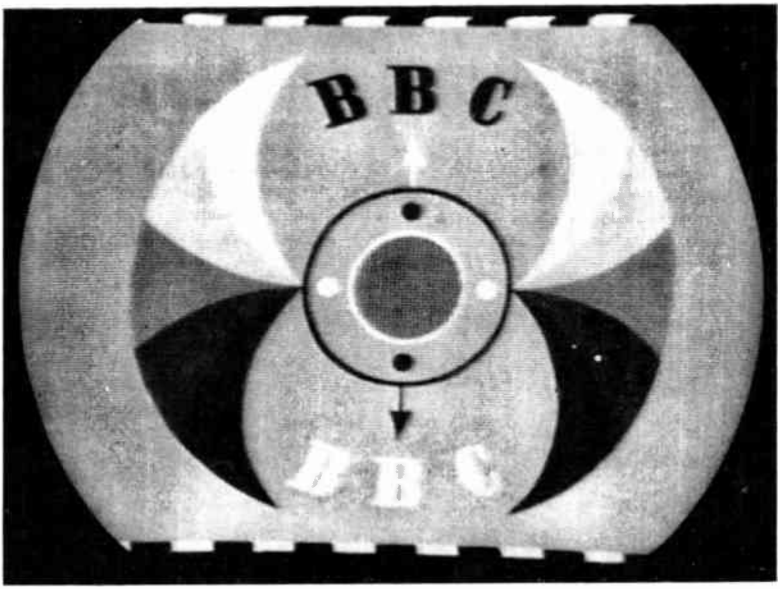
*Dorset House, London, S.E.*1.
February, 1960.

CORRECTING PICTURE FAULTS

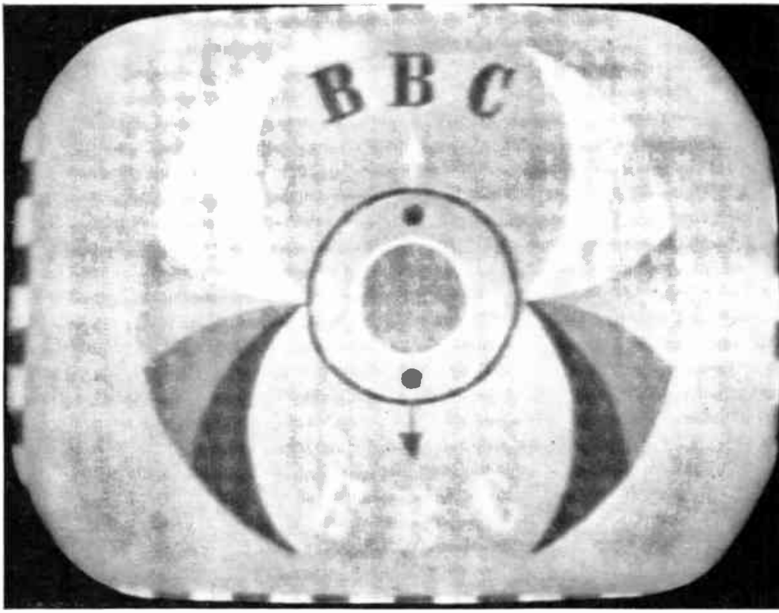
Photographs in the following eight pages show the effects of maladjustment of the adjustable controls on a television receiver. The subjects of the pictures are early B.B.C. tuning signals, which are no longer used, but they are retained because they show the effects on a normal picture better than does the latest tuning signal, which is a line drawing with no half-tones.



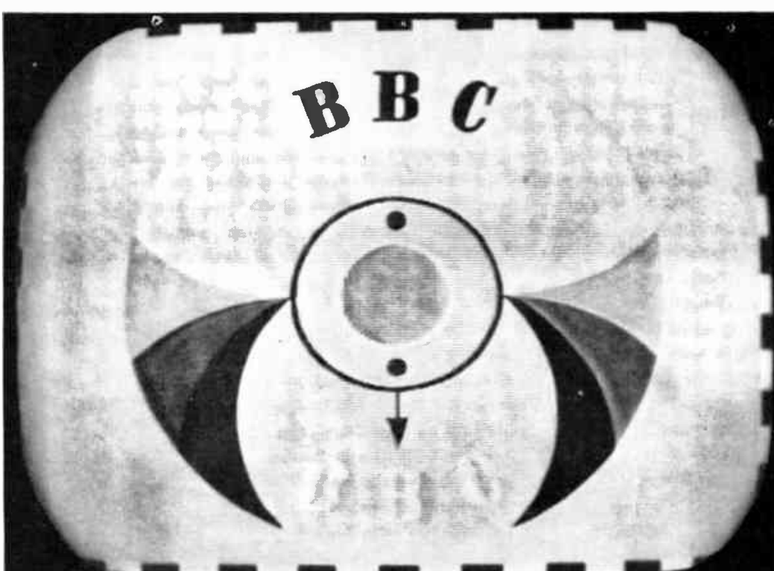
The B.B.C. tuning signal, as transmitted



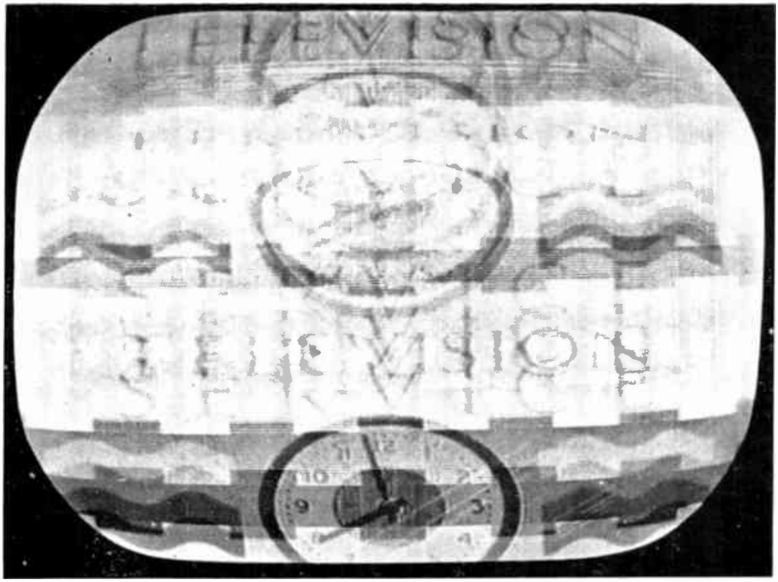
A reasonable reproduction of the tuning signal as received on an average receiver when the controls are adjusted properly



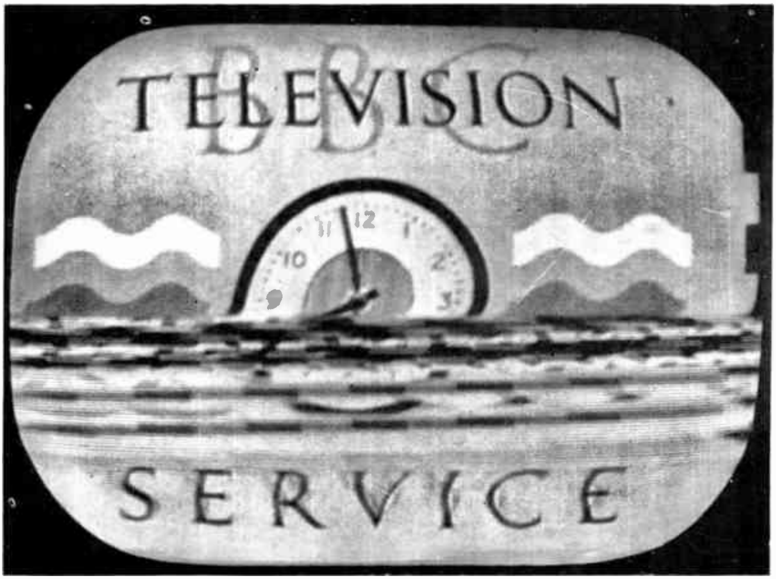
Too much brightness, showing flyback lines at the top, and too little contrast



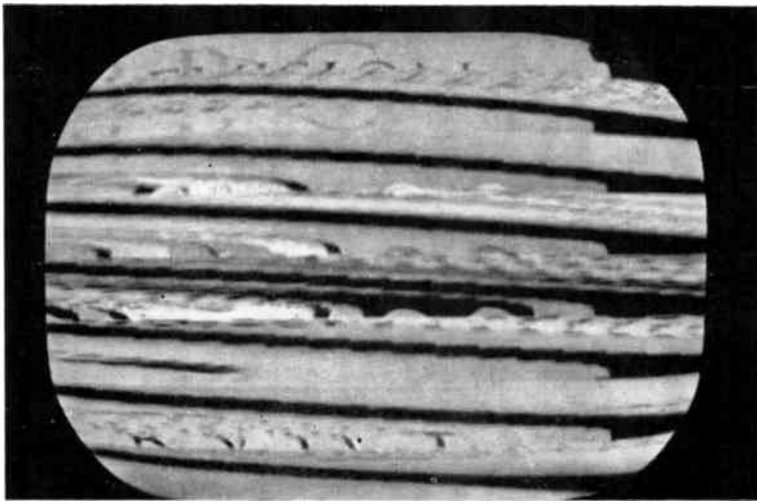
Too much contrast, giving a " soot and whitewash " effect



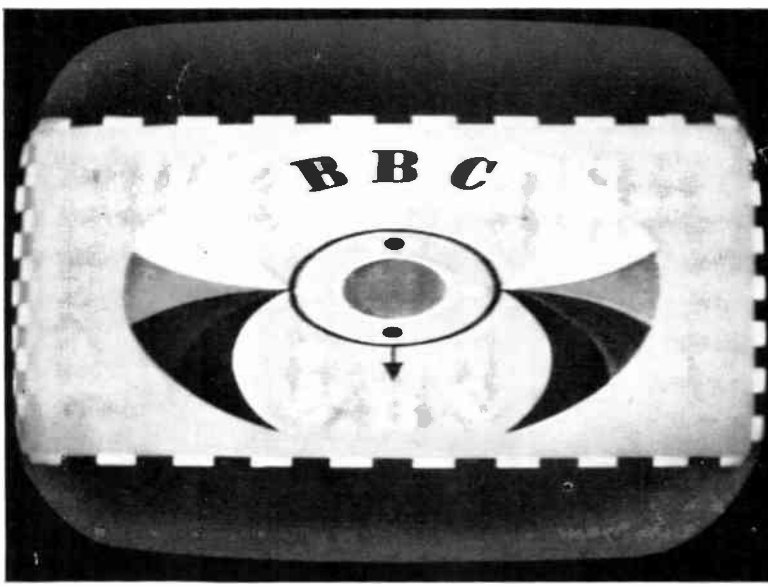
Effect of frame slip through loss of frame hold. Adjust frame (or vertical) hold control



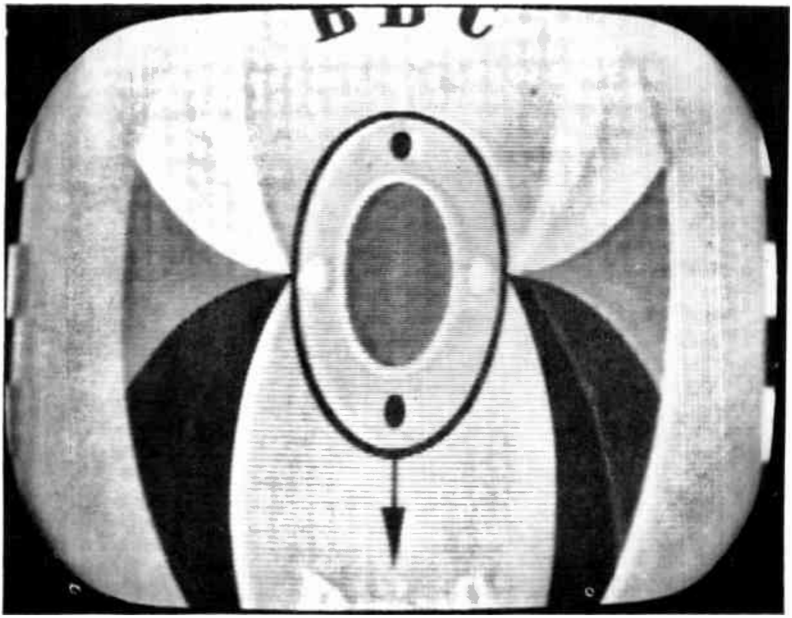
Effect of partial line slip. Adjust line (or horizontal) hold control



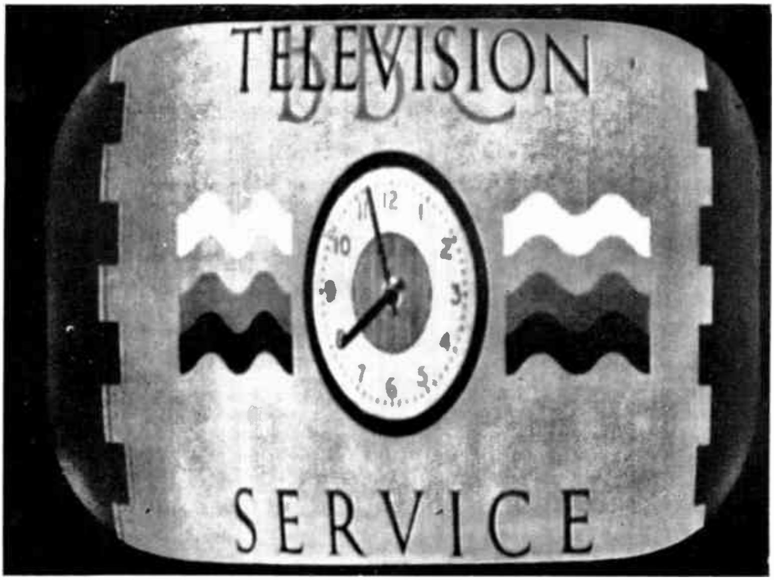
Here the picture is slipping badly in a horizontal direction. Adjust line (or horizontal) hold control



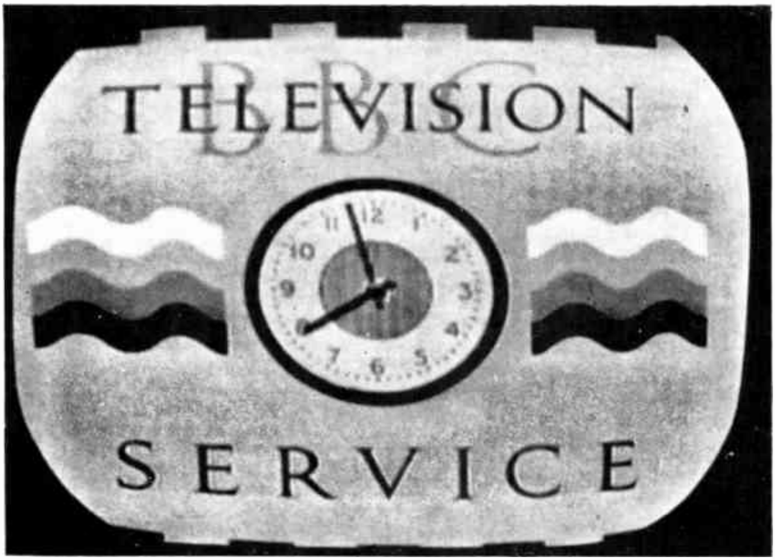
Picture too shallow. Adjust height (or frame amplitude) control until the pattern is circular



Picture too deep. Adjust height (or frame amplitude) control until pattern is circular

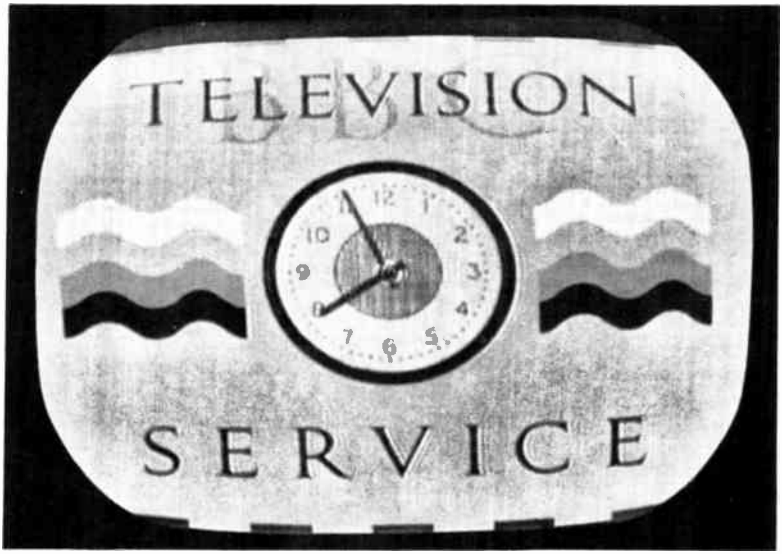


Picture too narrow. Adjust width (or line amplitude) control until the circle is correctly shaped

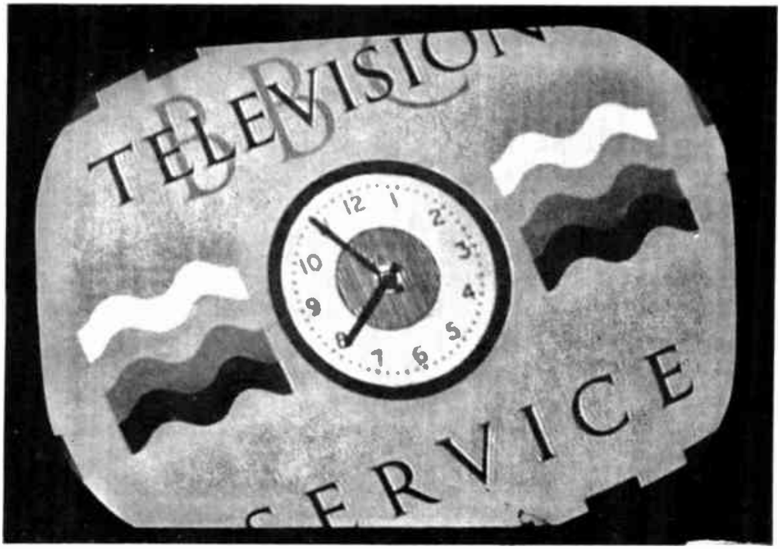


Picture slightly too wide. Adjust the width (or line amplitude) control until the circle is of the correct shape

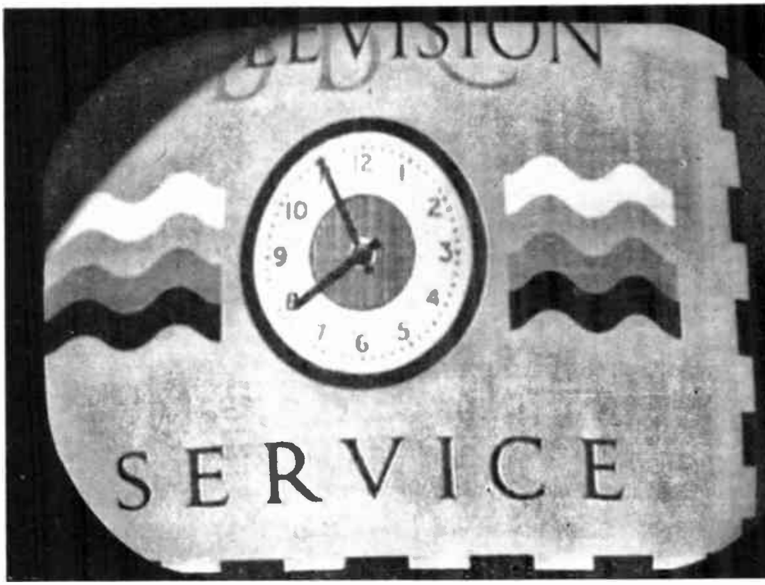
Picture out of focus. Adjust focus control



Picture slightly compressed at the top. Adjust frame linearity (vertical form) control, and then the height control if necessary

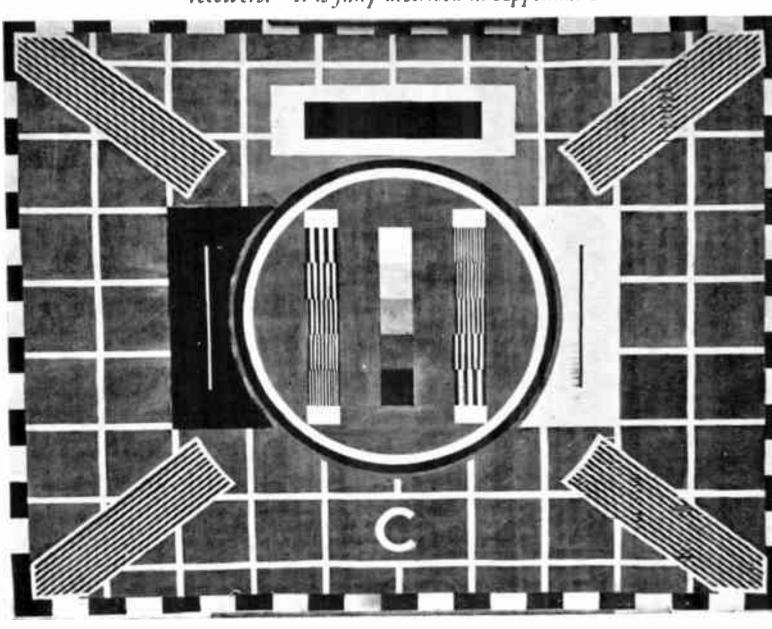


Picture not level. Rotate the scanning coil unit on the neck of the C.R. tube inside the receiver until lines are horizontal (using mechanical levelling controls if provided)



Picture displaced upwards and to the left. Adjust mechanical or electrical shift controls to centre picture. If corner shadow persists, scanning coils should be pushed forward

The special " C " test card, which is transmitted out of normal transmission hours for the benefit of the radio industry in testing receivers. It is fully described in Appendix I



Chapter 1

AERIALS

Dipoles – Feeders – Reflectors – Indoor Types – Multi-element Arrays – Combined Band I/Band III Aerials

NO APOLOGY IS OFFERED for commencing a book on television receiving circuits with a chapter on television aerials, since the aerial forms an important part of a television receiver, and its design, construction and siting are all more critical than in the case of the average aerial used with an ordinary broadcast receiver.

First of all, it may be said that the television aerial differs from the ordinary broadcast receiving aerial in that it is self-tuned to the frequency of the incoming signals While it is quite possible in districts of high signal strength to receive television on an ordinary aerial, or even a short length of wire, this is not an efficient arrangement, and would be quite unsatisfactory in regions of low or even moderate signal strength.

Furthermore, the ordinary type of aerial may in any case result in poor picture quality (due to multiple images caused by reflections), and it does not permit one to reduce interference in the manner which can be employed in the conventional television aerial. This does not imply that it is always necessary to use an outdoor aerial of elaborate construction. In areas of high signal strength simplified forms of indoor aerials may be entirely satisfactory, but they should still be resonant.

The simplest resonant or tuned television aerial consists of a wire or rod whose length bears a certain relation to the wavelength to be received.

Theoretically it is equally desirable that a radio aerial should be self-resonant as it is that a television aerial should be, but because of the longer wavelength commonly employed for radio it is not so convenient in practice. For the same relationship between wavelength and aerial length a radio aerial would need to be something between some 30 to 500 times as long as a television aerial.

The B.B.C. television signals from the London station, for instance, are transmitted on a band whose wavelength is around 6·7 metres (45 Mc/s) which is approximately equal to 22 ft, whereas the wavelength of the London A.M. (amplitude modulated) Light Programme transmission at the time of writing is 247 metres, which is approximately 36 times as long. The "long wave" Light Programme wavelength is 1,500 metres.

A convenient length for a resonant aerial is half of the wavelength of the signal, and it is then called a "half-wave" aerial. If the wavelength were 6·7 metres, the aerial would consist of a straight wire or rod that is (electrically) half a wavelength long which, for 6·7 metres, is 3·35 metres or about 11 ft. As the B.B.C. London transmitter uses the longest wavelength of all British television stations, therefore, the longest television aerial is 11 ft overall, which, although quite long enough in many circumstances, is nevertheless a conveniently manageable structure, whereas a half-wave aerial for 247 metres would be quite out of the question for a domestic installation.

It is usual to refer to television transmissions not by wavelength but by frequency, which is directly related to wavelength. The B.B.C. London frequency is 45 Mc/s (45 megacycles per second), which, as we have seen, is equivalent to about 6·7 metres. The relationship is directly inverse, so that if the wavelength is doubled, the frequency is halved. Thus the London A.M. Light Programme is transmitted on 247 metres, which is equivalent to 1·214 Mc/s. It is impracticable to quote wavelengths for television stations because they are very short and because frequencies fall into awkward fractional divisions of wavelength. The actual wavelength of 45 Mc/s, for instance, is 6·6666 metres, the six recurring.

This difficulty becomes more marked as the frequency increases, and the London B.B.C. station quoted in the example has the lowest frequency, and thus the longest wavelength. At the time of writing the B.B.C. has five television frequencies, of which that used at Wenvoe (66·75 Mc/s) is the highest. Each transmission is allocated a channel, and the B.B.C. channels are numbered 1 (London) to 5 (Wenvoe). These five channels occupy practically the whole of Band I, which extends from

40 Mc/s to 70 Mc/s, and with one exception the channels are spaced regularly at 5 Mc/s intervals throughout the band.

A second band of frequencies is allocated to television transmissions in the neighbourhood of 200 Mc/s, and it is here that the I.T.A. transmissions are located. This is called Band III, and it extends from 175 Mc/s to 216 Mc/s. It is divided into eight channels, numbered 6 to 13, again at 5 Mc/s intervals, of which channel 9 (vision carrier 194·75 Mc/s) is allocated to the I.T.A. London transmitter. The difficulty of quoting such channels in wavelengths will be appreciated when it is realized that all eight channels fall between 1·4 metres and 1·7 metres, each going into several decimal places. The length of a channel 9 aerial is about 30 in.

It must be explained before leaving the subject that the radio wavelengths quoted earlier refer only to amplitude modulated radio transmissions. There are also the B.B.C. F.M. (frequency modulated) transmissions which began in 1955, variously referred to as F.M. and V.H.F. (very high frequency) radio transmissions. The frequency of this group, which is allocated the group title of Band II, is near 100 Mc/s (3 metres), the various channel frequencies ranging from 87·5 to 95 Mc/s. Obviously resonant aerials of the same general type as are used for television can be employed for reception of these transmissions. The only essential differences lie in their respective lengths and the fact that whereas television aerials are usually mounted in a vertical position, all V.H.F. radio aerials are horizontal.

Most of the British television signals are transmitted from a vertically disposed radiator and are consequently vertically polarized, and for the best results the receiving aerial should be mounted vertically. Some of the B.B.C. transmissions are horizontally polarized, however, as are all American television transmissions, and receiver aerials for these transmissions should be horizontal also.

If the half-wave aerial rod is mounted vertically, a standing wave is produced in it by the signal in such a way that there is zero current, but maximum voltage, at each end, and maximum current (zero voltage) at the centre. This is indicated in Fig. 1. In order to transfer the energy picked up by the aerial to the receiver, a " feeder " must be connected between the two, and this must be of a special type. It is usual to connect the feeder

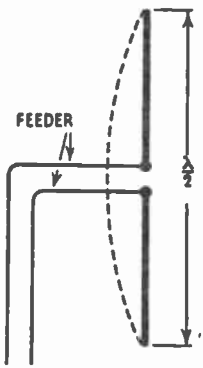


Fig. 1—Diagram of the half-wave dipole aerial largely used for television reception. The two halves are connected to the two leads of the feeder. The dotted line shows the current distribution in the aerial, with a maximum at the centre

to the point of maximum current in the aerial, that is, in the case of a half-wave type, to the centre.

The connection is made by breaking the half-wave aerial at its centre, and connecting each portion to one of the twin feeder wires. It is most important that the impedance of the feeder is fairly accurately matched to the impedance of the aerial, otherwise the maximum transfer of energy does not take place, and reflections giving multiple images may be set up.

The impedance at the centre of a half-wave aerial is 70–80 ohms, and this, therefore, must be the characteristic impedance of the feeder, unless the added complication of a matching transformer is introduced. While a high impedance feeder could be made from two air-spaced wires accurately separated over the whole of their length, the construction of such a feeder for the comparatively low impedance of, say, 80 ohms is not practicable. Instead, two parallel spaced wires embedded in rubber or plastic material are used; alternatively, the co-axial type of feeder is employed, this having a central wire surrounded by a tubular metallic braiding forming the other conductor, the two being separated by solid, or partly air and partly solid, dielectric. The co-axial type of feeder is now used almost universally. Two typical sections of feeders are shown in Fig. 2.

While it is possible to connect the feeder to the end of a half-wave aerial (which is then in one length), the impedance here is high, and special matching arrangements are necessary. Nevertheless, one manufacturer specializes in these types.

The total length of the television aerial is actually not exceedingly critical, and in any case, owing to the fact that vision and sound are transmitted on different frequencies, some compromise has to be made. Some manufacturers make their aerials to resonate at the vision frequency, while others choose a frequency at some value between the vision and the sound frequencies. This accounts for slight differences which may be found between the lengths of various makes of aerial.

The "electrical length" of an aerial of the rod type is greater than its physical length by about 5 per cent, so the aerial rods are made about 95 per cent of the theoretical calculated length. For a 45 Mc/s half-wave aerial the length will be about 10 ft 5 in., and for a 66·75 Mc/s half-wave aerial, about 6 ft 9 in. For the I.T.A. vision frequency (194·75 Mc/s) on channel 9 the half-wave length is about 30 in. The distance between the two halves of the dipole at the centre where the feeder is attached should be small, not much greater than 1 in. or 2 in.

With an unscreened twin feeder, one wire is connected to each half of the dipole; in the case of a co-axial feeder it is usual to

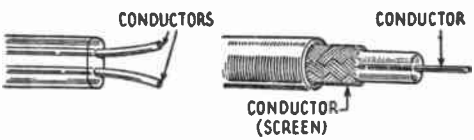


Fig. 2—Sections of typical feeders. Left, the ordinary twin-wire type; right, the coaxial type

connect the centre wire to the upper half of the aerial and the outer metallic braiding to the lower half. In some cases the co-axial feeder is connected via a transformer at the centre of the aerial, this permitting the two halves of the aerial to be accurately balanced to earth. However, except in special circumstances this is not essential.

Equally, at the receiver end, the feeder has to be matched to the input circuits, and though some manufacturers specify twin feeder and others the co-axial type, in practice it will usually be found that either type can be employed with any set with little or no noticeable difference, in areas of fairly high signal strength at least.

So far only the simple half-wave dipole has been mentioned; in special applications use is sometimes made of "folded" dipoles, the object of which is to make an aerial resonating at the correct frequency, but having a centre impedance of about 300 ohms instead of the 80 ohms of the normal type. Various shapes are employed for this purpose, but the principle is the same, and so is the method of connection to the receiver. The appearance of a conventionally shaped folded dipole is shown later on in Fig. 10. For indoor use, a " compressed " dipole, consisting of short rods loaded with inductances to give the correct electrical " length ", is sometimes employed.

In localities where signal strength is not great, and interference levels are high, better results than those given by the simple dipole can be obtained by the addition of a reflector. This consists of a rod or wire, also about half a wavelength long, mounted vertically behind the dipole, and usually a quarter or an eighth of a wavelength behind it. Such an arrangement forms the well-known "H" aerial, a prominent feature of the landscape in television areas, illustrated in Fig. 3.

The effect of the reflector is to reinforce the pick-up of the aerial in the forward direction and reduce it in the backward direction; that is, to increase the " front-to-back " ratio, from which it follows that the combination is to a certain extent directional, whereas, of course, the simple dipole picks up equally in all directions. Fig. 4 illustrates the type of polar diagram obtained by adding a reflector spaced by a quarter wavelength from the half-wave dipole aerial.

The forward directivity of the dipole with reflector is not critical, but the property can be used to give an appreciable increase in signal strength in the forward direction. Behind the

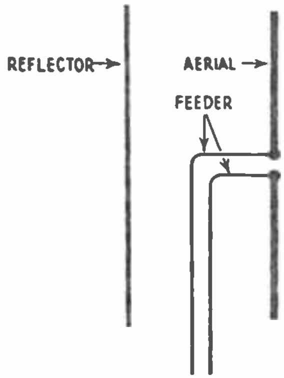


Fig. 3—A half-wave dipole with reflector. The supporting cross-bar (not shown) makes the arrangement into the shape of a letter " H "

aerial the directivity is more critical, and it can be used to decrease the pick-up of unwanted noise, such as that produced by car ignition systems, particularly if they emanate from a well-defined source.

For maximum signal strength the aerial proper must face the transmitting station, with the reflector behind it so arranged that

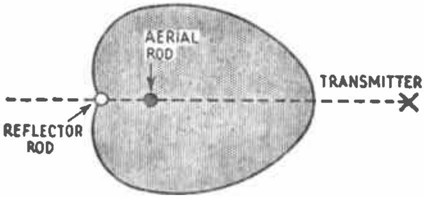


Fig. 4—Polar diagram of a dipole with reflector, showing increased pick-up in front of the aerial and reduced pick-up at the rear

a line drawn through reflector and aerial, if continued, would pass through the transmitter. However, since the alignment is not critical it sometimes pays to align for minimum interference rather than maximum signal.

The length of the reflector rod (which is not split, and is not in electrical connection with the aerial or anything else, although it can be earthed at its centre) is usually about 3 per cent less than the calculated length for half a wavelength; it is thus slightly longer than the aerial, which is 5 per cent less.

The distance between aerial and reflector may be a quarter of a wavelength, that is about 5 ft 6 in. for the London station or 3 ft 6 in. for the Wenvoe station, and, say, 15 in. for channel 9; it is not critical, and different spacings are sometimes used. However, since the presence of the reflector affects the impedance at the centre of the dipole aerial, mis-matching may occur with an 80 ohm feeder if the reflector is brought too close to the aerial.

It is possible, by making certain alterations to the lengths of the rods, and to the spacing between aerial and reflector, to affect the response curve of the aerial system. If the best definition of the television picture is to be secured, the aerial system, no less than the receiving circuits, must be capable of accepting the full band-width of the transmitted signal. By making the aerial rod shorter than the calculated value, and the reflector rod longer, and reducing the spacing, it has been found possible to secure a " double-humped " response whose effect is to increase considerably the band-width accepted by the aerial system. The diameter of the aerial rod also affects the response curve; the larger the diameter, the broader being the response.

Wherever external interference is bad, the dipole with reflector should be used in preference to a simple dipole, not necessarily to increase signal strength, but to increase the signal to noise ratio. As this may result, in areas of good signal strength, in the received signal being too great for the receiver to accept, it may then be necessary to fit a simple attenuator at the receiver end of the feeder. This will, of course, reduce the signal and any remaining interference in the same proportion. (*See* Appendix II, page 184.)

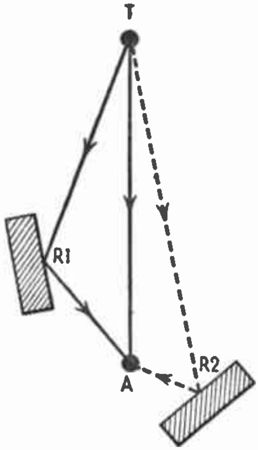
As far as the siting of the aerial is concerned, there is often not a great deal of choice, but it is usually the case that the higher the aerial the better the signal and the less the electrical interference. It is not essential to site a television aerial so that the length of the feeder is the minimum possible. Within reason, the length of the feeder is not important, since the losses in feeder cable of good quality are very low. It is much better, therefore, to place the aerial in the most advantageous position, even if the length of the feeder is thereby increased.

It has already been explained that matching of the feeder cable to the centre of a half-wave dipole aerial is achieved by the use of special twin wire or co-axial cable having a characteristic impedance of 70–80 ohms, and other types of feeder should not be employed unless a suitable matching transformer is used. In any case ordinary twisted flex is unsatisfactory.

At the receiver end, matching of the television feeder is provided for by the manufacturer of the receiver, and no special precautions need be taken here except to see that the maker's instructions are followed, and that proper connecting plugs are used. On no account should the two conductors of a feeder be splayed out for considerable lengths; only the minimum length necessary should be opened out for fitting of the plugs.

The reason for the importance of correct matching is that it ensures the maximum transfer of energy to the receiver. Incorrect matching may mean that part of the signal is reflected back from the point where the mis-match occurs. If this is at the receiver input sockets, for instance, the reflected part of the

Fig. 5—Diagram (not to scale), showing how external reflections occur. T is the transmitter, A the receiving aerial, and R1, R2 reflecting bodies



signal may return to the aerial, where it is reflected back again, and a portion of it may enter the receiver circuits in addition to the signal proper. There is obviously a time lag between the original signal and the reflected one, and the lag will depend on the distance the reflected signal has travelled: that is, on the length of the feeder.

The effect on the receiver is that the reflected signal produces an image which is displaced to the right of the normal image (because the cathode-ray spot travels from left to right when building up the picture line by line). The amount of displacement depends on the time lag between the normal and reflected signals, and it is possible to calculate the displacement for a given time lag, and hence for a given length of feeder. It can be said that with a feeder less than 100 ft long the effect of the reflection, if present, will be negligible. With longer feeders, if mis-matched, one gets blurring of the image, or, as the length increases, a recognizable displaced image separated more and more from the true image.

With severe mis-matching, multiple reflections may occur, even with a short feeder, giving multiple images, equidistant from each other, and gradually tailing off in intensity.

If internal reflections in the feeder system do occur, the reflected image is fainter than the true one, but nevertheless it may be very troublesome, and must generally be eliminated by proper feeder matching. There is another form of reflection, external to the aerial system, which can produce similar displaced images. These external reflections often result in considerable displacement due to the greater distances involved.

The diagram in Fig. 5 (not to scale) illustrates how simple external reflections occur. T represents the television transmitter, A the receiving aerial, and R1 and R2 are bodies, such as buildings or hills, which act as reflectors to the signal. The direct wave, TA, is picked up by the aerial normally, while an indirect wave, say TR1, is reflected by R1 and travels in the line R1A, being also picked up by the aerial, though it arrives later than the direct wave.

The time lag obviously depends on the difference in length between the total indirect path TR1, R1A, and the direct path TA, and may be quite large in its effect on the television screen. The diagram shows another indirect path, TR2, R2A, which may also produce an image due to the reflection at R2.

To give some idea of the effect, it can be said that, with a picture 10 in. wide (12 in. tube) a displacement of the secondary image of 1/10 in. occurs when the difference between the two paths is of the order of 250 yd. With larger tubes the displacement will be larger in direct proportion to the size of the tube.

Another effect is that produced when the reflected signal arrives out of phase with the direct one. In this case the "ghost" image may be a negative, with black portions of the picture white, and vice versa.

The only method of dealing with the reflection problem at the receiving end is to use a type of aerial which is as directional as possible. The dipole with reflector may help, particularly if the reflected signal is arriving at the rear of the aerial, but it is possible to use a dipole with a number of reflector or "director" rods to produce a narrow angle of reception. A director rod is shown in Fig. 9.

So far we have mainly been concerned with the type of aerial which is mounted out of doors, on a chimney, wall or pole. In the early days of television in the London area, few sets were installed without using an outside aerial of some sort, for manufacturers and dealers were not inclined to experiment with indoor types which might, or might not, be satisfactory in a given locality. The customer, too, tended to regard the outside aerial as a visible sign that he was one of the pioneer television viewers.

Since those days the situation has changed. Television is becoming more commonplace, and much practical experience has been gathered on the performance of aerials in various areas. It has been found in the case of the latest high-power stations that in many of the so-called "swamp" areas where signal strength is considerable, an outside aerial of the H type, or even the plain dipole, is unnecessary. The only exception to this is where bad interference also happens to be present, and, as explained earlier, a dipole with reflector is advantageous in improving the signal-to-noise ratio.

Indoor aerials may be sited in the loft of a house, or in one of the rooms (preferably not that in which the receiver is situated). Two suitable types for use in lofts (in which the full-sized dipole might be too large) are shown in Fig. 6 at A and B.

At A is the "inverted T" type, formed of three rods each a quarter of a wavelength long. The vertical one is the aerial, and

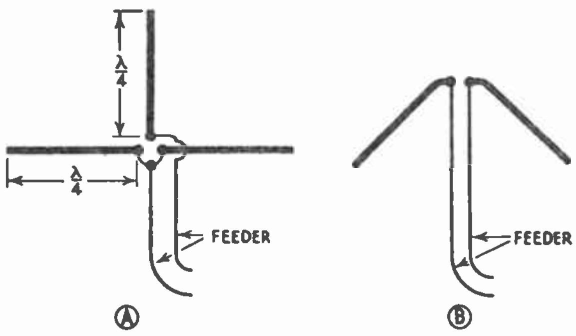


Fig. 6—Two popular forms of loft aerial. At A is the "inverted T" and at B the "inverted V". Supports are not shown

the two horizontal ones, which are joined together, form a counterpoise. Actually, a single horizontal half-wave rod would serve as a counterpoise. Since such an aerial is only half the height of a half-wave dipole, it is particularly suited to erection in a loft. It must be mounted so that the horizontal portion is at right angles to the direction of the station.

The aerial as shown at A corresponds to a plain dipole. If a reflector is necessary, another similar assembly is mounted a quarter or an eighth of a wavelength behind the aerial proper.

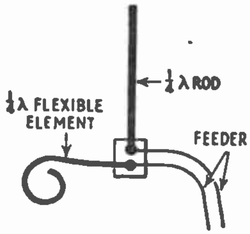


Fig. 7—Indoor aerial, with one element flexible, permitting a number of different arrangements

In this case the rods of the reflector are all connected together electrically, and no external connection is made to them.

At B is the " inverted V " type of loft aerial, comprising two quarter-wave elements arranged roughly at 45 degrees to the vertical, each being connected to the feeder as shown. The shape of this aerial is particularly suitable for its erection high up in a loft, under the peak of the roof. This aerial has a horizontal figure-of-eight polar diagram with a sharp minimum along the plane of the elements, that is, sideways. For maximum signal, the direction of the station must be perpendicular to the plane of the elements, that is, as drawn, perpendicular to the page. The two fairly sharp minima that occur in line with the aerial elements are useful in avoiding impulsive interference, but this type of aerial is rather susceptible to aeroplane " flutter " interference.

One form of indoor aerial for use in a room (not necessarily that in which the set is situated) is shown in Fig. 7. This consists of a quarter-wave rod, forming one element, which is normally mounted vertically, with an insulated flexible quarter-wave wire forming the other element. The feeder is connected as usual. With the rod mounted vertically on a door post, the flexible element may be fixed at right angles along the skirting board, or under the carpet. Various other arrangements are possible.

Using an indoor aerial, particularly in the room in which the receiver is situated, often results in difficulties due to the effect on the signal strength of persons moving near the aerial. Big variations may thus be caused, and it is often necessary to have the aerial in a room which is unoccupied during programme hours. The siting of such aerials is also more critical due to the effects of metalwork (for example, bedsteads, metal pipes or silvered mirrors). Nevertheless, in many cases where the signal strength is high, an indoor aerial will be found quite effective.

In areas of poor signal strength, normally referred to as "fringe" areas, even a standard dipole with reflector, well elevated, may not be adequate. Frequently the problem again is not so much to increase the signal, but to reduce interference. In such cases it is possible to employ multi-element arrays with some success. One form is shown in Fig. 8, and consists of a half-wave dipole aerial and three reflectors. The reflectors are located on a parabolic curve, and the aerial is at the "focus" of the parabola, this having the effect of narrowing the angle of signal pick-up, and therefore giving a greater angle of effective rejection of interference.

Another means of narrowing the angle of reception is to use a "director" as part of the array. The director is a single rod, which like the reflector is not connected externally, but it is placed in front of the aerial, not behind. Its length is *less* than that of the aerial, by about 4 per cent, whereas, as already mentioned, the reflector length is slightly greater. The spacing of the director from the aerial is not critical, although quite small changes can affect the characteristics of the aerial in several ways. It is usually between one-eighth and one-tenth of a wavelength.

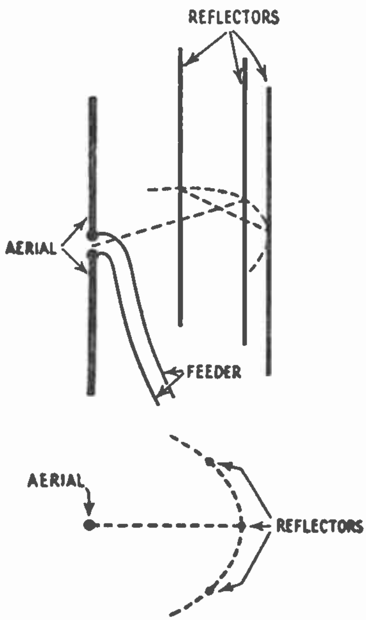


Fig. 8—One form of multi-element array, comprising a dipole aerial and three reflectors located on a parabola, the aerial being at the focus

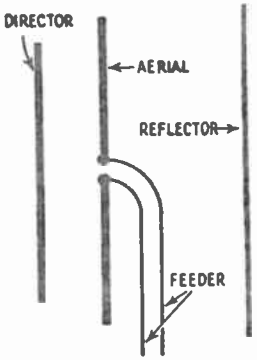


Fig. 9—A three-element array, comprising a dipole aerial with a director in front and a reflector behind

A three-element array using aerial, director and reflector is shown in Fig. 9. Directors and reflectors are referred to as " parasitic " elements.

Little quantitative information has been published on the relative merits of these forms of aerial, but they are both more directional than the two-element dipole and reflector, and can be made to give more signal strength. However, the design of multi-element arrays is complicated by the fact that different arrangements and spacings result in variations in directivity, selectivity, impedance and front-to-back pick-up ratio.

The impedance at the centre of the dipole is affected by close-spaced elements, and matching problems are therefore encountered. A common solution to this problem is to use a different kind of aerial element, known as a folded dipole. This type of aerial has a natural impedance of about 300 ohms at its centre, and as the effect of the other elements is to *reduce* the

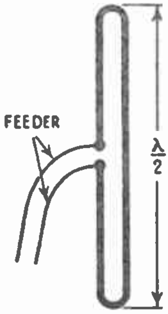


Fig. 10—Practical type of a folded dipole, which forms a closed loop and has an impedance of about 300 ohms at the terminals

impedance, it is possible by this means to adjust matters so that the impedance of the complete assembly approximates to that of the normal 70–80 ohm feeder. Fig. 10 shows the practical form of the folded dipole.

In view of the importance of the aerial in a television receiving installation, particularly in localities of poor signal strength, and where interference is serious, it is likely that these and other special types will be worth investigating where the ordinary dipole with reflector is not entirely satisfactory.

This also applies particularly in certain areas covered by the high-power stations where reflections or "ghosts" are commonly encountered.

It applies particularly to Band III aerials, which, even in areas only just outside the immediate swamp area, usually need at

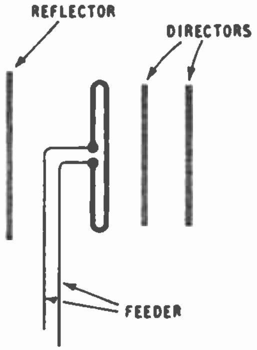


Fig. 11—An aerial array employing a folded dipole with a reflector and two directors. It is referred to as a 4-element array and is very often used for Band III reception

least three elements altogether (one reflector, one director and the folded dipole itself). This is due partly to the need for increased signal strength (the signal is attenuated by distance more rapidly than on Band I) but principally to the need to reject reflections, which are often prolific on Band III. Ordinary electrical interference is usually much less severe on Band III than on Band I. Where more than two parasitic elements are required they are always directors, which often become progressively shorter as they get farther from the dipole element.

Band III aerials are so small that they can easily be accommodated inside the loft of a house, even though the simplest of these aerials may have three elements. The arrangement of a typical Band III four-element aerial with a folded dipole, which is very common, is shown in Fig. 11.

BAND I/BAND III COMBINED AERIALS

With Band I signals and Band III signals present in the same area, and in view of the fact that each requires a different kind of aerial, it is obvious that a receiver that is designed to receive both signals will require two aerials. There are several ways in which this may be achieved, and in some cases the method adopted is dictated by the type of receiver.

If the receiver is an early one designed to work only on Band I, for instance, and it is already equipped with a Band I aerial, it can be adapted by fitting a suitable Band III tuner to it to receive the alternative programme in Band III, but it will then require a Band III aerial. This can take the form of an entirely separate aerial, with a separate feeder, and in some cases this suits the adapted receiver, which may have separate Band I and Band III aerial sockets.

Alternatively, as long as the site is not too far from the Band III transmitter, the existing Band I aerial itself can also be adapted by fitting adaptor rods to the dipole element which convert it into a combined Band I/Band III aerial. Two examples of this are shown in Fig. 12, where at (a) is seen a simple dipole aerial with Band III adaptor rods fitted to it. The Band III reflector rod is an optional addition to the system, and it can still be used even when the Band I aerial has a reflector also. If the two transmitters are in different directions, the two reflectors can be swung round independently to their appropriate positions.

A set of slightly differently shaped adaptor rods is shown in Fig. 12 (b), fitted in this case to an "X" aerial, but the same bayonet-like rods are also used with straight dipoles, although in the case of the "X" aerial, adaptors can be added effectively on the reflector elements, provided that both transmitters are in the same direction. The original feeder in both types of adapted aerial carries the Band I and Band III signals, so that with this arrangement only a single feeder is available at the receiver.

Specially designed combined aerials, as distinct from adapted ones, are made for use with multi-channel receivers, and they are generally more efficient than adapted aerials, being as good in performance as two separate Band I and Band III aerials.

They can be constructed with long-range Band III elements and short-range Band I, or vice versa, as required, but they provide a combined output in a single feeder, which suits modern receivers because they almost invariably have a single aerial socket for both bands. Numerous designs of combined aerial are made, but as is general with television aerials, the designs are many and varied and it is not possible to show an illustration of each type.

One example is shown in Fig. 13 (a) which is typical in so far that the Band I and Band III elements can easily be identified by their respective dimensions. In this particular case the Band I section is a simple dipole, while the Band III section has 5 elements and is very directional. The number of elements can be varied according to the requirements, but the overall sensitivity is just about the same as a separate Band III aerial with the same number of elements.

This Band III aerial does not work in quite the same way as a separate one, however, because it has no identifiable dipole element and it uses no deliberate reflector. Coupling takes place on Band III with the Band I dipole, and the signal goes down the

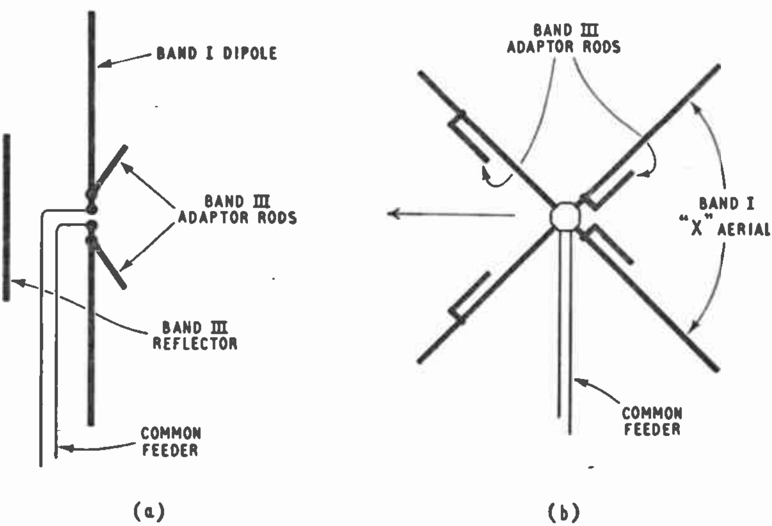


Fig. 12—Two examples of the adaptation of an existing Band I aerial to enable it to work also on Band III. At (a) *adaptor rods are added near the centre of the dipole, with an optional reflector behind them. At* (b) *four adaptor rods as used on a Band I "X" aerial. Note:* (a) *and* (b) *face in opposite directions*

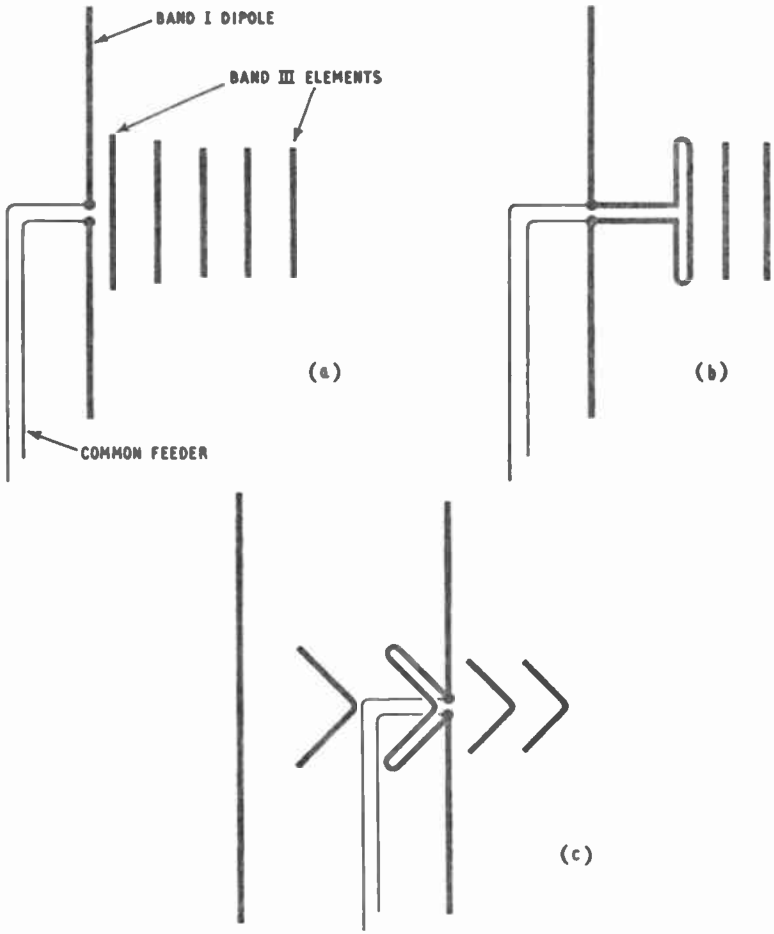


Fig. 13—*Three examples of commercially made combined aerials for Band I and Band III. At* (a) *separate sets of elements are provided for each band, but although they are not electrically connected, a single feeder carries both signals. At* (b) *is a folded Band III dipole with directors combined with a Band I dipole to a single feeder. At* (c) *is shown a directly connected combination with inclined Band III elements* common feeder. On Band I the dipole behaves quite normally, and if a reflector is required it can be fitted and directed appropriately, irrespective of where the Band III array is pointing.

Another type of combined Band I/Band III aerial is shown in Fig. 13 (b). Again the simple Band I dipole is easily recognizable by its length in comparison with the small Band III elements. The Band III dipole is a folded type and has two directors in front of it. The Band I dipole acts on Band III as a reflector, and its feeder carries the signals on either band, but in this aerial there is actually a pair of conductors between the folded dipole and the Band I dipole, and their length is critical.

A third style of combined aerial is shown at Fig. 13 (c), whose Band III elements form what looks like an arrowhead. The reason for the staggered Band III elements here is that at the channel frequencies for which the aerial is designed, the principal lobes of high sensitivity on Band III are not at right-angles to the elements, but at 45 degrees to them. As with the two preceding types, a single feeder connected to the Band I dipole carries the signals for both bands, but in this particular design the ends of the Band III folder dipole are actually connected directly to the elements of the Band I dipole.

It follows from the foregoing that some aerial systems, namely those involving separate aerials for the two bands, use two separate feeders, while others, which we have called combined aerials, use a single feeder. As we have already seen, also, some receivers have separate Band I and Band III aerial sockets, while others have a single socket common to both bands. Sometimes the aerial arrangement is chosen to suit the receiver, and it is a common practice when the I.T.A. transmitters are first brought into service to adapt the receiver but to instal a separate Band III aerial. Old receivers, therefore, often require two feeders, but new ones seldom do.

Cases arise, therefore, when it is desirable to combine the two feeders from separate aerials and take a single feeder to the receiver; or to divide the single feeder from a combined aerial and split it into separate Band I and Band III feeders to suit a receiver that has separate aerial sockets; and these are met by using a device variously called a "diplexer", a "combining unit", or a "cross-over unit". The same unit can be used either to combine the two feeders from separate aerials or to split a combined feeder into two simply by reversing the unit.

The device works on the principle that when two frequencies are sufficiently widely separated that one can be termed low as compared with the other, they can be separated by using a "low pass" circuit for the one and a "high pass" circuit for the other. This simply means that a circuit has a high impedance at the frequency to which it is tuned, and a comparatively low impedance to other frequencies. Band I, although in no sense can it be considered to be in a low frequency region, is low compared with Band III, the ratio between them being between three and four to one, and quite efficient high-pass and low-pass filters can be designed to separate frequencies of this order.

The circuit of a cross-over unit of this kind is shown in Fig. 14. If a Band I aerial is connected to the low-pass section its signals

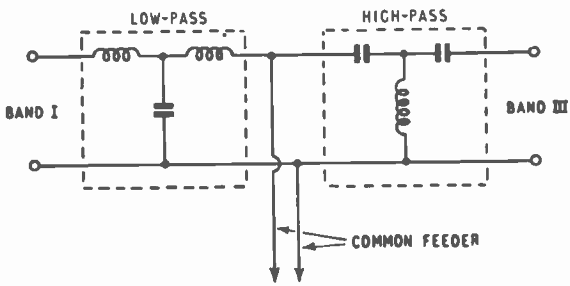


Fig. 14—Diagram of a cross-over or aerial combining unit used to combine the outputs from separate Band I and Band III aerials or to split up the output from a combined aerial to give separate outputs

will pass through the low-pass circuit and reach the common feeder, but they will be barred from reaching a Band III aerial connected to the opposite end by the high-pass circuit there. Similarly the Band III signals from the other end will pass through the high-pass section and reach the common feeder, but they are prevented by the low-pass filter from reaching the Band I aerial. The common feeder goes to the aerial socket of the receiver.

If the function of the unit is reversed, the common feeder goes to a combined aerial, from which Band I and Band III signals are issued. As before, only the Band I signals can pass through the low-pass filter, and only the Band III signals can pass through the high-pass filter. If separate feeders are attached to the Band I and Band III terminals on the unit, therefore, they can be taken to the separate Band I and Band III aerial sockets on a receiver so fitted.

In the form shown in Fig. 14, the circuit is suitable only for use with a co-axial feeder cable. For use with balanced twin feeder the inductance of the coils in the low-pass section would have to be divided between the two conductors, while the values of the capacitors also would have to be distributed in the high-pass section. All three feeders in either case could have the same characteristic impedance.

As in the case of ordinary radio receivers, it is possible to design a "portable" television receiver which works without an aerial as such. In one set of this kind, intended for use in situations of reasonably high signal strength, the pick-up was obtained on a portion of the mains lead of the receiver that was effectively half a wavelength long.

Another kind of portable television receiver has a telescopic aerial rod fitted in the top of its casing, giving good reception over quite a wide range in the service area of a transmitter. To complete its portability, it is designed to be operated from the normal house mains or from a car battery and a vibratory convertor, and it can actually be used in a car.

To sum up, the aerial system of a television receiving installation is of considerably more importance than is the case in an ordinary sound radio installation. For use in locations of moderate signal strength the standard dipole with reflector mounted on a mast or a chimney is probably the safest choice. Close to a transmitter, an outside aerial will not be essential, and a loft, or even a room type on Band I, will be effective where local interference is not high. In the fringe areas, conditions vary considerably, and one of the special arrays, mounted as high as possible, and accurately aligned to the transmitter, is desirable.

The deciding factor in fringe areas is not so much the low signal strength as the level of local interference. The local topography, too, has a large effect on long-distance reception. In a location shielded from the transmitter by a hill, reception may be impossible, whereas even at a greater distance in open country the signal may be quite adequate. Again, in a hilly area, direct reception of the station may be almost impossible, but by rotating the aerial array suitably a stable reflection from a nearby hill may provide satisfactory reception.

RUNNING EXTENSION FEEDERS

Occasions arise in which it is desired to use a receiver in two rooms, and it follows that it is necessary to have an aerial available in both rooms. Two methods are normally possible to provide alternative aerial points: (*a*) to use two separate aerials and feeders; (*b*) to run an extension from one aerial point to a second one in the other room.

It is feasible to use method (*a*) only in cases where a simple dipole aerial suffices, and it is fitted in, say, the loft, so that it is not expensive and requires about the same amount of extra feeder as would an extension from the first point. Method (*b*) permits the same aerial to be used in either room, and will still work with combined aerials of the most elaborate type. It can also be used to feed a third room if required.

Method (*a*) requires no explanation, and on the face of it, it might seem that method (*b*) was simple enough, too. It is simple, but it must be done the right way. The usual manner in which to terminate an aerial feeder is to take it to a small metal connecting box containing a co-axial socket, to which the aerial feeder is connected. The box is screwed on to the window frame or skirting board near the receiver, and a short length of co-axial feeder with a co-axial plug at each end is plugged into the box and into the aerial socket of the receiver.

To run an extension from the connecting box to another room, the most natural method would be to solder the end of the co-axial extension feeder to the same two points as the aerial feeder is soldered to, but that is the way it must *not* be done. When the lead from the set is plugged into the box there will be three co-axial cables joined together at their ends, and one effect of that is to upset the matching. Another effect is that when using the set at the first point, the unused extension will still be connected, and as it is not properly terminated " standing " waves will be set up on it, and it is likely to produce reflections of the kind described earlier in mis-matched feeders.

The correct way to run the extension is to provide it with its own co-axial plug at the aerial end, so that either the receiver lead or the extension can be connected to the aerial, but not both. The receiver, with its short lead, will be wheeled away into the second room, and when it is plugged into a connecting box there it will be connected to the aerial via the extension, which will be plugged into the aerial connecting box in the first room.

If a third room were involved, its extension feeder would be terminated at the aerial end with a co-axial plug as before, but it could be plugged into the box in the first room or the second room, according to which involved the shorter total length of feeder cable. In no case, however, should two lengths of feeder be connected to the feeder carrying the aerial signal.

A different set of circumstances arises when it is desired to run two extensions from an aerial simultaneously; in other words, to split up a feeder into two branches to operate two receivers from a single aerial. In such a case as this, the three feeder cables must be isolated from one another by resistors, so that each feeder is properly terminated and matched.

The method then is to connect a resistor to the end of the inner conductor of each of the three feeders involved, leaving one end of each resistor free. Then join together the free ends of the resistors, so that each goes to the other two. Finally, join together the outer braiding of all three feeders. You then have in effect the signal coming down the aerial feeder, passing through the resistor in its lead, then splitting up into the two paths offered by the two outgoing resistors and their cables.

It follows from the need to isolate the three feeders from each other and to maintain proper matching, that the values of the resistors must be chosen carefully. Actually it is not very critical, but the correct value for 75 ohm cable, for instance, is 25 ohms for each resistor, all three having the same value. This scheme can be used only where the signal is strong enough, because the signal received by each receiver is only about a third of that available before splitting it up. Where an attenuator is normally required, of course, the signal strength is ample and the " splitter " might obviate the need for an attenuator.

Chapter 2

THE SIGNAL

Sequential and Interlaced Scanning – Transmitted Waveform – Band-width Occupied – Double and Vestigial Sideband Systems

BEFORE COMMENCING TO DESCRIBE the circuits of a television receiver, it is important to consider how the picture is built up on the screen of the cathode-ray tube. This will make clear the necessity for the fairly complicated type of signal which has to be provided for the transmission of television intelligence, compared with the far more simple sound transmission. A knowledge of the form of the television signal also enables us to understand the need for certain special circuits in the receiver, and the tasks they have to carry out.

It is hardly necessary to say that the picture on the screen in a modern television receiver is built up by a succession of almost horizontal lines which are "drawn" by the cathode-ray spot. In one form of transmission the spot is caused to move across the screen, tracing out a line, and is then made to return at a much faster pace to a point just below the start of the first line. It then proceeds to trace out a second line, just below and parallel to the first. This continues until a complete picture area has been built up, when the spot moves back to its starting point and repeats the performance again.

The effect on the viewer, due to persistence of vision and a certain degree of afterglow on the tube screen, is that a complete set of lines is seen, though actually at any given instant there is only the single spot of light drawing out the picture.

The complete set of lines on the tube screen is called a "raster", and as described, of course, it merely produces an illuminated area, with no picture. The picture intelligence is conveyed by causing the television signal to vary the intensity of the spot of light, from zero (black) to maximum (white). Thus each line on the screen in practice consists of a large number of picture elements varying in shade between black and white, and in this way the complete picture is built up.

Each picture area is called a "frame", on the analogy of a cinema film, and, as in the cinema, it is necessary to transmit a certain number of frames per second before flicker is eliminated. To a certain extent the amount of flicker noticeable depends on the picture brightness, and the B.B.C. television system, by transmitting 50 frames per second, completely eliminates flicker even with brilliant pictures.

The method of building up the picture already described is known as "sequential scanning," and is illustrated diagrammatically in Fig. 15. Only seven lines are shown in the raster for the sake of clarity, and the slopes of the lines are exaggerated thereby. Let us imagine that the cathode-ray spot commences its journey at A. It moves across the screen to the right, and traces out the line AB. At the end of the line, it quickly returns to a point C, which is just below A, ready to trace out the second line. The dotted line BC (which is actually not visible on the tube screen) is known as the "flyback," and occupies much less time than that taken to trace a line.

From C the spot traces the second line CD, following which there is another flyback, then the third line, and so on. This continues until the complete raster has been drawn, the last line in our illustration being EF. At F the spot, having finished one frame, flies back to A, where it commences the second frame, and this continues at a frequency depending on the number of frames being transmitted per second. It will be realized that when an actual picture is being received the spot is continually

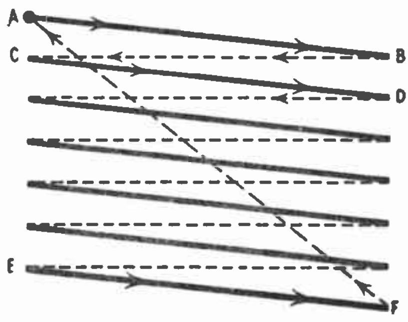


Fig. 15—Diagram illustrating sequential scanning, which is explained in the text. It is not to scale, and only seven lines are shown. The "flyback" from F to A in practice is not a straight line as depicted

varying in brightness during the periods when it is tracing out the lines.

So much for sequential scanning, a modification of which is at present used by the B.B.C. It has already been stated that the amount of flicker depends on the frequency at which the frames are transmitted, and it is also a fact that as we increase the number of complete scans of the picture per second we also increase in the same proportion the maximum frequency necessary in the transmission, and therefore the band-width occupied in the frequency spectrum.

For instance, it is found that a picture frequency of 25 per second is insufficient for complete elimination of flicker with a bright picture. If the picture frequency is increased to 50 per second flicker is no longer apparent, but the vision signal will require twice the frequency band.

To avoid this, the B.B.C. employ "interlaced scanning", which has the following characteristics. The travelling spot on the cathode-ray tube screen traces out parallel lines on the screen as before, but there is a gap between adjacent lines greater than with sequential scanning. The spot, in fact, traces out alternate lines, and when it has covered the picture area it returns to trace out another series of lines in the gaps between those in the preceding frame.

This will be understood by reference to Fig. 16, which shows just a few lines (for clarity) of an interlaced raster. Assuming the spot starts at G, it first traces the line GH, and the flyback HI takes it to I, which is twice as far below G as C was below A in Fig. 15. The spot now traces out the line IJ, and so on until

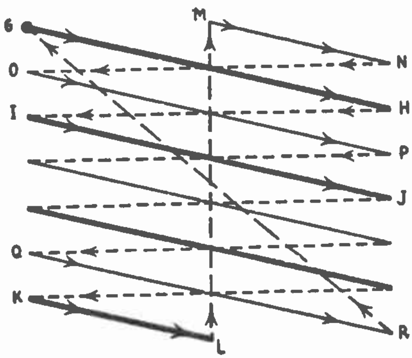


Fig. 16—Diagram showing interlaced scanning, not to scale. The "flybacks" LM and RG are not in practice straight lines, neither does the interlace necessarily start half-way across the frame. The diagram is drawn as shown for convenient explanation in the text

it gets to the bottom line of the raster, starting at K. Instead of completing a full line, however, the spot is arrested theoretically half-way along, at L, and is caused to fly back to a point M, which is half-way (approximately) along a line above GH.

The spot then starts a new frame, completing the line MN, flying back along NO, and tracing the line OP, which, it will be noted, is mid-way between GH and IJ in the previous frame.

It is fairly easy to see that had the spot not been arrested at L, but had been allowed to complete the last line of the first frame, it would have traced the second frame exactly over the first one. As it is, it interlaces as shown in the diagram.

It continues to trace out the second frame as indicated by the lighter lines in Fig. 16, and reaches Q, the beginning of the last line of the second frame. It is allowed to complete the full line QR, and therefore the flyback brings it to point G again, ready to trace out two more interlaced frames.

In the diagram of Fig. 16, the total number of lines composing the picture is 7, but these consist of $3\frac{1}{2}$ lines of one frame interlaced with $3\frac{1}{2}$ of the next. Thus we have two frames to each complete picture scan. We have not altered the total number of picture elements scanned in a second compared with Fig. 15, so the maximum frequency required for the transmission is the same as if the 7-line sequentially scanned picture of Fig. 15 were transmitted; we have, however, doubled the number of frames per second, thus reducing the flicker.

It might be thought that to reduce flicker we could increase our picture frequency slightly, thus avoiding the complication of interlacing, and only slightly increasing the frequency band required. However, it is found that the picture frequency must be at the mains frequency or at some multiple or sub-multiple of it, otherwise any residual " hum " in the receiver circuits is likely to cause travelling bands of light and shade across the picture. Hence, if it is necessary to go above 25 frames per second, the next frequency permissible is 50. In America, where the standard mains frequency is 60 c/s, the frame frequency is 30 or 60. The present B.B.C. transmission uses 405 lines ($202\frac{1}{2}$ interlaced with $202\frac{1}{2}$) with a frame frequency of 50 (or 25 complete scans) per second.

Having seen how the picture is traced out line by line and frame by frame by the spot, which is actuated as to movement by local scanning circuits in the receiver, it is fairly obvious that the television signal must convey not only the means of modulating the light intensity of the spot (the " picture " signals) but also the intelligence necessary to make the spot move in exact synchronism with the spot which is scanning the scene at the transmitter end. The spot itself, it must be explained, is not part of the signal but is actually the end of an electron beam inside the cathode-ray tube.

Not only must the receiver spot move at exactly the same speed as that at the transmitter, but it must always be at the same relative position on the screen. For example, both spots must start at the beginning of the first line of each frame at exactly the same instant, and thereafter they must keep in step.

This result is achieved by suitable synchronizing signals, included in the complete television signal, which at the receiver are separated from the picture signal, and used to control the " time-base " circuits which deflect the spot across the tube screen.

At this juncture, therefore, it is desirable to examine the form of the complete signal which is transmitted, and to see how the picture and synchronizing signals are combined. This will enable a clearer picture of what happens in the receiver to be obtained.

The diagram (Fig. 17) showing the form taken by the television signal has been deliberately simplified as far as possible. Distances measured vertically represent the signal voltage, while horizontal distances represent time. The carrier wave varies from sub-

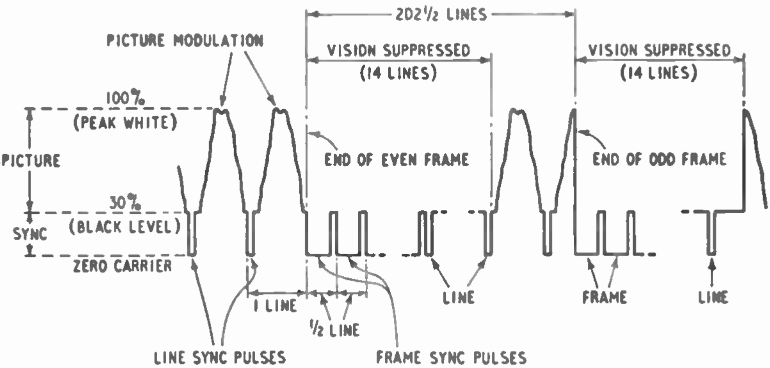


Fig. 17—Simplified diagram of the B.B.C. television waveform, showing the main features, which are fully described in the text

stantially zero to 100 per cent, the latter representing full white in the picture. Black is represented not by zero, but by 30 per cent carrier, so that the complete tone values of the picture lie between 30 per cent and 100 per cent carrier.

Below 30 per cent (often referred to as " blacker than black ") we have the synchronizing signals, and it is clear that by the use of an amplitude filter in the receiver it is possible to separate these from the picture signal.

The first section of the diagram, starting from the left, shows two complete lines of the picture. At the beginning of each line there is a rectangular line synchronizing pulse, extending from 30 per cent down to zero carrier, which occupies in time about one-tenth of the line. Following this, the carrier goes up to " black " level for about one-twentieth of a line before the actual picture signal commences.

The picture signal occupies the carrier between 30 per cent and 100 per cent, the whiter the tone the greater being the carrier voltage. Towards the end of the line the carrier again drops to " black " and remains there for a short period (about 1·5 per cent of the line period) before the commencement of the next line synchronizing pulse.

Frame synchronizing signals precede each frame, but to secure interlacing, the signal differs at the end of even and odd frames. The next section of the diagram indicates the form of the signal at the end of even frames. Following the last line of the frame there is a series of frame synchronizing pulses, eight in number (though only two are shown). These each occupy 4/10 of a line, with a return to 30 per cent carrier (black) for 1/10 of a line between each. Thus the frame pulses are at half-line intervals. Following the eight pulses (four lines), for the rest of the interval between frames (another 10 lines) the vision signal remains suppressed, but the usual line synchronizing pulses are continued.

The next section of the diagram shows the state of affairs at the end of odd frames. Instead of the frame synchronizing pulses starting at a line pulse, the first pulse starts half-way through the last line of the preceding frame, the carrier dropping to zero, and a train of eight pulses follows at half-line intervals. Following these pulses, the vision again remains suppressed for another 10 lines, during which time only the line synchronizing pulses are transmitted, then the vision (or picture) signals of the next frame commence, starting with a half-line signal. The whole train of operations then repeats.

To sum up briefly, suppose we have reached the end of the line 405 (the end of an even frame). The first four lines of the next frame carry the frame synchronizing pulses; then come 10 black lines, and the 15th line starts the picture which continues up to line 203, with a line synchronizing pulse at the beginning of each line.

Only half of line 203 is traced when the synchronizing pulses commence for the next (interlaced) frame, occupying four lines, followed by 10 black lines as before. At the middle of line 217 the picture signal recommences, and it continues until line 405, when the cycle is repeated.

It will be seen that there are actually 188·5 lines per frame carrying the picture signal, or 377 per picture (two interlaced frames), the other 28 lines being used for frame synchronization.

One important difference between the television signal and an ordinary sound broadcasting signal is that the former must occupy a considerable band-width, and therefore it is necessary for the transmission to take place in the ultra-short (or very high frequency) wave-band. The necessity for high modulation frequencies in television transmission will be realized in the light of the following consideration.

The picture intelligence, as we have seen earlier, is conveyed by scanning the scene to be televised in a large number of horizontal lines 25 times per second. It should be clear that the vertical size of the picture element to be scanned cannot be larger (or smaller) than the " thickness," or the height, of one of the lines, and on the assumption of a symmetrical cathode-ray spot, and equal definition horizontally and vertically, the horizontal size of each element must be the same. Fig. 18 shows part of a single line, much enlarged, with successive square picture elements indicated.

It is possible to calculate the total number of such picture elements that must be transmitted per second from a knowledge of the form of the television "raster". Assuming there are 377 lines per picture actually in use (the remaining 28, as we have seen, are used for frame synchronization), the number of elements in a square picture would be 377 × 377. However, in the B.B.C. transmission the picture now is wider than it is high in the ratio

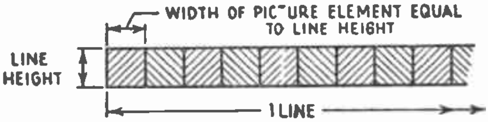


Fig. 18 *(above)—Diagram of part of a single line (enlarged) to show the conception of picture elements*

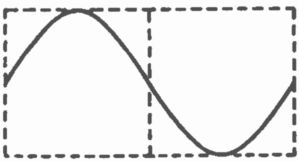


Fig. 19 *(left)—Showing how the positive and negative half-cycles of a complete sine wave cover two picture elements (dotted)*

of 4 to 3 (a change from the original 5 : 4), so that the actual number of elements becomes $\frac{377 \times 377 \times 4}{3}$, or about 190,000.

As there are 25 complete pictures per second the total number of elements to be transmitted per second is 190,000 × 25, or 4,750,000. Naturally, this figure determines the highest modulation frequency to be transmitted, but since each complete cycle of a sine wave can deal with two picture elements, the actual signal frequency is one-half the total number of picture elements, or 2·375 Mc/s (see Fig. 19). It can be seen readily that if the number of lines per picture is increased, the total number of picture elements is increased, and with it the necessary band-width. In fact, the band-width is increased in proportion to the square of the increase in the number of lines.

In order to transmit the square picture elements, the fundamental frequency must normally be accompanied by a series of harmonics, and the higher the harmonics, the more accurately will the resultant waveform correspond to a square shape. On this basis, the maximum modulation frequency might very well rise to 25 Mc/s or so, and would involve considerable difficulty in transmission and reception.

Actually, owing to the fact that the cathode-ray spot on the end of the tube is of appreciable size, and other considerations, it is found that in practice such higher harmonics would be wasted, as the spot would not be able to deal with them. As a result, the highest modulation frequency actually transmitted is only slightly greater than the fundamental frequency as found above. The transmission contains modulation frequencies up to about 2·75 Mc/s, and the total band-width required for a double sideband transmission, as used to be employed for the London station, is about 5·5 Mc/s.

It is clear, in view of the fact that the whole of the M.W. band from 200 to 500 metres only occupies a band-width of 0·9 Mc/s, that, were it possible to transmit on this band, only one-sixth of a single television transmission would occupy the whole of the

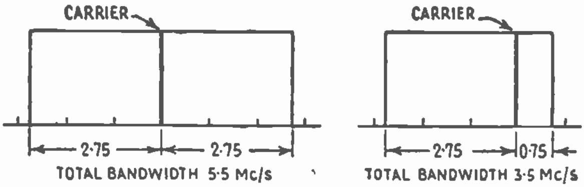


Fig. 20—Comparison between idealized double and vestigial sideband transmissions, showing a saving of band-width of about 2 Mc/s when the latter is employed

band, and in fact the whole transmission would extend from, say, 500 metres down to about 50 metres. This, of course, is quite impossible, and it is only by going into the ultra short-wave (or V.H.F.) band that television becomes practicable as far as band-width requirements are concerned.

In any case, the carrier frequency must be several times as great as the maximum modulation frequency, and that is partly why a value such as 45 Mc/s (6·7 metres) was chosen for the vision transmitter of the London station. The vision band originally extended from about 42·25 Mc/s to 47·75 Mc/s, and therefore by transmitting the sound at 41·5 Mc/s (7·2 metres), the sound channel just cleared the low frequency edge of the vision band.

The full band-width of 5·5 Mc/s was permissible when the first B.B.C. station was planned, as there were no other stations in the vicinity to be considered. When the question of securing a widespread coverage for television in the British Isles was tackled, it was realized that even down in the V.H.F. band there would not be enough room for all the stations necessary if they all occupied 5·5 Mc/s each.

In order to obtain enough space for five stations (a minimum number to give a reasonable coverage) in the total band available, it was necessary to adopt the system known as " vestigial sideband " transmission for the four extra stations planned. The London station was allowed for the time being to remain as it was, with double sideband transmission, as otherwise the many receivers already in use would no longer be suitable without modification, but it was brought into line with the other stations when the new transmitter at Crystal Palace replaced the old one that had operated at Alexandra Palace.

Vestigial sideband transmission means that only one of the sidebands (the lower one, in the case of the British stations) is fully transmitted, most of the other half being suppressed, leaving only a vestige in the resultant waveform. Fig. 20 compares double and vestigial sideband transmissions, and shows the saving in total band-width. It is assumed that in the case of the vestigial sideband transmission about 0·75 Mc/s of the upper band will remain, giving a total pass band of about 3·5 Mc/s.

The frequency allocations for the five B.B.C. television channels in Band I are given in the following table, the channel number being followed by the name of the main transmitter to which it was originally allotted. On the right of the table are shown some of the smaller transmitters, erected to fill in the " pockets " created geographically by gaps in the coverage achieved by the five main transmitters, which share a channel with one of the main transmitters. An (H) following one of these stations indicates that its transmissions are horizontally polarized.

Channel No.	*Main Transmitter*	*Sound Carrier* (Mc/s)	*Vision Carrier* (Mc/s)	*Smaller Transmitters Using Same Channel*
1	London	41·5	45	Belfast (H)
2	Holme Moss	48·25	51·75	Plymouth Brighton
3	Kirk o' Shotts	53·25	56·75	Isle of Wight Norwich (H)
4	Birmingham	58·25	61·75	Aberdeen (H) Channel Isles (H)
5	Wenvoe	63·25	66·75	Pontop Pike (H) Isle of Man

All the others are vertically polarized. These are but a few of the earliest supplementary B.B.C. transmitters, however. Altogether there are more than 30, including satellites, planned or actually working, at the time of writing.

At the time of writing plans are afoot for four additional smaller stations which are expected to be in operation by the end of 1957. These are Rosemarkie in North Scotland, which will operate on channel 2 with horizontal polarization; Blaen Plwy in West Wales, using channel 3 and horizontal polarization; a station in the Carlisle area on channel 4, again with horizontal polarization; and another in the Londonderry area using channel 2 and horizontal polarization. A fifth station may be erected in the Dover area but this depends upon the reliability of the signal in that area from Crystal Palace. The Dover station would use channel 2 and horizontal polarization.

The diagram in Fig. 21 shows the space occupied by the various channels in Band I. S1, V1, S2, V2, etc., represent the sound and vision carriers of each channel. The dotted outline of part of the London channel shows it as it was when the transmitter was located at Alexandra Palace, when a double sideband system was used. It will be seen that, without the partial suppression of upper sidebands of channels 2, 3 and 4, the stations would overlap. As already mentioned, the adoption of vestigial side-band transmission involves some modification to the receiver, compared with the double sideband system, and this will be more fully described later.

It will be gathered that the figure of 405 lines chosen for the British television system is in the nature of a compromise between

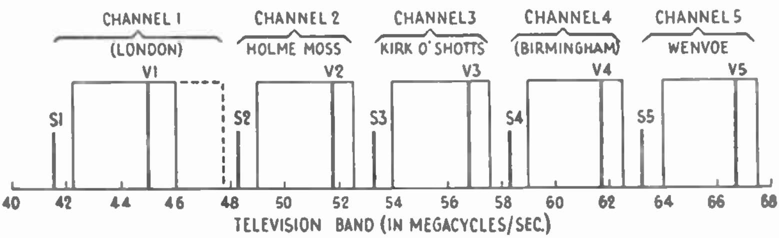


Fig. 21—Band I extends from 40 Mc/s to 70 Mc/s, and the five B.B.C. television channels are distributed within it as shown in this diagram, where the sound carriers are indicated as S1, S2, etc., and the vision carriers as V1, V2, etc. The old outline of channel 1 when it was double sideband is shown dotted

good picture detail and the frequency band necessary for transmission. The 405-line picture gives an acceptable amount of detail, yet permits five main stations to be accommodated comfortably within the frequency range of Band I.

Nevertheless, it is obvious that greater detail can be secured by an increase in the number of lines employed in the picture. The U.S.A. employs 525 lines, but in order to secure a really appreciable improvement over the British system it is probably necessary to go to over 600 lines. On the Continent the C.C.I.R. system, which uses 625 lines, has been adopted fairly generally, and the same standard has been adopted in the recently opened Australian system. In the latter country the problem of frequency band allocation is not so serious as it is in Europe, as stations separated by 200 miles or more can probably work on the same frequency band without mutual interference.

Pictures of 819 lines are being transmitted from several stations in France, including Paris and Lille, and as many as 1,000 lines are mentioned as the ideal to aim at, but it is unlikely that this standard will prove practicable on a national basis in any country for many years to come. The greater the number of lines the greater the band-width necessary, and greater band-width means fewer transmitting channels in a given band of frequencies. It also increases the cost of the receiver to a small extent.

When our television service was extended by the addition of alternative programmes, space was allocated for the transmitters of the Independent Television Authority in Band III, which is large enough to accommodate eight channels at 5 Mc/s intervals. The complete list of channels with their frequency allocations is shown below, but at the time of writing only channels 8 to 11 have been allotted to stations, and they all belong to I.T.A.

Channel No.	*Sound* (Mc/s)	*Vision* (Mc/s)	*Channel* No.	*Sound* (Mc/s)	*Vision* (Mc/s)
6	176·25	179·75	10	196·25	199·75
7	181·25	184·75	11	201·25	204·75
8	186·25	189·75	12	206·25	209·75
9	191·25	194·75	13	211·25	214·75

Chapter 3

THE RECEIVER OUTLINED

Main Units Required – Superhet and Tuned Radio Frequency Circuits

HAVING DEALT WITH THE FORM of the signal and the considerations which affect its frequency, we can now begin to examine the receiver with a clear picture of what is required of it. Leaving out the sound for a moment, it will be remembered that the vision signal actually contains two sets of information—the intelligence necessary to form the picture signal (or "waveform"), and the synchronizing pulses (or "waveform") for "assembling" the picture correctly. "Sync" is a widely recognized abbreviation for "synchronizing".

In the early stages of the receiver both sets of information are dealt with in the same way, but later in the set they have to be separated from each other so that each can perform its particular function.

As in the case of a receiver for ordinary sound broadcasting, the television receiver must first amplify the incoming signal, and then remove the carrier wave, leaving the modulation, which is the part that is required.

Again as in a radio receiver, the modulation is extracted by a "detector" which "rectifies" the signal. The modulation is termed the "video" signal (or "waveform") and it comprises the picture waveform and the sync waveform. The detector is usually followed by a video amplifier, and then by a sync pulse separator. This last separates first the sync waveform from the picture waveform, and then the line and frame sync pulses from each other.

While it is possible to use either the "straight" tuned radio frequency type of receiver circuit or the superheterodyne type for television reception, the latter renders the problem of tuning the receiver to different transmitters a fairly simple one, and modern receivers are almost invariably superhets. Fortunately, the complete circuit can be split up into a number of well-defined sections, and this has been done in Fig. 22, which shows the basic arrangement of a superheterodyne television receiver in block diagram form.

Starting from the dipole aerial on the left, we have first of all a radio frequency (R.F.) amplifier, broad enough in its band-width to accept both the sound and vision transmissions. Following this is a frequency changer stage, containing a local oscillator running at a suitable frequency to produce the correct vision I.F. (intermediate frequency) signal. As, however, the sound signal is also present in this stage, a sound I.F. signal is also produced, though naturally at a different frequency from that of the vision I.F. signal. It is thus possible, at this stage, to separate vision and sound signals by suitable tuning circuits.

The sound signal therefore splits off at this point, and passes successively through the sound I.F. amplifier, the sound demodulator or detector, and the audio frequency amplifier and output stage, to the loudspeaker. This part of the receiver therefore differs very little from the conventional superheterodyne sound broadcasting receiver, except that the detector is almost invariably followed by an interference limiter.

Continuing with the vision signal, after leaving the frequency changer stage this passes to a vision I.F. amplifier, which must, of course, be of the wide-band type capable of dealing faithfully

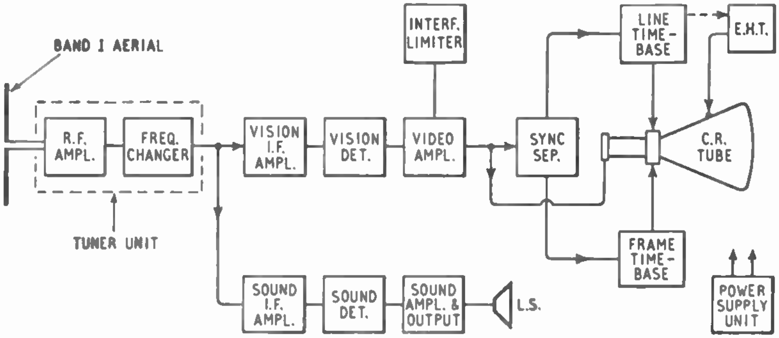


Fig. 22—Block schematic diagram showing a representative basic arrangement of a complete television receiver of the superheterodyne type. The sound amplifier may comprise two valves, as it does in Fig. 23

with an input of the full band-width occupied by the vision signal. This amplifier will probably contain a number of stages to provide the requisite overall gain, for wide-band amplifiers have very low gain.

Following the vision I.F. stages there is the vision demodulator, from the output of which we obtain the video modulation, comprising the picture waveform and the synchronizing signals. This output is passed to a video frequency amplifier of one or more stages which must also be capable of amplifying the wide-band signal without serious loss.

The output from this amplifier is fed both to the modulating (or control) electrode of the cathode-ray tube, and to the sync separator, which first removes the vision portion of the signal, leaving the synchronizing pulses, and then separates the line and the frame pulses from each other. There is almost always an interference limiter.

The pulses are fed separately to the scanning generators, or time-bases, of which there are, of course, two. These generators are solely concerned with providing the sawtooth currents necessary to deflect the cathode-ray tube beam and produce the "raster" on the screen. The synchronizing signals injected into them are used to control the scanning generators so that every line, and every frame, of the picture commences at exactly the correct instant.

This completes the receiver proper, but there is of course a power supply circuit which provides all the operating voltages for the various sections of the receiver, including, of course, the E.H.T. supply for the tube. The latter supply, in modern receivers, is almost always obtained as a by-product of the line scanning generator, as will be seen later.

The superheterodyne type of circuit has a number of advantages, notably those of high sensitivity, with freedom from instability, and comparative ease of separation of the sound and vision signals. However, there are disadvantages, too, such as the possibility of production of superheterodyne "whistles" which in a vision receiver result in dark bands or patterns interfering with the picture; greater complexity; and the problem of frequency stability of the oscillator. The effect of this last is more readily noticeable on sound than on vision, owing to the relatively narrow pass band of the sound I.F. amplifier compared with that of the vision I.F. amplifier. When the oscillator frequency slowly changes, the effect is termed " drift."

A limited degree of drift is permissible, and in modern receivers it is accommodated by increasing the sound I.F. band-width beyond that necessary for normal high fidelity sound reproduction, so that a small change of intermediate frequency can be accommodated without sideband cutting. Users of certain pre-war television receivers may have noticed that, until the receiver had been in use for half an hour or so, and everything had settled down to a steady working temperature, it was necessary to readjust the tuning slightly from time to time. A " user " control was provided for that purpose.

The " straight " R.F. circuit, though at one time popular in commercial receivers, is now practically obsolete owing to the necessity to tune to at least two channels. In fact almost all modern receivers can be tuned by the user to any three at least of thirteen channels, and most can be tuned to twelve or even to all thirteen channels.

However, apart from this point, and where extreme sensitivity is not required (that is, within the normal service area of the television transmitter), the T.R.F. type of circuit has proved entirely satisfactory. It is usually found that three or four R.F. stages are required to give adequate sensitivity coupled with a pass band sufficiently flat to accept the complete vision signal. The necessity for this wide pass band (up to just over 6 Mc/s in the case of a receiver for the double sideband London transmitter, and just over 4 Mc/s for vestigial sideband receivers), which has been explained, carries with it the problem of discriminating between the sound and the vision signals.

With the vision at 45 Mc/s and the sound at 41·5 Mc/s, for instance, in a double sideband receiver the vision extends approximately from 47·75 Mc/s to 42·25 Mc/s, and the sound is at 41·5 Mc/s, so that the lower frequency side of the vision band is slightly under 0·75 Mc/s from the sound channel. With circuits having a pass band of 6 Mc/s, and a necessarily far from abrupt cut-off, the gap between the two channels is small. In practice few domestic receivers will accept the full 6 Mc/s pass band without a certain amount of attenuation at each edge of the band.

The usual method of increasing the discrimination between sound and vision in T.R.F. circuits is to insert rejection filters tuned to the sound channel in the vision R.F. amplifier, and, much less frequently, a vision frequency rejector in the sound R.F. amplifier. In modern superhets it is the common practice to include, say, two sound I.F. rejectors in the vision I.F. amplifier, and usually another one tuned to the I.F. of the sound signal of the adjacent channel.

Early receivers could use a kind of single sideband reception of the double sideband transmitter, the R.F. circuits being accurately tuned and made so that they are free from drift. In this case, only the (upper) vision sideband from 47·75 to 45 Mc/s is received, and there is thus a separation of very nearly 3·5 Mc/s between the sound and vision, which is nearly seven times as great as with double sideband reception. However, single sideband working is more usually employed in superheterodyne receivers, and it was very common in them when the London transmission used the double sideband and the need to operate from a vestigial sideband transmission had not arisen. This " dodge " cannot be applied to the reception of vestigial sideband transmitters, since virtually only the lower sideband is present, and thus that is the one that must be received.

The effect of sound getting into the vision circuits is that dark irregular bands, usually horizontal, and occasionally patterned, appear on the picture, and they vary with the sound modulation being received. Synchronization may also be disturbed.

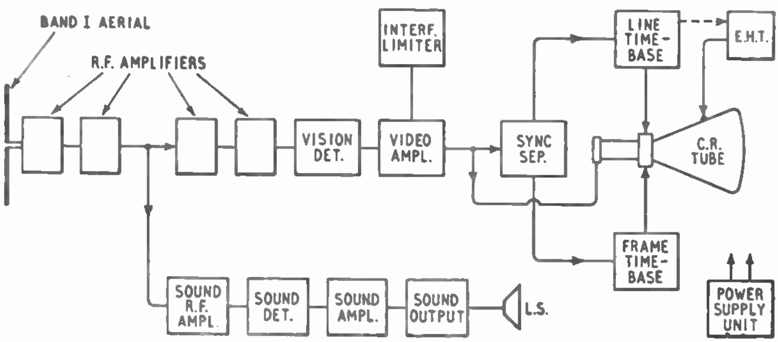


Fig. 23—Block schematic diagram showing a representative basic arrangement of a television receiver using a " straight " tuned radio frequency (T.R.F.) circuit up to the time when the Birmingham transmitter came into operation at Sutton Coldfield (December, 1949). The sound amplifier and output may be combined as in Fig. 22

Fig. 23 shows a block diagram of a typical T.R.F. or "straight" receiver as they were up to (and a little after) the introduction of the B.B.C. regional system based on the five main transmitters with vestigial sideband tuning. There were, of course, numerous differences in detail, but the general pattern is indicated in the diagram. Usually four R.F. amplifying stages preceded a diode vision detector, and this was followed by a video amplifying stage whose output was coupled directly (D.C. coupling) to the control electrode of the cathode-ray tube. The same output signal was applied also to the sync separator from which synchronization pulses were fed to the two time-base circuits, otherwise known as scanning generators.

The first two R.F. amplifiers carried the complete sound and vision signal, from 41·5 Mc/s to almost 48 Mc/s, but the last two were tuned either to the upper sideband only or over both sidebands. In both cases sound rejector(s) might be used with them, but in the latter case they almost certainly would. An interference limiter was usually associated with the video amplifier to reduce the effect of interference pulses, mainly from motor car engines. The E.H.T. supply might be derived from a simple high step-up mains transformer, a moderately high frequency oscillator, or from the line flyback energy in the line time-base output circuit. Any of these would have its own E.H.T. rectifier.

The sound R.F. amplifier usually took its signal from the second R.F. valve, and frequently the sound R.F. amplifier consisted of two valves tuned to the sound carrier frequency. This was followed by a diode sound detector, usually of conventional radio receiver design, whose audio frequency output was passed via an A.F. amplifying stage to the output valve and so to the speaker. There was usually a sound interference limiter between the detector and A.F. amplifier, but otherwise the circuit followed normal radio practice.

Before considering the various stages of the television receiver in greater detail, a few words on the general design may be helpful in indicating some of the fundamental differences between television receivers and radio receivers. In the superheterodyne type up to the I.F. stages, and in the "straight" type up to the output from the demodulator, we are dealing with extremely high frequencies. This means, of course, that extreme care has to be taken by the designer in the manner of screening, in the use of short leads, particularly in grid and high R.F. potential circuits, and in decoupling.

The mounting of components on strip assemblies, with the attendant increase in length of connecting wires, is avoided, and " earth " returns to the chassis in each stage are usually all taken to the same point on the chassis to avoid the appreciable impedance which might exist between separate points on the chassis at such high frequencies.

Decoupling capacitors in these circuits are usually of the ceramic or some other special type. Wherever a change of value is liable to affect the stability of tuning to any appreciable extent, temperature-compensated capacitors are desirable.

Until the advent of the five B.B.C. transmitters made it necessary, variable tuning had not been employed in British television receivers at all, but subsequently for manufacturing and distributing convenience manufacturers were obliged to make provision for changing the channel to which the set was tuned, either by providing alternative R.F. amplifier " strips " or sets of plug-in coils, with a variable adjustment to the oscillator tuning, or by arranging for pre-set tuning for all circuits so that they could operate anywhere in the British Isles.

Later still, of course, with the introduction of alternative programmes from the I.T.A. transmitters in Band III, it has become necessary not only to make the set adjustable to any one of the five channels in Band I, but to render it actually tunable by the user simply by the turn of a knob to a number of channels of widely different frequencies. How that is accomplished is described later.

Chapter 4

SINGLE-CHANNEL RECEIVERS

R.F. Amplifiers—I.F. Amplifiers—Frequency Changers

IN CONSIDERING THE VARIOUS stages of a television receiver, we will confine ourselves to the superhet type of circuit because it is the kind that is used almost exclusively to-day and in any case it is much more interesting in many respects than in the T.R.F. type of receiver. It may be borne in mind, however, that the frequencies at which a T.R.F. receiver works on channel 1 (41·5 Mc/s sound, 45 Mc/s vision) are not very different from those of the I.F. of a modern superhet (38·15 Mc/s sound, 34·65 Mc/s vision) so that almost anything that is done with a superhet of that type can be done equally well in a T.R.F. circuit, with one important exception: the T.R.F. cannot be tuned by the user to several alternative programmes. The reason for the inversion of the sound and vision frequencies in the superhet will be explained later.

In almost all cases it will be found that an R.F. amplifier stage precedes the frequency changer of the superheterodyne, partly, of course, to amplify the signal picked up by the aerial and improve the signal to noise ratio, but also to minimize the possibility of interfering signals reaching the frequency changer, by increasing the discrimination between wanted and unwanted signals. The latter, which may be harmonics of signals in quite a different waveband, may beat with the oscillator signals or harmonics of them to produce undesirable I.F. responses which would result in interference patterns on the television screen. The R.F. stage also acts as a " buffer " between the aerial and the frequency changer and helps to prevent the oscillator in the receiver from radiating its frequency from the receiver aerial, which would cause interference with other receivers.

Although the stage gain of a single R.F. amplifier at television frequencies is not likely to be very great, this amount of pre-frequency changer amplification is useful in that it reduces the amount of gain necessary in the I.F. stages, in which the majority of the amplification of the signal is attained, and this helps in ensuring a good degree of stability in the I.F. amplifier.

A more important advantage of the R.F. stage of the receiver, particularly in districts of low signal strength, is the improvement in signal to noise ratio which results, compared with a receiver in which the aerial is fed direct to the frequency changer. " Noise " is used here to mean the " grainy " background to the picture on the television screen which is the vision counterpart to background hiss in a sound receiver.

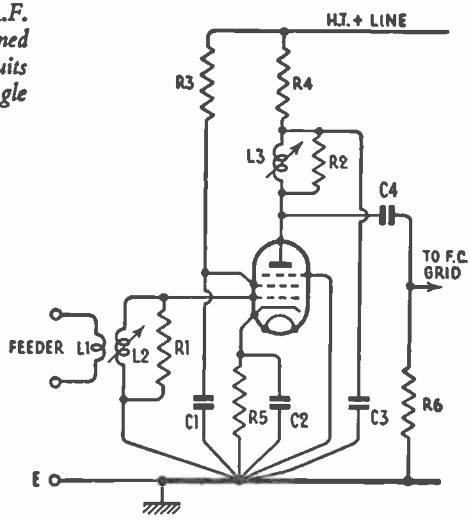
The noise introduced into a receiver due to the valves themselves, and not to external interference, is mainly attributable to the initial stage of the receiver, where the level of the signal is low. If this stage produces a good degree of signal gain, noise in succeeding stages, where the signal level is relatively high and subsequent gain is low, is unimportant.

Since the frequency changer valve produces a large amount of noise and very little gain compared with a good R.F. stage, the importance of feeding the incoming signal into a preliminary R.F. stage is obvious. The explanation given is actually only a very simple statement of the case, but it indicates another reason why, unless a really good signal strength is available, an R.F. stage is very desirable.

The design of a television R.F. stage is complicated by the fact that whereas we obviously require the maximum possible gain, we must also retain a very wide acceptance band for the signal. These two features do not go together, and in practice a compromise must be made whereby we obtain the maximum gain possible with an adequate band-width.

In view of the fact that in the majority of receivers the R.F. stage must accept both the vision and the sound channels, that is, when tuned it should amplify without serious loss all frequencies from, say, 46 Mc/s to just under 41·5 Mc/s (in the case of the London transmitter), the band-width should be about 4·5 Mc/s. In practice it is usually somewhat less than this, since a certain amount of attenuation of the sound channel is unimportant, and the stage can be tuned with the mid-point of its acceptance band slightly closer to the centre of the vision band than to the sound channel. Usually the response is a broad curve which

Fig. 24—A simple television R.F. stage illustrating points mentioned in the text. Note that all circuits of the R.F. valve return to a single point on the chassis



trails away at both ends and might easily overlap the edges of adjacent channels in other areas than London.

Another factor in the design of the R.F. stage is that the input impedance of the R.F. pentode becomes very low at television frequencies, and has a big effect on the characteristics of the input circuit. Further, the input impedance will vary considerably with the bias of the valve, and the use of variable cathode bias to control the gain will almost certainly affect the response characteristics of the stage.

In practice, the damping due to the valve, which is applied to the input tuned circuit, is used to good advantage to assist in securing the requisite large band-width; the load caused by coupling the feeder to this circuit also helps in this respect. The combination of the two is often sufficient to obviate the need for any further damping, though in some cases a parallel fixed resistance is necessary.

Fig. 24 shows a simple R.F. stage with tuned-anode coupling to the following (frequency changer) valve. The aerial feeder wires are connected to terminals of the coupling coil L1. Sometimes they go direct to the tuned grid coil L2, one being connected to its earthy end, and the other to a suitable impedance matching tapping on it. Other and more complicated coupling arrangements may also be found, and an electrostatic screen is often introduced between L1 and L2.

The tuned coil L2 is shown with a parallel damping resistance R1, which may or may not be necessary. No tuning capacitor is shown; in practice the grid/cathode capacitance of the valve, plus stray circuit capacitances, are sufficiently high for this purpose, and the adjustment of tuning is carried out by varying the inductance of L2. This is achieved by sliding in or out of the coil, axially, a brass rod, or slug, or by using an adjustable dust-iron core. This adjustment is pre-set.

The tuned anode coil L3 is also shown shunted by a damping resistance R2, and the amplified signal is coupled, via C4, to the grid of the frequency changer valve, R6 being the grid circuit resistance. Often a coil will take the place of R6, or if R6 is present R2 might be omitted. If a coil is used, it will form in conjunction with L3 a band-pass circuit.

The screen of the R.F. valve is fed from the H.T. line via R3, with the decoupling capacitor C1, and the anode circuit contains the decoupling components R4, C3. The suppressor grid of the valve (which is brought out to a separate pin) is connected to chassis. R5 is the cathode resistor providing fixed bias; it is by-passed by C2.

All by-pass and decoupling capacitors are very small and of the ceramic type, and it will be noted that all earth returns associated with the valve go to a common point on the chassis to avoid introducing impedance between the various earth returns, which might exist at television signal frequencies. The earth return of R6 would not go to the same point on the chassis as the returns associated with the R.F. valve, since R6 belongs to the frequency changer circuit.

It will be noted that in Fig. 24 no provision is made for variable gain control, but in Fig. 25 this is included. The feeder in this circuit goes directly to one end and a tapping on the tuned input coil L1, across which is the damping resistor R1. The output from the R.F. valve is coupled by means of R4 and C4 to a tuned circuit L2, R2 in the grid circuit of the frequency changer valve. R3 and C1 are the decoupling components for the anode and screen of the R.F. valve; the suppressor is connected to chassis. The resistor R5 provides fixed minimum grid bias, and the variable gain control is obtained by means of the fixed resistors

R7, R8, and the variable resistor R6, connected as shown in the cathode circuit. Since the suppressor of the valve is connected to chassis, and not to cathode, the suppressor is biased by the drop in voltage across the resistance network between cathode and chassis, this being varied by means of R6. However, the control grid return does not go to chassis, but to the junction of R7, R8, so that the grid bias variation is only that due to the change in voltage across R7. Normally R7 is made much smaller than R8, so that the variation in grid bias is only a fraction of the variation in suppressor bias.

The result of using this method of gain control is that the variation of the grid input characteristics of the valve with change of amplification is considerably reduced. Other methods of gain control may be employed, but in any case since the special television R.F. pentodes are usually of the short-grid base, non-variable mu type, the range of control must be limited. In practice, the R.F. gain control is often employed as a pre-set sensitivity control only, the "contrast" control of the receiver

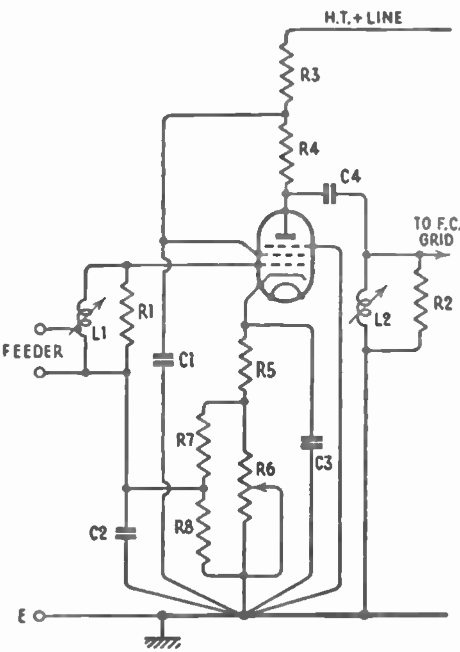


Fig. 25—Another type of R.F. stage, in which gain control by R6 is incorporated, and resistance-capacitance coupling to a tuned grid circuit is employed

(equivalent to the volume control of a sound receiver) operating only on the I.F. amplifier.

An alternative method of avoiding the detuning that otherwise results from operation of this type of gain control is to insert yet another resistor in the cathode circuit, between the top of R5, C3 and the cathode itself. Its value would be quite small, say 50 ohms, and it would not be by-passed by C3. Inverse signals are developed across such a resistance, resulting in negative feed-back to the control grid circuit, which compensates for the change in bias. Both suppressor grid and control grid circuits can be returned to chassis, so that the potential divider R7, R8 and the capacitor C2 are not needed.

Although both diagrams show a single tuned circuit in the output of the R.F. amplifier (tuned anode in Fig. 24 and resistance-capacitance fed tuned grid in Fig. 25), it is quite common to find a transformer coupling from the R.F. valve anode to the frequency-changer grid circuit. In this case the transformer will have band-pass characteristics necessary to deal with the wide-band signal. Both primary and secondary circuits of the transformer may be damped by shunt resistors, though a resistor across the secondary may not be necessary in view of the damping which is imposed by the grid-to-cathode impedance of the frequency-changer valve.

In order to increase the sensitivity of receivers for use in "fringe" areas where the signal strength is low, additional pre-amplifiers are often available for connection between the aerial and the input of the receiver. These consist of single or two-stage R.F. amplifiers, tuned to the station being received, and supplementing the existing R.F. stage or stages in the receiver.

Following the R.F. stage in the superheterodyne television receiver, we come to the frequency changer, which comprises the functions of local oscillator and mixer. In very early receivers this usually employed a triode-heptode valve or a triode-hexode, or two separate valves might be used for the same purposes. Later on it became more common to use a single pentode valve for the combined functions, its control grid, cathode and screen grid acting as a triode oscillator and the complete valve acting as a pentode mixer. Other designs used two separate triodes in a rather special arrangement. With the introduction of multi-channel tuning for alternative programmes, however, nearly all makers reverted to the triode-heptode valve, but it was of quite a different type from its predecessors, being designed for Band III.

It has already been stated that in the majority of cases the R.F. amplifier stage handles both the vision and sound input, the tuned circuits being broad enough to accept the frequency band involved without appreciable attenuation.

As the same frequency-changer stage is used for vision and sound, it will have the output from the R.F. stage fed to its mixer grid circuit, and the effect of the local oscillator will be to cause both vision and sound I.F. signals to appear in the mixer anode circuit, but at different intermediate frequencies. It is clear that at this point separation between the vision and sound can be achieved.

Let us see how the two I.F. signals are produced. Taking the London B.B.C. transmission on channel 1 as an example again, and assuming the "preferred" I.F. as recommended by the recognized industrial organization B.R.E.M.A. to be used, we require an I.F. "carrier" of 34·65 Mc/s for vision. The transmitted carrier frequency is 45 Mc/s, so the oscillator frequency can be the sum or difference of the two others, as it is with radio. B.R.E.M.A. recommends the sum, which puts it above the carrier. Thus 45 Mc/s + 34·65 Mc/s = 79·65 Mc/s for the oscillator frequency.

Using the same oscillator frequency (since we use the same frequency changer) the sound I.F. must be 79·65 Mc/s − 41·5 Mc/s = 38·15 Mc/s, from which it will be observed that the relationship between sound and vision has been reversed, or inverted, and the sound frequency is higher than the vision. This inevitably occurs when the oscillator frequency is higher than that of the signal frequency, and all frequencies associated with the signals are similarly inverted, as we shall see later, but the difference between the sound and vision intermediate frequencies is still maintained at 38·15 − 34·65 = 3·5 Mc/s, as it was in the original signal. The same form of inversion takes place in radio, but then it passes unnoticed because the signal is symmetrical in all respects, and inversion does not alter its character.

Had the alternative oscillator frequency been selected, so that it equalled the difference, instead of the sum, of the two frequencies, it would have been 45 — 38·15 = 6·85 Mc/s, giving a sound I.F. of 41·5 — 6·85 = 34·65 Mc/s. The two intermediate frequencies still work out to the same values, and they are still 3·5 Mc/s apart, but the sound frequency is now lower than the vision frequency, retaining its original relationship as it always does when the oscillator is below the signal frequency.

The result is just the same when the signal frequency is up in Band III. Let us take as an example the London I.T.A. transmission on channel 9, with a vision frequency of 194·75 Mc/s and the same I.F. as before, as it would be in many modern receivers. With the oscillator above the signal, the oscillator frequency is 194·75 + 34·65 = 229·4 Mc/s. The sound frequency is transmitted at 191·25 Mc/s, so the sound I.F. becomes 229·4 — 191·25 = 38·15 Mc/s as before. From this it is evident that all that is necessary to tune in a station is to alter the oscillator frequency, even though the change is the large stride from channel 1 to channel 9. Any R.F. stage(s) must, of course, present the correct frequency to the mixer, and it thus becomes necessary to tune this stage at the same time as the oscillator, as in a radio superhet.

It must not be forgotten, however, that with a wide band input signal the I.F. signal produced will also have a wide band. Thus a 34·65 Mc/s vision I.F. signal actually occupies the band from about 34 to 37·5 Mc/s.

The choice of the value of the intermediate frequency in a television receiver is governed by a number of considerations, which in some cases oppose one another, and as usual the individual designers generally arrive at what they consider to be the best compromise. Having decided on the I.F. values, they must also consider whether the oscillator frequency is to be above or below that of the signals.

Interference problems, due to the feeding back of I.F. harmonics to the input circuits; direct pick-up of extraneous signals at intermediate frequency, which may be due to short-wave stations or their harmonics; and similar causes, all have to be considered when deciding on the I.F. to be employed. The problem is made worse by the wide-band nature of the vision signal.

Various British receivers have been produced with I.F. values ranging from as low as 5 Mc/s in some very early receivers up to about 36 Mc/s as we have just seen, but a strong case has recently been made for standardization on the values we have quoted, although not all designers have adopted it at the time of writing. With a low I.F. value, greater amplification per stage may be obtained, but it becomes more difficult to prevent a residual I.F. signal passing through the demodulator with the wanted video frequency signal.

The principal reasons underlying the choice of so odd a pair of values as 34·65 Mc/s and 38·15 Mc/s as the standard I.F. values are considerations of interference between one and another of the many services using the ether, particularly since the introduction of Band III

The oscillators of both radio and television receivers, and more particularly their harmonics, are one source of such interference, but there are many others, and the ether is now so crowded that it is difficult to find a space in the frequency spectrum that is not affected by some form of oscillation from any of the numerous channels of communication, either from the

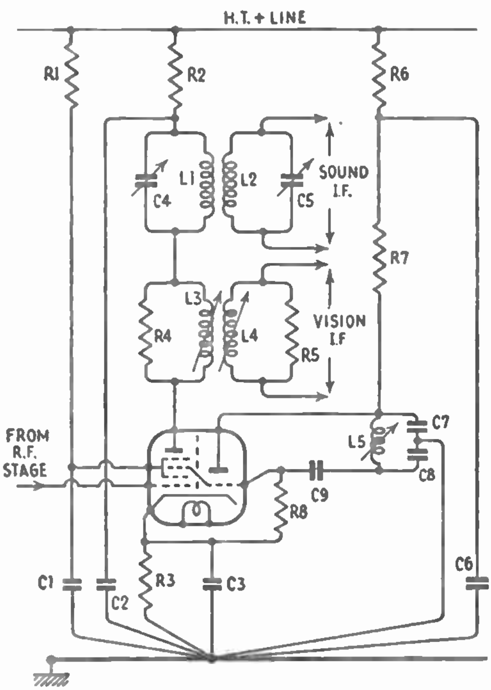


Fig. 26—An early type of triode-hexode frequency changer stage

fundamental or a harmonic. Some manufacturers chose their I.F. values very carefully several years before any form of standardization was recommended. They decided upon 16 Mc/s and 19·5 Mc/s, with the oscillator high, and they adhered to it consistently, while others changed from one pair of values to another, and they have been slow to change from their own adopted standard to a new one which even yet is not universally adopted.

As an example of a frequency changer stage, let us consider Fig. 26, which shows an early circuit in which a triode-hexode valve is used. Separation of the vision and sound I.F. signals takes place in the hexode anode circuit. The input from the preceding R.F. stage is, of course, fed to the mixer control grid. The usual decoupling is provided for the mixer screen grids (R1, C1) and anode (R2, C2). A small bias for the mixer grid is applied by means of the cathode resistor R3, by-passed by C3.

The triode oscillator section utilizes a Colpitts type of circuit, with the coil L5 and the two capacitors C7, C8 with their junction connected to chassis. C9 and R8 are the usual grid capacitor and resistor, but their values, in conjunction with those of L5, C7 and C8, and the oscillator anode voltage, have to be carefully determined in order to provide a suitable degree of oscillation.

L5, in the case shown, is tuned by means of a brass slug or by a movable iron-dust core, or possibly by a combination of both. In very early receivers it formed a variable tuning control, and was brought out to a knob for adjustment by the user, who was instructed to adjust it for maximum sound volume. If the sound I.F. were thus correctly tuned, it followed that the same applied also to the vision.

In all later receivers, prior to the introduction of 5-channel tuning, all tuning adjustments were of the pre-set, or fixed, type. The oscillator anode voltage is applied via the decoupling and load resistors R6, R7, and the decoupling capacitor C6. Note that all the returns to chassis for this stage usually go to the same point on the chassis.

As explained earlier, both the vision and the sound I.F. signals occur in the anode circuit of the hexode mixer, and if in series in the anode circuit we place two tuned circuits, one tuned to the vision I.F. and the other to the sound I.F., the I.F. signal voltages will appear across their respective tuned circuits, and can be fed to separate I.F. amplifiers.

In Fig. 26, L3, L4 form the vision I.F. transformer unit, with primary and secondary coils damped by R4 and R5 to provide the necessary broad band tuning. L1, L2, tuned by C4, C5, form the sound I.F. unit. The primaries of these units are in series in the hexode anode circuit; the secondaries are quite separate.

Chapter 5

5-CHANNEL TUNING IN BAND I

Ganged Tuning – Individual Tuning – Single-valve Pentode Frequency Changer – Separating Sound and Vision Signals

WITH THE NEED FOR 5-CHANNEL TUNING, frequency changer design changed. The changes were due partly to the need for adjustable tuning and partly to improvements in valve and circuit design resulting from catering for what were in those days regarded as high frequencies. Previously the highest frequencies were those of channel 1, but the second station to open was Birmingham on channel 4, with a vision carrier frequency of 61·75 Mc/s. Wenvoe, on channel 5, was to use a vision frequency of 66·75 Mc/s.

The methods of achieving variable tuning, which involved the adjustment of three or four tuned circuits, differed greatly between different manufacturers, but in due course they eventually settled down mainly to two general groups. One of these used separate knobs for the tuning circuits, usually consisting of extensions of the normal pre-set adjustments not easily accessible to the user but hidden from him only by a cover, which might be the back cover of the receiver. The other group used a set of ganged tuning coils, usually arranged in a triangular assembly so that they were close together, but sometimes arranged in a row with a metal plate which covered all three coil cans, and the tuning control raised or lowered the plate, moving all three cores together.

These tuning systems were simple to adjust, but it was not the intention that the user should adjust them, although any reader of this book should be able to do so without difficulty. Even with the ganged system it was sometimes desirable to make a final adjustment to the individual cores after re-setting, and with the other method it was sometimes a part of the channel-changing procedure to use proper alignment instruments.

The advantage of the ganged system was simplicity of operation, although it made design difficult. The advantage of the individual core system was that it ensured more accurate adjustment and enabled four circuits to be adjusted, whereas the ganged system was limited to three. Often in the individual system the oscillator control was brought out as a control for the user to adjust, and it was then usually calibrated in channel steps. The minimum number of core adjustments was three, comprising the aerial coil, the R.F. coupling coil to the mixer, and the oscillator coil. Where individual adjustments were used it was possible to use band-pass coupling between the R.F. amplifier and the mixer, involving four adjustments.

In general the adjustments were fairly simple, but they were best performed with a proper signal generator. Using the signal from the transmitter in the new location to which the receiver had been taken, with the volume control turned right up, the oscillator control knob was screwed inwards or outwards, according to the design and the relative frequencies of the old and new transmitters, until the sound channel was audible, the volume control being backed off as the strength increased. The other two (or three) knobs were then adjusted in the same

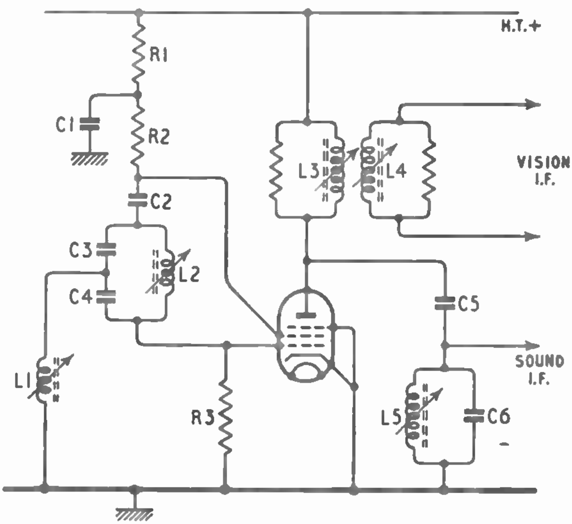


Fig. 27—A typical example of the single-valve pentode frequency changer circuit that was popular in the days of 5-channel receivers for Band I coverage

direction as the oscillator knob for maximum picture brightness, adjusting the contrast control, and possibly the sensitivity control, as the strength increased. In some cases the cores were subsequently backed off from the maximum position after it had been found. In a few cases tuning capacitors were adjusted instead of coil cores, usually in the oscillator circuit.

As compared with that in the earlier single-channel receivers, the principal difference in circuitry in the frequency changer stage of these receivers was the fairly general adoption of a single pentode valve for the complete operation, although some receivers went over to the use of two triode valves, or rather a double-triode valve. A typical pentode frequency changer circuit is shown in Fig. 27, where L1 is the R.F. coupling coil to the mixer and L2 is the oscillator tuning coil, tuned by C3, C4. The oscillator circuit is of the Colpitts type, the screen grid acting as the anode of a triode valve and the circuit being connected between screen and control grid via C2, which isolates the H.T. circuit. The signal is injected into the mixer via the

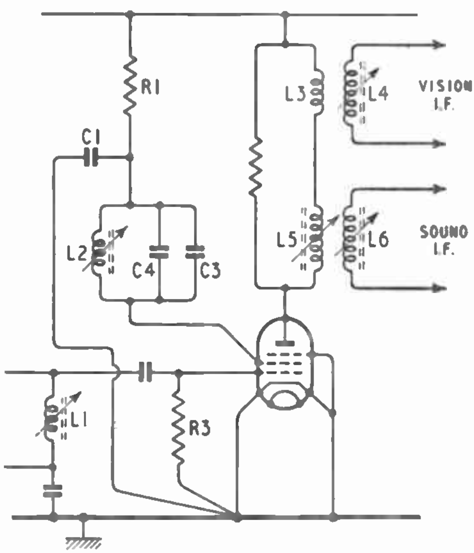


Fig. 28—Another type of single-valve pentode frequency changer of the same period as that in Fig. 27. This one has what appears to be an isolated oscillator circuit; it also has separate I.F. secondaries from a common primary, which was not usual in that period

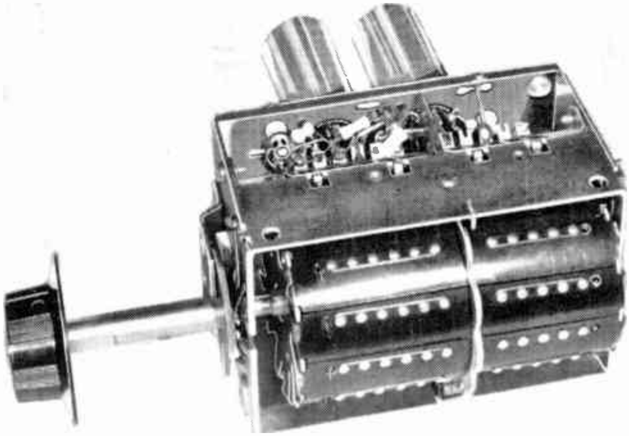


Fig. 29—An underside view of the Cyldon 12-position rotary turret tuner unit, with its screening cover removed to show the " biscuits " on the drum. The two valves are in the cylindrical screens projecting vertically above the unit

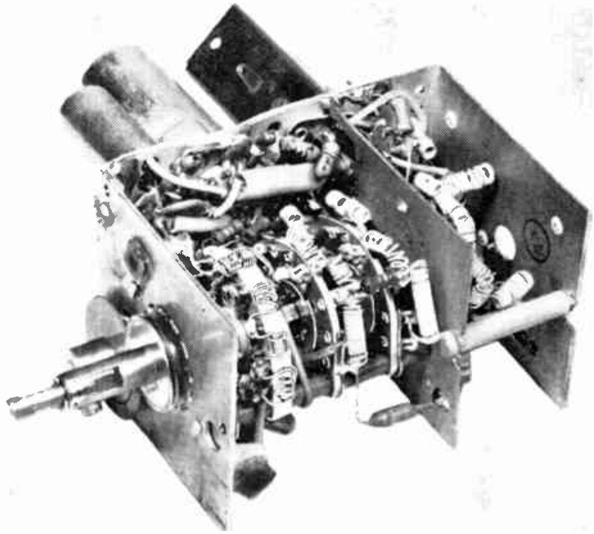


Fig. 30—Three-quarter underside view of an incremental tuner unit. Only the Band I coils can be seen on this side of the unit, but the Band III " coils " on the other side are short straight pieces of wire with curved pieces in parallel with them for adjustment

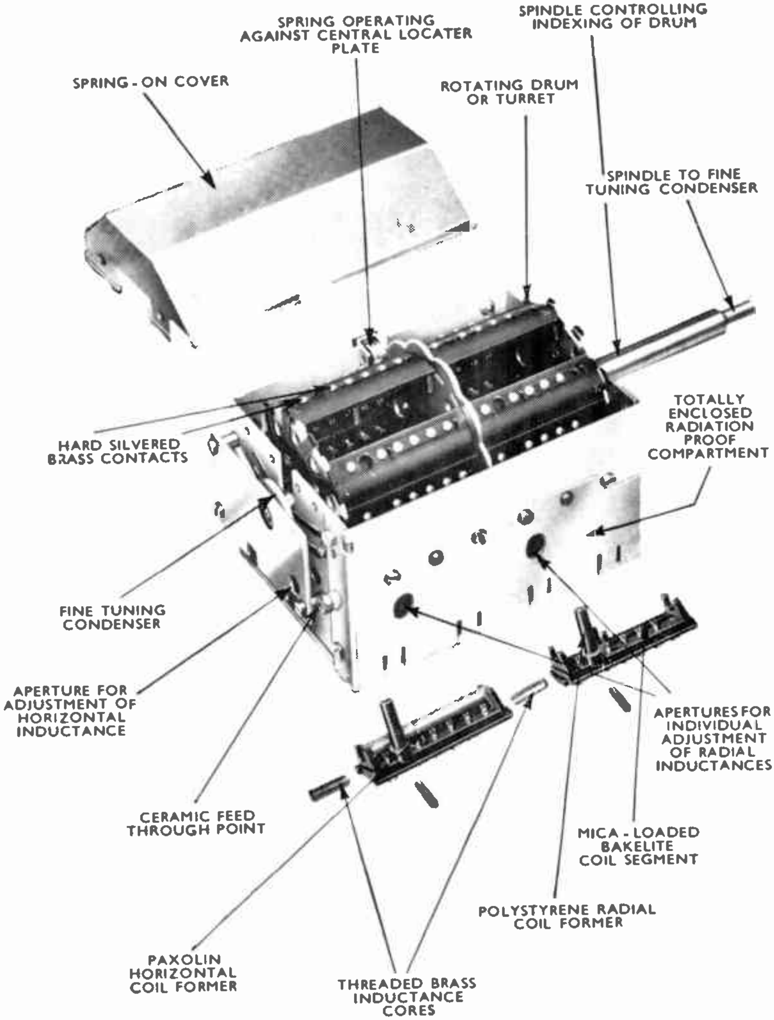


Fig. 31—Another kind of turret tuner, but still a typical example of these 12-channel units. This one is made by Edison Swan Clix and the captions in the illustration identify the various parts

oscillator circuit at a point that is approximately at earth potential. R2 is the "anode" load resistor, and R1, C1 provide decoupling. R3 is a normal grid leak.

An important feature of the diagram is the method it shows of feeding the I.F. signal to the two I.F. amplifiers, because it is probably the most common method in use, and has been so for a number of years. The vision I.F. output of the frequency changer is developed across the circuit comprising L3 and the stray capacitance of the circuit which are tuned to the vision I.F. The transformer L3, L4 then forms a band-pass coupling to the grid of the first vision I.F. valve. The frequency changer output at the sound I.F. is developed across L5, C6 which are tuned to the sound I.F., and the top of the circuit goes to the control grid of the first sound I.F. amplifying valve.

C5 performs two functions. It isolates the H.T. circuit from the valve grid, of course, but also forms part of a series-tuned circuit with L5. Its value is always very small, usually in the neighbourhood of 2 pF (two millionths of a microfarad) and it is fairly critical, sometimes having a value like 1·5 pF, for instance. Whereas L5, C6 form a parallel-tuned circuit with a very high impedance at its resonant frequency, L5, C5 form a series-tuned circuit which has a very low impedance at its resonant frequency. We know that L5, C6 are tuned to resonate at the sound I.F.; but L5, C5 resonate at the edge of the vision pass-band, not at the vision carrier frequency but at the outer end of the vision pass-band, adjacent to the sound channel. Thus L5, C5 form a short-circuit across the output of the frequency changer at this frequency, giving a sharp cut-off at about 2·7 Mc/s away from the vision carrier and preventing interference from the sound signal on the vision channel. This type of interference is what we have already referred to as "sound on vision."

Another form of the single-valve pentode circuit is shown in Fig. 28. Although there are many small differences between one circuit of a given type and another of the same type, the single-valve pentode circuit can be divided into two groups, of which one has its oscillator circuit connected directly between screen and control grid, as shown in Fig. 27, while the other, whose general style is shown in Fig. 28, seems to have its oscillator circuit coupled to the valve only at one electrode. Although it is connected only at one electrode, however, the oscillator circuit is coupled to the control grid via the internal capacitance of the valve, just as though there were an external capacitor connected between the two.

This needs to be explained, because it is not at all obvious from the diagram; in fact without an explanation it is difficult to understand why such an arrangement should oscillate at all. The answer is that the inter-electrode coupling is capacitive, and the change of phase across it is conducive to oscillation. The "top" end of L2 in Fig. 28 is effectively earthed via C1.

Two other features of interest in Fig. 28, which is copied from the diagram of an actual receiver that was current in 1952, are that two cathode connections are shown going to chassis and that the series-connected double I.F. transformer shown in Fig. 26 is employed. Although our diagram does not provide a good example of the principle, the two cathode connections are intended to be used to permit the use of separate common earth return points for the input and output circuits associated with the valve. Just in the same way as a single common earthing point is used for the whole valve in Fig. 26, so are the input and output returns taken to separate common points in Fig. 28. They might also be taken to separate points in a circuit like that of Fig. 27, which was also copied from an actual receiver, but in that particular case the precaution was presumably deemed unnecessary. The valve makers' purpose in providing a separate connection at each end of the cathode is to reduce the inductance of the total lead lengths. This feature is not peculiar to frequency changers but may be found in any valve designed for work at very high frequencies, even in an I.F. amplifier.

Although the pentode frequency changer was used very widely at this period, there were other types, usually employing a triode-hexode valve, or a separate triode oscillator and pentode mixer which came to very much the same thing. Another type that was used employed two triode valves for the same two purposes but mixed "additively" instead of "multiplicatively" as did the triode-hexode and the pentode. The two triodes usually comprised a double-triode valve, in which one triode operated as the oscillator and the other as the mixer.

Whatever the type of frequency changer, the oscillator frequency determines the frequency of the signal that is passed on to the I.F. amplifier, and it must therefore have a high degree of stability with change of temperature, or else tuning drift will be troublesome. Provided that the I.F. stages of the sound channel of the receiver are made somewhat broader than is theoretically necessary, however, a small degree of frequency drift can often be tolerated, and the degree of stability achieved by the use of modern components designed to compensate for drift is adequate.

Evidence of the presence of compensation is seen in Fig. 28, where two tuning capacitors C3 and C4 are shown connected across the oscillator tuning coil L2. There are other reasons for using two capacitors instead of one, but the most common reason is that one of them has a negative temperature characteristic which offsets the effect that an increase in ambient temperature has on the other components in the circuit. Otherwise it is usually simpler to use a single capacitor.

Chapter 6

MULTI-CHANNEL TUNERS

Turret Tuners – Incremental Tuners – Method of Channel-changing – Converting Band I Receivers

SO FAR WE HAVE TALKED about R.F. amplifiers and frequency changers as they were prior to the opening of Band III, when all receivers worked on Band I only, and the only form of variable tuning necessary was that involved when moving a receiver from one district to another. The tuning operation was performed once and for all time, so to speak, and it was not a very serious matter if the operation took an hour and required the services of a professional technician. Some receivers that were designed only for a single channel in Band I might take several hours to convert to another channel.

With the coming of alternative programmes in Band III, however, it was necessary to provide the user with some means of tuning his receiver himself in a matter of a few seconds to the alternative bands, if not to several channels in a given band. Coupled with this physical difficulty, there was also the engineering difficulty of designing receivers that would operate efficiently at the then new V.H.F. region around 200 Mc/s, which was between three and four times as high as anything previously used for domestic applications. The problem that presented itself was limited to the design of a tuner unit comprising the frequency changer and any earlier stages, of course, because after that the same I.F. stages could be used as for existing frequency changers. Provided that the new method would tune to the new V.H.F. signals, amplify them and frequency change them to the I.F. of the receiver, that was all that was necessary, and if it would work at 200 Mc/s it would be a simple matter to get it to work at 50 Mc/s.

The most common type of tuner unit adopted was the turret tuner. This comprised a self-contained unit, usually of a box-like shape measuring perhaps $5 \times 3\frac{1}{2} \times 3\frac{1}{2}$ inches, with a control spindle projecting from one end and two valves projecting from the upper surface, or deck. The two valves were a signal frequency (or R.F.) amplifier and a frequency changer, both being of very special types. Curiously enough the frequency changer reverted back to a triode-pentode valve, but it was a very different valve from the early triode-hexode of Fig. 26.

The next most common type of tuner was the "incremental" tuner, using the same type of circuitry and valves and having very much the same outward appearance and size. In addition to these two, there were several tuners of different types, most of them being designed to work with existing Band I receivers to enable them to receive Band III signals.

Physically the turret tuner is characterized by a rotating drum, usually having twelve positions in a full revolution, which occupies almost the whole of the space inside the unit. Round its periphery are clipped twelve sets of tuning coils, all mounted on small moulded blocks called "biscuits". The coils are on the insides of the biscuits, within the drum, while on the outsides are arranged on each biscuit a row of contact studs. The studs make contact with a set of springy contact leaves mounted in a row on the inside of the box, and thus the tuning coils are connected to the valve circuits.

The external appearance of one of these tuner units is shown clearly in Fig. 29, *facing page* 56, where a shaped screening cover which normally encloses the bottom has been removed, showing the rows of contact studs on the exposed sides of the biscuits. The biscuits are in pairs, all the studs of a given pair being on the same line.

One biscuit of the pair carries the aerial coils and usually has five studs, the other carries the R.F. coupling and reaction coils and usually has six studs. When the control spindle is turned one-twelfth of a revolution (one position) the next row of studs comes into position, bringing into circuit a new set of tuning coils, pre-set tuned to the required channel. In this manner a receiver can be tuned by an ordinary householder to twelve different channels in as many seconds if he wishes.

Most features of the drum of a turret tuner are shown in the illustration in Fig. 31, *facing page* 57, where one pair of biscuits is shown out of the drum, exposing their coils. The biscuits are held in position by spring clips, and can be lifted out easily. Detail differences are to be found in different makes of turret tuner, but the general principle is always the same. Two different makes are shown in Figs. 29 and 31.

The incremental tuner works on a different principle altogether, but this applies only to the method of tuning, and in other respects the two tuners are alike, employing the same valve types and the same valve circuitry. Whereas in the turret tuner different tuning coils are switched into position for each channel, the incremental tuner uses one long tapped inductor (or coil) as the tuning coil with the twelve tags of a rotary wafer switch connected to the tappings.

The inductor is actually mounted directly on to the switch tags, so that it is wrapped round the switch wafer. In order to keep the leads very short at these very high frequencies, which are around 200 Mc/s on channels 10, 11, 12 and 13, where a straight piece of wire between two adjacent switch tags is longer than is required, a second, curved length of wire is connected in parallel with it to form a pair of inductors in parallel, reducing the total inductance. The internal appearance of an incremental 12-channel tuner is shown in Fig. 30, *facing page* 56, where the coils of the Band I half of the four switch units can be seen in detail. On the right is the aerial wafer unit, in the centre are the two R.F. transformer wafer units, and on the left the oscillator unit.

The circuitry associated with these tuners follows a fairly common pattern in most makes of receiver. The R.F. amplifier is a special double-triode valve used in a special type of circuit called "cascode". What this means is shown in Fig. 32, where V1a and V1b are two triode valves connected in cascode, one valve being actually in series with the other. The two triodes form the two sections of a double valve, and they act as a single valve. The advantage of this kind of circuit over the conventional kind is that useful amplification can be achieved without producing a large degree of "noise". The circuit acts like a pentode valve, but it is less noisy.

V1a is connected in a conventional manner, with its cathode earthed via C3 and the signal fed to its grid. V1b, however, is connected as an "earthed grid" triode, or "grounded grid"

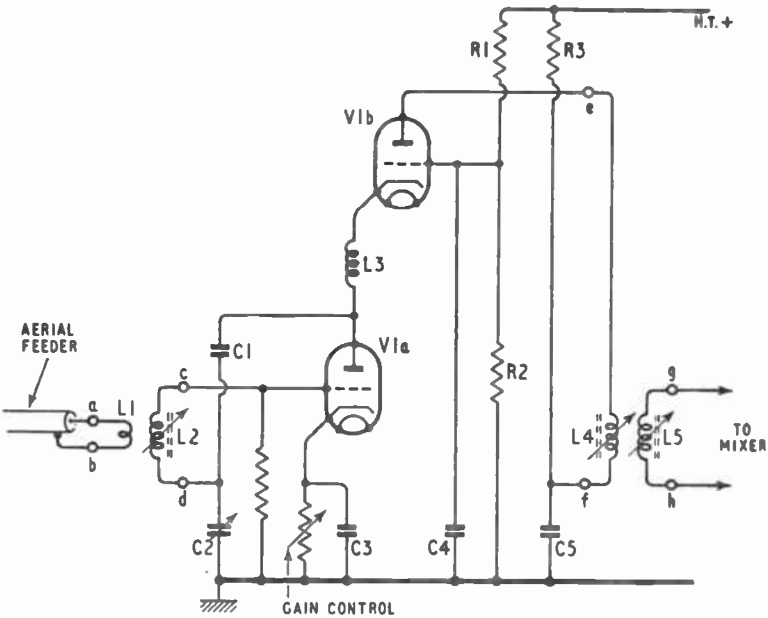


Fig. 32—The commonest R.F. amplifier for multi-channel operation is the cascode circuit, employing two triode valves connected in series. Here they are V1a and V1b. They are both housed in the same envelope physically and they act as a single valve amplifier

to use the American term. Its grid is earthed via C4, and the signal is fed to its cathode from V1a anode. The H.T. potential divider R1, R2 provides the grid with the correct bias. V1b anode is coupled to the mixer stage by means of a band-pass transformer. The gain of the stage is adjusted by means of the cathode potentiometer.

C1 and C2 form a neutralizing circuit, and C2 may be made adjustable for this purpose, but their values are very small, being only a few pF between them. It follows from this that the components themselves must be physically very small also, because otherwise they would have a larger " accidental " capacitance to chassis and other parts of the circuit than the intended capacitance assigned to them, and this applies to almost every component in a tuner unit. Everything is miniaturized, even the resistors and decoupling capacitors, yet despite this, the movement of a single component from its original position might upset the operation of the unit. Any repair is a delicate operation requiring considerable skill, even if it is only to replace an H.T. feed resistor.

The circuit of Fig. 32 is a generalized representation of what is commonly used, but details vary in every different receiver. Where a turret tuner is used, the transformers formed by the coils L1, L2 and L4, L5 are replaced by a new set of coils each time the drum is turned to tune the receiver to another channel. The terminations shown in the diagram at a, b, c, d, e, f, g and h represent the contact studs by which they are connected. Damping resistors can be fitted across any coil, on the actual biscuit, and it is thus common to find damping across a coil on one channel, and no damping across the same coil on another channel. The coil L3 is fixed. Its purpose is to resonate at the top end of Band III, around 200 Mc/s, and make up for the falling gain in that region. It is called a "peaking" coil.

If an incremental tuner were used, the complete inductor with its tappings and switches would be connected between each pair of terminals. In such a case L1 would usually be omitted, and

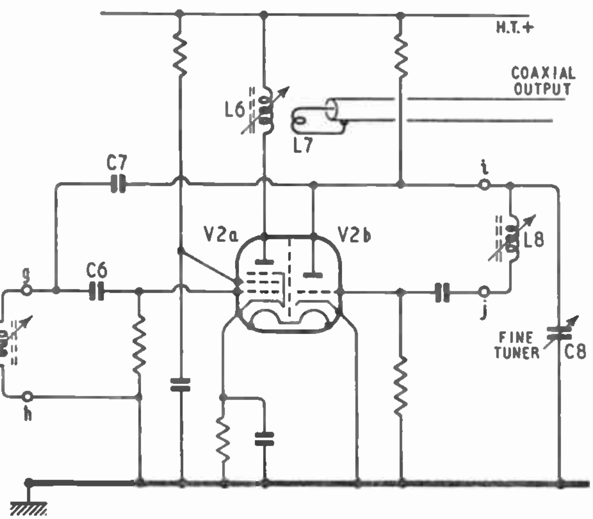


Fig. 33—The cascode amplifier of Fig. 32 is usually followed by a frequency changer employing a circuit of the type shown here. Coils L5, L8 (and L4 of Fig. 32) are mounted on the same "biscuit". V2a and V2b are separated by screening inside the valve. C8 is a manual "fine" trimmer

the aerial would be tapped into the turns of L2 at some point, saving a complete switch unit and a set of coils.

The arrangement of the frequency changer stage is shown in Fig. 33, which continues on from the secondary coil L5 of Fig. 32. The valve V2 is a triode-pentode of special design, having very low inter-electrode capacitances, very high gain, and a low input resistance at the very high frequencies at which it has to operate. This is important if L5 is not to be heavily damped. The triode section V2b operates as a Colpitts oscillator, with L8 as the tuning coil which must be very stable. To compensate for a small amount of drift, and to permit a small degree of correction by the user when changing from one channel to another, a very low-value tuning capacitor C8 is provided. Its control spindle is brought out to a knob marked "tuner" or perhaps "fine tuner," and it is usually concentric with the larger knob marked 1 to 12 which controls the rotation of the turret drum or the incremental switch.

The signal from L5 in Fig. 33 is applied to the control grid of the pentode section V2a, which operates as the mixer, and the output from the oscillator is very "loosely" coupled to the same point via C7, which might be as small as 1 or 2 pF. The local oscillations and the signal are thus added together in the mixer and amplified, the resulting intermediate frequency being selected by the tuning coil L6 in the anode circuit.

A low impedance coupling coil L7 forms the secondary winding of a transformer comprising L6 and L7 and matches the output to a 75 ohm co-axial cable of the same type as the aerial feeder. Thus the output at intermediate frequency can be taken away to any point, far or near, and applied to an I.F. amplifier. All that is necessary is to couple it with another low impedance coil like L7 at the far end.

All multi-channel tuners are not exactly like our example, and as we have already seen the tuning system may consist of a turret or a tapped inductance. Often instead of coupling the oscillator to the mixer by means of C7, the coil L8 will be coupled inductively to L5. In a turret in any case the two coils will be mounted close together, the studs e, f in Fig. 32 and g, h and i, j in Fig. 33 always being mounted on the same biscuit.

The two general categories just described, however, are representative of the majority of multi-channel tuners in modern commercial receivers, and they can be tuned to all twelve positions, so that twelve different channels could be tuned in if signals were available. In fact some incremental tuners have fourteen positions, and there are small turrets with only four and five positions. But it is not generally anticipated that a viewer will need more than one channel in Band I and two channels in Band III, and some makers cater exactly for that, fitting a three-position switch to their receivers and channel-changing just as it is done in radio receivers for S.W., M.W. and L.W. The circuit used, however, is still on the general lines of Figs. 32 and 33, and the coils are tunable by means of pre-set adjustments so that they can be aligned to receive any Band I channel and any two Band III channels.

CONVERTING BAND I RECEIVERS

A special state of affairs arises when a receiver that was originally designed to work only on Band I, and especially so if it was designed only for channel 1, is fitted with an adaptor to permit it to receive Band III. At the time when the alternative programmes in Band III were first mooted all commercial receivers could be tuned by one means or another to any channel in Band I, and they all used vestigial sideband tuning.

The manufacturers realized that it would be necessary if their sets were to sell that they must be convertible to receive the new programmes when they began to be radiated about a year or two later, otherwise the prospective set buyers would wait until suitable sets were available before buying a new set. So they designed convertors and adaptors, or tuner units, of various kinds that could be used with their current receivers when the alternative programmes became available.

In general these tuners used very much the same kind of circuitry that we show in Figs. 32 and 33, but the method of tuning varied widely, and in some cases the tuning was actually carried out by using plungers to depress coil cores to the desired positions in their coils, with coil springs behind the cores to maintain opposing pressure. Good engineering ensured fine adjustment and stable settings, and the tuning held well within the limits of the fine tuner, which was always provided.

Usually these tuners converted the Band III signal to the intermediate frequency of the receiver, and their output was permanently connected to the input circuit of the I.F. amplifier, by-passing the Band I tuning as shown in the diagram of Fig. 34. Often the means adopted was to couple it to the cathode circuit of the valve circuit in the Band I receiver. A switch in the tuner unit, when turned to "Band III", automatically cut off the H.T. supply to the Band I R.F. valve and oscillator, and the converted Band III signal passed through the mixer, which acted

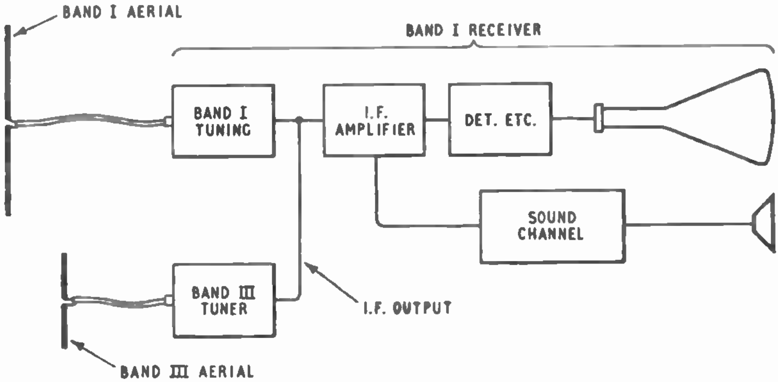


Fig. 34—Block schematic diagram showing the method of connecting a Band III tuner to a Band I receiver, by-passing the Band I tuning system

as an additional I.F. amplifier, its output circuit already being coupled to the I.F. amplifier.

Similarly, when the tuner switch was turned to its alternative position, which was marked "Band I", it switched off the H.T. supply to the tuner unit, and the Band I receiver functioned normally again with its own H.T. supply restored.

An alternative method of coupling the tuner output to the receiver was to add another I.F. valve to the receiver, connecting its anode directly to the anode of the frequency changer. The output from the tuner was then taken by co-axial cable to the control grid of the extra valve, while the change-over switch cut out the H.T. supply either to the first two valves in the receiver or to the screen grid of the new valve. In both cases very simple H.T. circuit switches effected the Band I/Band III change-over. Both the Band I and the Band III tuning systems were permanently connected, and no switching was necessary in the signal circuits. As these tuners were added to the receiver and replaced

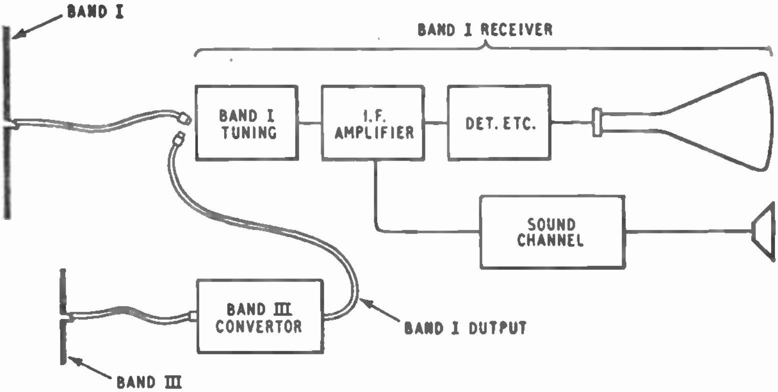


Fig. 35—When a superhet converter is used to convert a Band I receiver for Band III reception it is connected as shown in this diagram. If the receiver is also a superhet, a double-superhet system results

the R.F. and frequency changer stages of the receiver while it was operating in Band III, they required their own separate aerial feeders. This was not a very important matter, because they also needed a separate aerial, and running a separate feeder cable down to them simplified the installation. It was with this type of tuner in mind that reference was made earlier in Chapter 1 to the need for separate aerial feeders in some receivers.

There is, however, still another type of tuner unit, and whereas commercially those we have described as adaptors can be spoken of in the past tense, this other class will remain with us commercially as long as there are any " Band I only " receivers in use. This is sometimes referred to as the " double superhet convertor", and the reason for its popularity lies in its simplicity, because it can be purchased and fitted by the set owner without any technical knowledge and will work with any kind of receiver.

The type of tuner that we have called an adaptor was usually made specially for a given receiver, or series of receivers, and it was made for them by the actual maker of the receiver. As we have seen, it provided its output at the correct frequency to suit the I.F. amplifier in the receiver, but it also had mechanical and other electrical features which rendered it particularly applicable to a given receiver, such as the method of coupling it without affecting the set's performance on Band I.

In its simplest form the double superhet convertor tunes only to one channel in Band III, although usually it tunes to two or more channels. It has its own Band III aerial, and its circuit follows the general lines of Figs. 32 and 33, but the "I.F." output frequency is the same as that of the Band I transmitter in the district in which the receiver is located. Thus in London its output frequency would be that of channel 1, so that if the feeder from the Band I aerial is withdrawn from the aerial socket of the receiver, and the feeder carrying the "I.F." output from the convertor is inserted in its place, a channel 1 signal carrying the Band III programme is fed into the aerial socket, and the receiver treats it as a channel 1 signal.

Thus the Band III signal is converted to a Band I signal by the superhet convertor. It is called the double superhet principle because there is one superhet convertor (frequency changer) in the convertor unit and another in the receiver (if it is a superhet), so that there is a double change of signal frequency.

The arrangement is shown diagrammatically in Fig. 35, which is drawn on the same lines as Fig. 34 to make a convenient comparison between the two methods. All that is necessary to change over from Band I to Band III or vice versa is to change over the feeders at the aerial socket. In some of these convertors two aerial sockets are provided: one for the Band I feeder and one for the Band III feeder, and the output is permanently connected to the aerial socket of the receiver, as shown in Fig. 36.

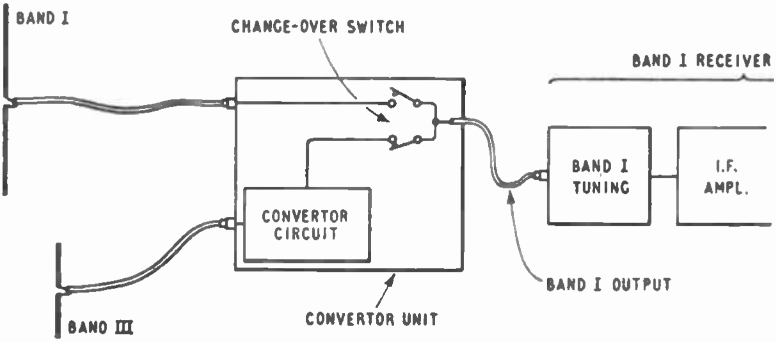


Fig. 36—In order to avoid the inconvenience of changing over the aerial plugs when changing from Band I to Band III, it is usual to incorporate an aerial switch in the convertor itself and provide two permanent aerial sockets

A change-over switch in the unit then either connects the convertor output to the set or passes the Band I aerial feeder straight through the convertor to the receiver. This avoids the need to change over the aerial feeders, and band-changing is accomplished by the more professional process of turning a knob.

There are two principal drawbacks to this method of tuning. The first is that when it is used in areas close to the Band I transmitter, " break through " is likely to occur, and the Band I signal will then interfere with the reception of the Band III signal. This results from the fact that the receiver is still tuned to the Band I channel while receiving on Band III, and in an area of high field strength it will pick up the signal weakly on its own circuit wiring, its chassis, and probably from the Band III aerial system as well. Unless measures are taken to terminate the unused Band I aerial feeder correctly, the signal coming down it from its aerial will be radiated from it near the receiver. This is usually taken care of in the convertor unit, and is one of the advantages of using one with a change-over switch.

This form of interference may not result in two pictures being seen on the screen of the receiver, but rather in a vague shadowy background to the Band III picture, like a changing pattern of moiré silk, the changes depending upon the amount of movement in the interfering picture. The only way to eliminate it, or to reduce it, is to screen the R.F. and frequency changer circuits of the receiver very thoroughly and be careful about the earthing of the screening.

Owing to the difficulty of earthing anything effectively at television frequencies, it is often more satisfactory to experiment with the bonding (*i.e.*, earthing connections) between various parts of the equipment than to provide good earths as we know them in radio. This applies particularly to the " outers " (screening or braiding) of the several feeder cables, the metal case of the convertor unit, the chassis of the receiver, the screening round the inside of the cabinet, and any other metalwork associated with the aerial circuits, but no connection must be made between any part of the convertor or its feeder cables and any part of the receiver chassis, except that made by the aerial feeder plug in the aerial socket on the receiver.

The reason for this is that in almost all modern receivers the so-called A.C./D.C. technique is used to obtain power supplies from the mains, and the chassis is in direct connection with one side of the mains. If any D.C. path exists between such a receiver and the convertor or the aerial, any person touching either of them could easily receive a fatal shock. This cannot happen if a properly designed receiver and a properly designed convertor are used and simply connected via the aerial socket of the receiver, as shown in Figs. 35 and 36, but it can happen if interconnections are made between the actual receiver chassis and the convertor casing or the feeders. This is a very serious warning, and it is essential that it is observed.

This " patterning " is one of the drawbacks, and close to a powerful transmitter it might be impossible to eradicate the interference. The second drawback has no visible effect on the receiver using the convertor, but it can cause serious interference with other receivers working in the neighbourhood on Band I. This again is due to the fact that the convertor output is tuned to the same frequency as the local Band I channel.

What happens is that in the same way as the various metal surfaces and wiring can act as a receiving aerial and pick up the local Band I signal, so can they act as a transmitting aerial and radiate it. The convertor acts as a transmitter, transmitting the Band III signal on the local Band I channel, and if the radiation efficiency of the conductors carrying it is good, the spurious signal is picked up on other receivers in the vicinity.

This has been known to happen as far away as a quarter of a mile, and it is an offence against the conditions of the G.P.O. licence to permit it to happen. It can be checked fairly easily by contacting the nearest neighbour with a television receiver and asking him to let you know whether he experiences interference on Band I while your receiver is working on the Band III signal.

Unfortunately there are thousands of these units now in use because they are so convenient to fit to any receiver. Usually, however, the interference can be suppressed by reducing the radiating efficiency of the metalwork, and the method is exactly the same as was described for eliminating break-through from Band I. It is always preferable, however, to fit a tuner unit whose output goes directly to the I.F. amplifier of the receiver.

Chapter 7

THE VISION I.F. AMPLIFIER

I.F. Coupling Circuits – Upper Sideband Reception – I.F. Frequency Response Curve – Sound Rejection – Gain Control

THE SELECTIVITY OF A RECEIVER is determined by the characteristics of the I.F. amplifier, and it is not a very critical feature of the preceding circuits. Whatever type of tuner is used in front of the I.F. amplifier, all it need do in the matter of selectivity is to pass the whole band-width of the channel being received. It will probably pass it very broadly, permitting the fringes of the adjacent channel to reach the I.F. amplifier, but the I.F. circuits will eliminate them. The whole video bandwidth must be passed, however, together with the sound channel, the two again being separated by the I.F. amplifier.

Complete separation of the vision I.F. signal from the sound I.F. signal in the anode circuit of the frequency changer is not, in practice, possible without additional filter circuits incorporated in the I.F. amplifiers, as we shall see later. For the present, however, we assume that the two signals are separated and fed to their respective amplifiers, and we will consider the vision I.F. amplifier only.

In general, the design of a television I.F. stage follows the same principles as that of the corresponding stage in a sound radio receiver, but there are two big differences which naturally influence the problem. In the first place, instead of an I.F. value of, say, 470 kc/s, which is commonly used in a sound receiver, the vision receiver may have an I.F. up to 36 Mc/s, as explained earlier. This at once makes a difference, though with modern valves, coil design and screening technique, the problem is not unduly difficult. The second difficulty in the design of a vision I.F. amplifier is due to the fact that we need a fairly high overall gain, coupled with a band-width acceptance of some 2·5 to 3 Mc/s.

It is obvious that with normal high-gain radio I.F. couplings employing sharply tuned circuits it would be impossible to secure anything approaching a 3 Mc/s band-width acceptance. Since picture detail depends on the retention of the sidebands in the amplifier, some other form of coupling must be used.

Unfortunately, though there are various methods of increasing the band-width of the amplifier, they all result in a reduction in the stage gain, and to compensate for this, more stages must be used. It is quite common for a television receiver to use three I.F. valves, and as many as five valves were employed in early receivers.

The couplings employed between the valves may be of the tuned anode, tuned grid, or tuned transformer type, and the wide-band properties can be secured in several ways. In practice, a combination of methods is often used in a single receiver.

It will readily be appreciated that one method of broadening the response of a tuned circuit is to introduce resistance in series with the inductance and capacitance of the circuit. More commonly, a resistor is connected across the parallel tuned circuit, of such a value as to have the same effect as the requisite series resistance. Such an arrangement damps the tuned circuit, and broadens its response, but at the same time it reduces the efficiency of the circuit, and therefore results in a lower gain for the complete stage.

Another method of securing the necessary pass-band is to adopt the principle of "staggered" tuning, in which instead of having all the couplings tuned to the same frequency (the mid frequency of the pass-band), some circuits are tuned progressively lower than the mid frequency while others are tuned higher by the same amounts. By careful adjustment of the tuning points it is possible to secure a fairly flat-topped response curve of the requisite width, though with a reduction in overall amplification.

Naturally the correct tuning of slightly staggered circuits is a difficult matter, and any inaccuracy here will result in an asymmetrical or uneven resonance curve which will introduce bad picture quality. Consequently, "staggered" circuits, once adjusted, should only be readjusted if the necessary equipment and information and skill are available.

Fig. 37 shows in skeleton form three types of coupling circuit which may be used. Resistance damping is indicated in each case, but staggered tuning may be employed, either additionally or alone, and in the latter case the parallel resistors may not be present.

Fig. 37 at (a) shows the conventional tuned anode coupling, L1 being the coil, tuned by its own and stray circuit capacitances, and adjusted by a variable dust-iron core. R1 is the damping

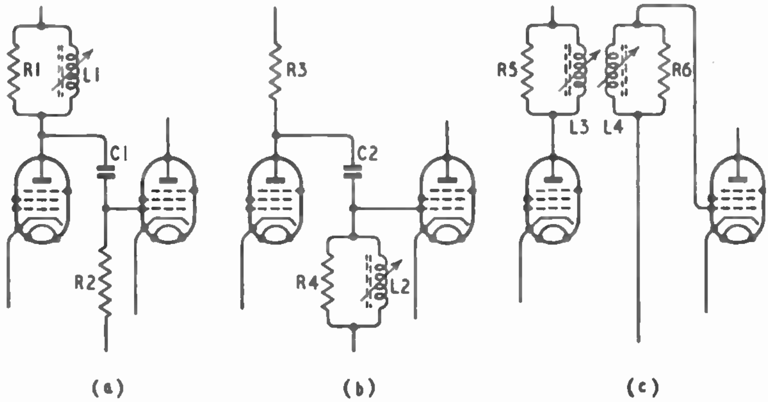


Fig. 37—Three typical examples of I.F. coupling circuits: (a) *tuned anode;* (b) *tuned grid;* (c) *simple band-pass transformer*

resistor, C1 the coupling capacitor and R2 the grid resistor of the succeeding valve.

At (b) in Fig. 37 we have the tuned grid form of coupling, with the anode load resistor R3, coupling capacitor C2, tuned coil L2 and damping resistor R4.

At (c) in Fig. 37 two coupled tuned circuits forming a band-pass transformer are employed. Tuning is achieved by varying the inductance as in (a) and (b). R5 and R6 are damping resistors, one or both of which may be omitted.

In the case of the London station, which until it moved away from Alexandra Palace transmitted a double sideband signal, some designers of early receivers reduced the band-width acceptance necessary in their receivers by working on one only of the two sidebands transmitted. The I.F. stages were adjusted so that a response curve showing acceptance of a band just under 3 Mc/s wide was obtained, with its centre about 1·5 Mc/s above or below the carrier. Such an arrangement permitted a greater amplification per stage to be obtained, without sacrifice of bandwidth.

This leads to the method described earlier, in which only the upper sideband was used, which had the additional advantage that interference from the sound channel was eliminated without rejectors. The lower sideband was "suppressed," as it were, by reason of the fact that none of the I.F. circuits was tuned to it. Whether in fact it was the upper or lower frequency side of the carrier in the I.F. amplifier depended upon whether the oscillator frequency was higher or lower than the signal frequency, because when it is higher it inverts the relative frequencies. The suppressed sidebands were in any case always those adjacent to the sound channel.

Unfortunately for the owners of such receivers, which are now very old in terms of television receiver vintages, when the B.B.C. regional plan was developed it was decided to *suppress* the upper sideband of the signal at the transmitter, using vestigial sideband system. The effect of this on old channel 1 receivers that used only the upper sideband would appear at first sight to be to rob them of their vision signal altogether, but the position is not quite as serious as that. As much as 0·75 Mc/s of the upper sideband is transmitted, and the response of the older receiver did not cut off the lower sideband sharply, with the result that something up to 1·5 Mc/s definition could be achieved.

Vestigial sideband transmission commenced with the opening of the Birmingham transmitter at Sutton Coldfield at the end of 1949, and all receivers designed to receive that station, and all subsequent receivers designed to receive on more than one channel, work on the lower video sideband only.

The frequency response of the I.F. amplifier in such receivers has a very well-defined shape, which is fairly critical. Ideally it would follow the contour of the heavy line in the diagram in Fig. 38, but a permissible deviation which can be achieved reasonably well in practice is shown by the contour in lighter line. This curve applies to all B.B.C. and I.T.A. transmissions, and was equally suitable for reception of the double sideband transmissions from Alexandra Palace, although it rejected the upper sideband.

It will be noted that the tuning is adjusted so that the carrier frequency lies on the right of the curve, half-way down the sloping edge. At a frequency 0·75 Mc/s above the carrier, the response is zero; at the carrier frequency it is 50 per cent of maximum, and at 0·75 Mc/s lower than the carrier it is at the maximum, and continues level up to a frequency 2·75 Mc/s less than that of the carrier, that is, to the edge of the outer sideband.

The reason for attenuating the response on the right hand side of the curve is as follows. The lower picture frequencies are contained in both the lower sideband and the part of the upper (vestigial) sideband which remains in the transmitted wave. On the other hand, the higher picture frequencies are only

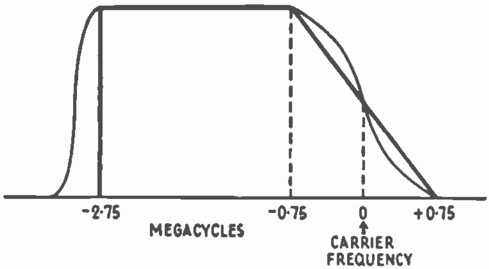


Fig. 38—The heavy lines here show the ideal response curve for the I.F. amplifier of a vestigial sideband receiver, while the lighter lines represent a reasonable compromise. As the pass-band here is on the low-frequency side of the carrier, the oscillator frequency would be lower than the signal frequency

present in the lower sideband, their opposite numbers in the upper sideband having been eliminated by the attenuation of the upper sideband at the transmitter.

If the receiver gave uniform response for three-quarters of a megacycle on each side of the carrier, the low frequencies would be emphasized at the expense of the high frequencies. To avoid this, the response of the receiver ideally should follow the shape of Fig. 38, when, in the region between the carrier frequency plus 0·75 Mc/s and the carrier frequency minus 0·75 Mc/s, the effect of the two sideband voltages is additive, and reaches the voltage produced by the single sideband occupying the band from – 0·75 Mc/s to – 2·75 Mc/s.

The I.F. response curve shown in Fig. 38 is obtained in a receiver using staggered I.F. tuning by adjusting the various tuned circuits accurately to slightly different frequencies, so chosen that the overall response curve of all the circuits approximates to the required shape. In a band-pass tuned I.F. amplifier the whole band-width would be covered by the band-pass transformers. In some receivers a mixture of band-pass tuning and stagger tuning is employed.

It may be pointed out that the same type of response may be similarly secured from a non-superheterodyne type of receiver, using R.F. stages, so that vestigial sideband receivers need not be of the superhet type. Two advantages in this respect in favour of the superhet, however, are (*a*) that the value of the frequency of amplification can be chosen; and (*b*) that it is a simple matter to tune a superhet to a number of different stations, whereas it would be virtually impossible to do so with a T.R.F. circuit.

The almost square-shaped contour on the left of the diagram in Fig. 38, that is to say at the high frequency edge of the video pass-band at 2·75 Mc/s below the carrier (or above the carrier), is necessary to prevent the video I.F. amplifier from embracing the sound carrier, which is 0·75 Mc/s farther on, 3·5 Mc/s from the vision carrier.

Such a sharp drop in response is very difficult to achieve, even though band-pass circuits are used in several stages. It is obtained in television receivers by inserting rejectors or wave-traps in the I.F. amplifier, and there may be as many as three or four of these, according to the design. They may all be alike in a given receiver, or they may be of different types. Whereas the various vision tuning circuits are all broadly tuned, rejector circuits are all very sharply tuned. They are more sharply tuned even than the sound channel I.F. circuits, and any drift that occurs in the oscillator frequency is likely to be noticeable in producing the sound-on-vision effect sooner than causing sideband cutting in the sound channel.

Four commonly used sound rejector circuits are shown in Fig. 39. In each of the four diagrams L1 is a vision I.F. amplifier tuning coil, and L2 is part of a rejector circuit. At (a) is a simple absorption wave-trap tuned to the sound channel frequency. It absorbs power from the tuning coil L1. The circuit L2, C1 at (b) provides negative feed-back at the sound channel frequency.

The double-resonant circuit referred to earlier and shown in Fig. 27 as a sound take-out device is shown at (c). It forms a series-tuned circuit C1, L2 which virtually short-circuits the

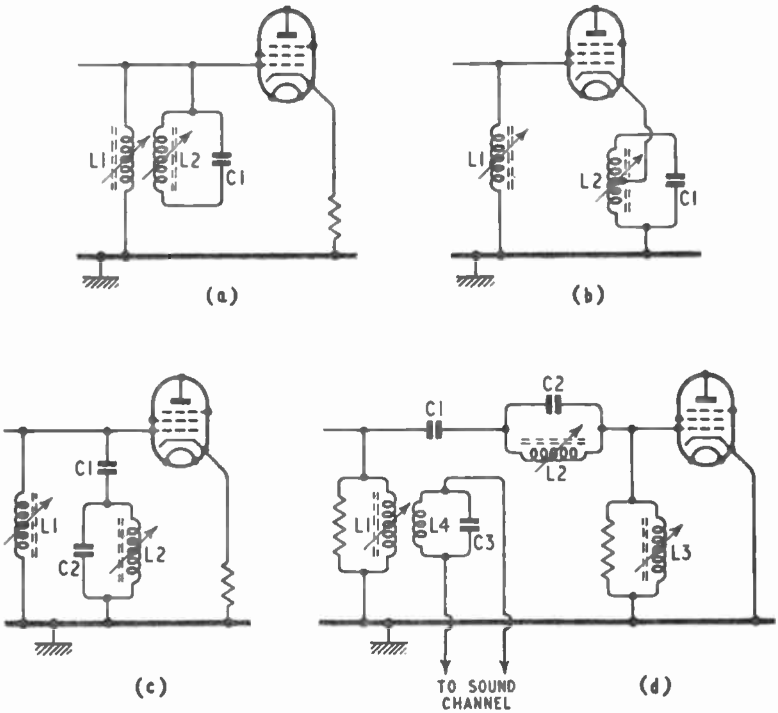


Fig. 39—Various types of sound rejector circuit: (a) *is a simple absorption wave trap;* (b) *introduces a high degree of negative feed-back at the sound channel frequency;* (c) *is the double-resonant rejector seen earlier in Fig. 27 as a sound take-out circuit;* (d) *is a more elaborate rejector, with L2, C2 inserted in the band-pass coupling and L4, C3 acting as an absorption circuit*

grid circuit of the valve at the sound channel frequency, and a parallel-tuned circuit L2, C2 which resonates at the outer edge frequency of the video pass-band, tending to increase the response at the 2·7 Mc/s cut-off of the response curve of Fig. 38. The parallel-tuned circuit is coupled to the I.F. valve only by C1, which is very small, usually about 1–3 pF, but in some receivers its effect is so marked that it causes the response actually to peak at, say, 2·75 Mc/s in Fig. 38, and instead of having a slightly rounded corner at the top it actually has a little pip there, followed by an almost vertical drop between the edge of the video pass-band and the sound carrier.

At (d) is shown a rather more elaborate type of sound rejector. L1 and L3 actually form a band-pass transformer tuned to cover the video pass-band, with C1 as the " top " coupling, the primary and secondary coils not being coupled inductively. Within the band-pass coupling is a parallel-tuned rejector circuit L2, C2 which resonates at the sound channel frequency, forming a very high impedance at that frequency. At the same time a second sound channel circuit L4, C3 is inductively coupled to L1. L4 acts as a sound take-out coil but its effect on L1 is to absorb power from it at the sound channel frequency. In effect, therefore, there are two sound rejectors in a single video I.F. circuit.

We have already seen that a gain control is often employed in the R.F. stage of the receiver, and is usually pre-set and used for adjusting the overall sensitivity of the receiver for any particular location and aerial. An independent gain control is also fitted in the I.F. stages of a superheterodyne receiver, and this usually becomes the " contrast " control, which is made readily accessible for adjustment by the viewer.

The primary purpose in having two independent gain controls, because that is what they actually are, is to provide a means of pre-setting the gain of the receiver, according to the field strength in the area in which it operates, with one, and to provide the user with a limited range of control with the other. It is one of the duties of the service engineer who instals the receiver to set the sensitivity control of the receiver to a point at which the overall gain of the receiver is correct when the contrast control is at its mid-point of adjustment. The user then has a range of control in both directions.

There are two other advantages in this arrangement. One is that a biasing control of some kind is necessary in the first valve circuit of the receiver to prevent a large signal from overloading the valve. The other is that it is inadvisable to use more gain than is necessary after the frequency changer because that is the " noisiest " stage in the receiver, and the noise is amplified at the same time as the signal. If no control of gain occurred prior to the frequency changer, the largest possible signal would be handed on to that stage and less amplification would therefore be necessary after it.

Several forms that may be taken by a contrast control circuit are shown in Fig. 40, where at (a) is shown the simplest type using a variable cathode resistance. Altogether the cathode resistance comprises R1, R2 and the variable element R3. R2 merely sets a limit to the minimum resistance, while R1 provides negative feed-back to counteract the change in input capacitance. At (b) is shown a simple type of control which

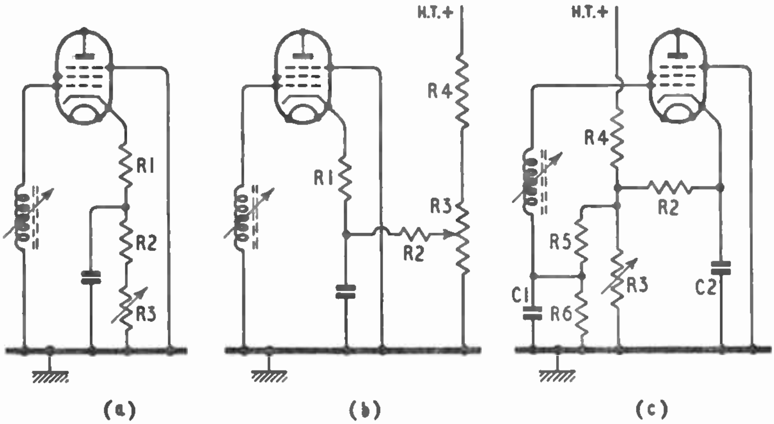


Fig. 40—Three of the several forms that a contrast control (or a sensitivity control) may take. The simplest type is a variable cathode resistance, as at (a); bias derived from an H.T. potential divider is shown at (b); at (c) different bias potentials are applied to control grid and suppressor grid

takes its potential from an H.T. potential divider, of which the variable element R3 forms part. Again R2 limits the minimum resistance of the cathode circuit and R1 provides negative feed-back. The advantage of this system over that at (a) is that the voltage-drop along R3 is more consistent than that along R3 in (a) because it is less dependent upon cathode current, which provides only part of the voltage-drop.

The circuit at (c) is a combination of that shown in Fig. 25 as a gain control and the circuit of Fig. 40 (b), because it provides different bias voltages to control grid and suppressor grid and uses an H.T. potential divider. Actually, all these contrast control circuits are equally applicable to sensitivity control, and in either case they may control two valves, possibly one R.F. amplifier and one I.F. amplifier.

Chapter 8

VIDEO AND SOUND CIRCUITS

The Vision Detector – Video Amplification – D.C. Component – Interference Limiters – The Sound Channel

THE SECTIONS OF THE RECEIVER already described have been concerned primarily with amplification of the received signal. It is true that, in the superheterodyne circuit considered, we have changed the carrier frequency, but this was only done for convenience, so that all the critically tuned circuits could be adjusted in the factory or workshop once and for all, permitting variable tuning to be performed with only one critical circuit, namely the oscillator.

The diagram at (a) in Fig. 41 shows the form of the signal at this stage; two complete lines and line synchronizing pulses are included, and it will be noticed that the carrier is still modulated by the picture signals at video frequency. The picture signals occupy the carrier from 30 per cent (black) to 100 per cent (white) of its amplitude; the sync pulses are in the " blacker than black " (0–30 per cent) region. The positive and negative phases of the carrier wave are symmetrical about the zero line.

Just as at this stage in the sound receiver it is necessary to " detect " the signal, and remove the carrier, leaving the A.F. signal which formerly modulated the carrier, so in the television receiver we now have to " detect " the video signal.

Consequently, the amplified I.F. signal, after leaving the I.F. amplifier, must be fed to a detector or demodulator stage, at the output of which we shall expect to be left with the video signal as at (b) in Fig. 41. Note that this still contains both the picture signals and the synchronizing signals. The removal of the latter for use in regulating the time base generators in the receiver is usually a post-detector operation.

The output from the demodulator shown in Fig. 41 (b) is shown as a " positive-going " signal, the voltage increasing in a positive direction with increase in signal. In order to secure a positive picture on the tube, this is the correct phase in which to apply the signal to the grid of the tube, as we shall see later. However, it may be necessary to amplify the video frequency signal before applying it to the tube, and if only one stage of video frequency amplification is used, the output from the demodulator will then be "negative-going," since 180 degrees phase reversal occurs in the single stage of amplification. It is quite easy to secure a positive or negative output from the demodulator stage, as required. In almost all modern receivers matters are arranged so that the output from the video frequency amplifier is negative-going, and is fed to the *cathode* of the picture tube, this being equivalent to feeding a positive-going signal to the grid of the tube.

So far as the actual circuit is concerned, it is possible to employ any of the demodulator circuits used in sound receivers, with suitable modifications made necessary by the 2·75 Mc/s bandwidth of the video signal and the high frequency of the carrier. In practice, either a single, or less often a double, diode detector is employed, though one manufacturer has used an R.F. pentode

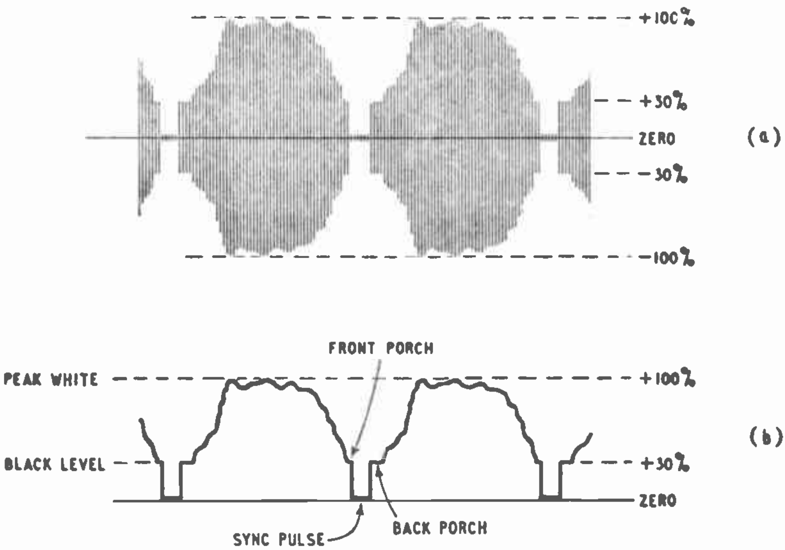


Fig. 41—The television signal waveform (a) *as it is applied to the vision detector, and* (b) *as it leaves it after rectification*

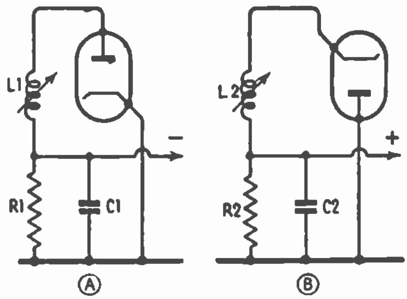


Fig. 42—Two half-wave vision detector circuits, arranged at (a) *to give a negative-going output, and at* (b) *to give a positive-going output*

operating under anode bend conditions. Recently, in order to reduce the number of valves in the receiver, there has been a tendency to employ the new-developed germanium crystal diodes for rectification purposes in place of thermionic diodes.

Unlike the majority of sound receivers, the tuned radio frequency type of television set also usually employed diode detection, so that from this point onwards both superheterodyne and tuned radio frequency types operate in a similar manner.

Two single diode television demodulator circuits are shown in Fig. 42. At A is an arrangement giving an output in negative phase, while at B the diode connections are reversed, and the output is in positive phase. That is to say, at A the output is negative-going, while at B it is positive-going.

L1 and L2 represent the final tuned circuits of the I.F. amplifier (in the case of a superheterodyne), while R1 and R2 are the respective load resistors and C1 and C2 their reservoir capacitors. The diode valves used are of a special type with a low internal resistance, and the values of R1, C1 or R2, C2 are much lower than in the same stage in sound receivers. R1 and R2 are usually about 5,000 ohms, and C1 and C2 are rarely more than a few pF; in fact, the stray capacitance of the circuit alone may be adequate, and by-pass capacitors are then omitted. The correct choice of values for the load resistors and by-pass capacitors is extremely important if a reasonable detector efficiency, coupled with an adequate frequency response, is to be secured.

In addition, however, the demodulator circuit must be properly filtered to prevent any R.F. or I.F. voltage superimposed on the V.F. signal from passing on to the following stage, or getting back to preceding stages. The design of a suitable filter at this point is therefore of considerable importance. The type and

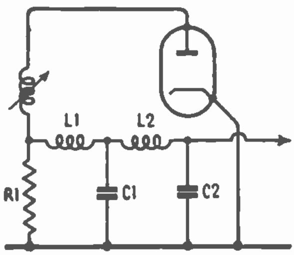


Fig. 43—A simple filter used in conjunction with a half-wave detector circuit

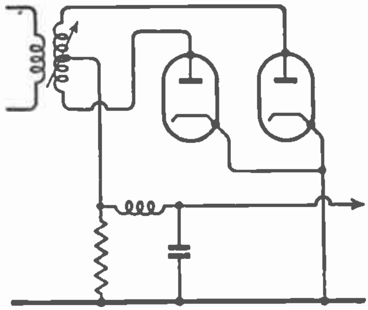


Fig. 44—The basic full-wave detector circuit, which is rarely used

complexity of the filter used varies a good deal, but a simple form of low-pass circuit, in conjunction with the detector diode, is shown in Fig. 43. Here R1 is the load resistor, and L1, L2 and C1, C2 the inductive and capacitative components of the filter.

Sometimes a push-pull demodulator circuit is employed, and a typical circuit is shown in Fig. 44, where two diode valves are used. Filtering problems are less difficult with this type of demodulator, though a simple filter circuit is included in Fig. 44. The input must be fed to the detector valves by means of a transformer with a centre-tapped secondary, of which the correct design is no easy matter. It is also possible to use two diodes in a voltage-doubler type of detector circuit.

The V.F. signal which emerges from the detector stage is actually of the correct form to be applied to the control (modulator) grid of the cathode-ray tube, provided it is positive-going. However, in view of the fact that a medium sensitivity cathode-ray tube may require a peak signal voltage of 20 to 25 V before full white is registered on the screen, it is unlikely that the detector output will be adequate for this purpose without at least one stage of amplification.

It must be remembered that apart from the vision content of the signal, which modulates the tube, the synchronizing pulses are also present, so that the actual voltage output required from the detector to ensure a vision output of, say, 25 V, is about 36 V. However, it was quite a common practice in the early days of television to dispense with amplification between the detector and the tube, and to feed the output from the diode direct to the control grid of the tube. Apart from other considerations, this is advantageous in that it eliminates the difficulties of retaining in the video amplifier full amplification of all frequencies of the wide-band video signal.

In modern receivers, however, it is the common practice to use one stage of V.F. amplification, and it is called the video amplifier. In one or two rare cases two video amplifiers are used.

The video amplifier in a television receiver is comparable with the audio amplifier in a sound receiver, but with three important differences. The first is that instead of an audio band of, say, 50 to 10,000 c/s, the video amplifier must handle a band of 0 to 2·75 Mc/s. The second is that a voltage output instead of a power output is required from the video amplifier, and the third (which really follows from the first), is that the video signal contains a D.C. component (0 c/s) which must be retained, or, if removed, must be replaced before the signal is fed to the cathode-ray tube.

The wide frequency band requirement causes the greatest difficulty in the design of the V.F. amplifier. Theoretically, the amplifier should deal equally with all frequencies, not only of the usual audio range, but through the normal long-wave and medium-wave ranges right up to a frequency equivalent to about 100 metres. It is obvious that this is not an easy problem, particularly since high frequency response will be reduced by stray capacitances due to the valve, the wiring, and the input circuit of the cathode ray tube itself.

The valve chosen for the task is often a television R.F. pentode of the same type that is used in the R.F. and I.F. stages of the vision receiver, but it is becoming more common to use valves that are specially designed for that stage. They are operated with a resistive anode load, which, to secure adequate high frequency response, must be kept low. This, of course, limits the gain of the stage.

In order to improve the gain without losing the wide frequency response, small correction chokes are usually employed. Fig. 45 shows a skeleton V.F. amplifier stage, using a pentode valve, in which R1 is the anode load resistor and L1 is a compensating choke in series with it. This choke neutralizes to a large extent the stray circuit capacitance, and incidentally permits a higher value for R1, thereby increasing the gain of the stage.

It is also possible to compensate by means of a choke in series with the output lead from the anode circuit, as shown in L2 in Fig. 45. This choke, with the valve, tube and circuit stray capacitances C2 and C3, resembles a low-pass filter, and besides improving the performance, has other advantages. Occasionally chokes are employed in both positions, as in Fig. 45, but this arrangement is somewhat critical from the designer's point of view.

R2 in Fig. 45 is a bias resistance which is normally fitted. The parallel capacitor, however, is often omitted, and the resulting negative feedback helps to improve the overall response of the amplifier though with reduction of gain. Often a by-pass capacitor, when it is fitted, is made adjustable and used as a "quality" control. It works as a rule in conjunction with a special coil in the anode circuit called a "peaking" coil which is tuned to "peak" at about 2·5 Mc/s, giving a boost to the stage gain at the outer edge of the video response, where it tends to fall off. With careful adjustment of the capacitor the response can be made to be very good, giving clear definition of the 2·5 Mc/s bars on a test card.

It does this by permitting negative feed-back to occur at lower frequencies, but preventing it at higher frequencies by by-passing

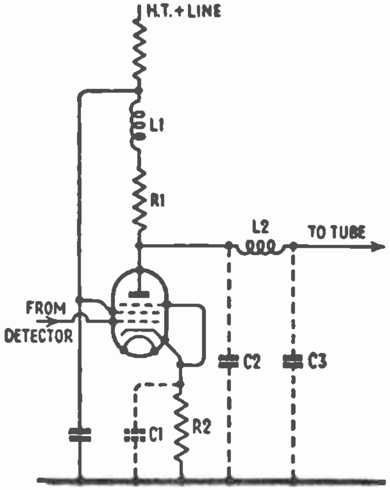


Fig. 45 — Basic vision frequency amplifier circuit, with two compensating chokes L1 and L2

the cathode resistor more effectively. The point at which this effect occurs is determined by the adjustment, and if the capacitor is maladjusted it can cause either poor resolution of the picture or severe over-shoot, which causes a white outline to occur on the right of any black object in the picture. A slight amount of over-shoot can be seen on the right-hand side of the clock in both photographs on page xv.

THE D.C. COMPONENT

Turning now to the problem of the retention of the zero frequency (D.C.) component of the signal, it is as well to explain the significance of this feature of the television signal. In the first place, it will be appreciated that every scene televised has a certain range of contrast, from the darkest tone (at black level) to the brightest tone (peak white). In addition, and this is not so obvious, each scene has an average brightness value.

As an example, take a scene in a living-room with normal artificial lighting, which has a certain contrast range. Now suppose the artificial lighting is dimmed. Theoretically the contrast range remains the same, but as the illumination has been reduced, the *mean* brightness is now less.

In the television signal the mean brightness is governed by a bias on the signal, which takes the form of a D.C. component superimposed on the vision modulation, and which fixes the mean brightness datum line of the picture relative to the " black " level. If this bias is removed we still get a similar range of contrast, but the signal contains no information enabling the tube to adjust itself to changes in mean brightness. Consequently, in the example mentioned above, the dimming of the light would not be appreciated, at any rate after the momentary period during which the signal settles down after the change.

Another way to look at it is to follow the position of black level, which should remain constant irrespective of the amplitude of the picture signal. Whatever the picture content, the signal voltage applied to the modulating electrode on the C.R. tube should always be of a constant value, which we call black level, just before the picture modulation commences on each line, and immediately after it has finished on each line. These two black level intervals are sometimes called the " front porch " and " back porch " of the line synchronizing pulse, which occurs between them, and they are indicated in Fig. 41 (b). When the synchronizing pulse occurs the signal voltage should drop to zero.

This all happens automatically when the signal is in the form shown in Fig. 41 (a), because as all technically-minded readers know, an A.C. signal without a D.C. component centres itself about the zero level, and as the waveform at (a) is symmetrical, that is to say equal at all points either side of zero, it remains centred on zero irrespective of changes in the waveform. This is exactly the same thing as happens in a radio receiver when a signal is fed from the anode of one valve to the grid of the next via a capacitor, which removes the D.C. component. It centres

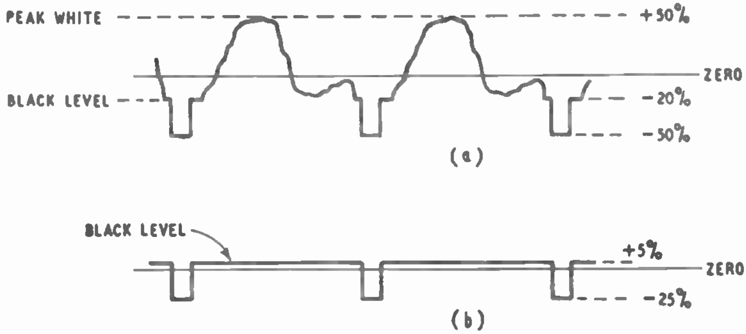


Fig. 46—The video signal after passing through an A.C. coupling circuit, thus losing the D.C. component. At (a) with picture modulation; at (b) without picture modulation. This drawing is not accurately scaled, but the enclosed areas either side of the zero line are assumed to be equal

itself on the D.C. potential of the grid, whatever that may be, and rises and falls equally above and below that value.

In a radio receiver a symmetrical A.F. signal is obtained after detection, but in a television receiver the video signal after detection is not symmetrical. Whereas the audio signal, or any A.C. voltage for that matter, makes equal positive and negative excursions, the video signal does not: it is always all positive-going or all negative-going.

If a video signal is A.C. coupled, that is to say coupled to the C.R. tube for instance via a capacitor, it loses its D.C. component just as does any other signal. Thus the rectified video signal in Fig. 41 (b), which is shown there as positive-going, and is no longer symmetrical, would centre itself around the zero line, with the result that the whitest parts of the signal would remain positive with respect to the zero line, but the sync pulses and black level would become negative.

How much negative they would go would depend on how much light or whiteness there was in the picture, but it would be somewhere about the extent shown in Fig. 46 (a). Here it can be seen that black level is lower than zero level and actually attains a negative value. The drawing is not to scale, but in practice the areas enclosed by the waveform on either side of zero would be equal. Therefore the position of the zero level in relation to the signal will change with a change of signal modulation, because the waveform would then be different, and to take an extreme case the waveform is shown at Fig. 46 (b) without any picture modulation. The waveform then comprises sync pulses and black level only, and again centres itself on zero level, when it can be seen that black level becomes positive by a small amount.

Percentage values shown in the drawings give some idea of the changing values as they are presented to the cathode-ray tube, but they are representative only and not calculated. Further, the drawings are not made to scale. Compared with the values of the same features in Fig. 41, however, they give a good idea of what happens to the picture when the D.C. component is omitted from the signal. The general effect on the picture is a lack of " life " and crispness, giving it a dull and somewhat wishy-washy greyish appearance as compared with a normal picture, although definition is still as good as ever.

The importance of retaining the D.C. component after detection is therefore evident, and in almost all modern receivers D.C. coupling is maintained between the vision detector and the C.R. tube, the intervening V.F. amplifier being D.C. coupled, as shown in Fig. 47 (c). The V.F. amplifier control grid is connected to the detector load resistor, and its anode is connected to the C.R. tube.

In early receivers, when it was usual to feed in the modulation to the grid of the C.R. tube, as shown in Fig. 46 (a), there was a certain danger in doing this. D.C. coupling means to all intents and purposes joining the grid of the C.R. tube (if it is grid modulated) directly to the anode of the V.F. amplifier, which might run at say 200 V. The cathode of the C.R. tube

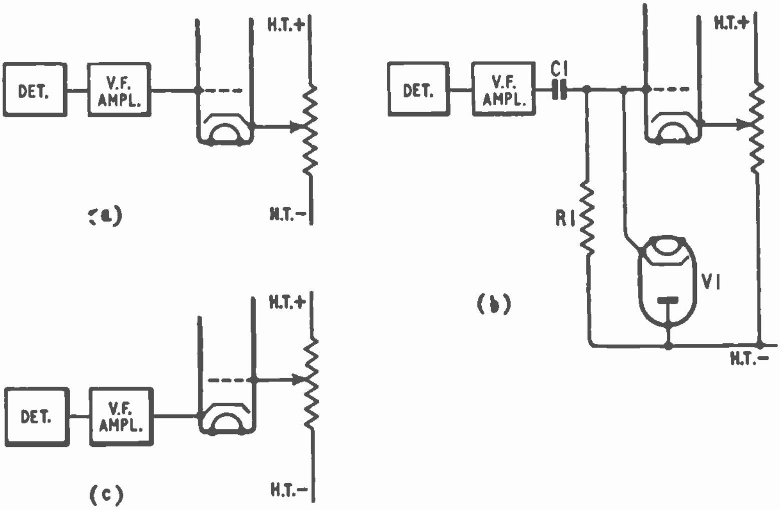


Fig. 47—Schematic diagrams of three video coupling arrangements from detector to C.R. tube. D.C. coupling throughout is shown at (a) *to the grid of the tube; A.C. coupling to the grid is shown at* (b) *with a D.C. restoring diode V1. Direct coupling to the cathode of the tube as at* (c) *is almost universal to-day*

is suitably biased by an H.T. potential divider to give the correct voltage difference between grid and cathode, so the cathode voltage would be something higher than 200 V, say 230 V. The principle is shown in Fig. 47 (a).

The danger lay in switching on and switching off, because if the cathode received its working voltage while the V.F. valve was not fully conductive, the correct voltage-drop would not occur across the V.F. anode load resistance, and the grid would go positive by perhaps 50 V or more. Another danger would arise if the V.F. valve should become faulty and pass no current. The H.T. positive line voltage would be applied to the C.R. tube grid, making it perhaps 150 V more positive than its cathode and damaging the tube.

To avoid this danger the tube was A.C. coupled as shown at Fig. 47 (b), and a D.C. restoring diode V1 was introduced to restore the D.C. component. Bearing in mind that the signal is positive-going if applied to the grid, the diode restores the D.C. component by the simple expedient of preventing the signal from going negative. Thus its cathode is connected to the grid of the C.R. tube, and when the signal tries to drive the grid negative, the diode cathode goes negative with it and, as the anode remains where it was and is thus positive with respect to its cathode, the diode conducts.

The conduction effectively forms a short-circuit across the tube grid circuit, but it conducts only while the signal is driving the cathode negative. As soon as the signal voltage reverses (which will be at the bottom of a synchronizing pulse in Fig. 46 (a) of course) the diode ceases to conduct, and the positive-going signal voltage, which has been held at zero potential by the diode, rises. But because it starts from zero level (not below it as in Fig. 46 (a)) its rise takes place above zero level, just as it did in Fig. 41 (b). Thus the D.C. component is restored.

The D.C. component is stored in the coupling capacitor C1, and it goes without saying that the values of C1 and the diode load resistance R1 have to be carefully chosen to give the desired time-constant. The cathode voltage derived from the H.T. potentiometer would be simply the desired bias voltage for the C.R. tube. This potentiometer is adjustable and it acts as the brightness control.

This method of coupling the tube is seldom used in modern receivers, however. Almost invariably now the grid of the tube

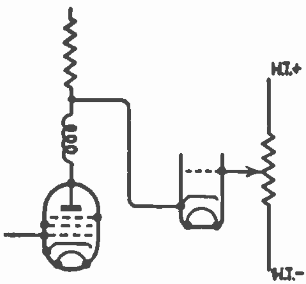


Fig. 48—The basic circuit of the V.F. coupling to the C.R. tube cathode in a modern receiver

is taken to an H.T. potentiometer and the signal is fed in at the cathode, which thus becomes the modulating electrode. This is called "cathode modulation". The detector diode output is made positive-going, and the 180 degree reversal that takes place in the V.F. amplifier renders it negative-going. The anode of the valve is connected directly to the cathode of the tube, which of course requires a negative-going signal. The basic arrangement is shown in Fig. 48, where the diode circuit is omitted. If the anode bend detector to which passing reference was made earlier is used, then Fig. 48 shows the complete circuit.

INTERFERENCE LIMITER

All television receivers to-day are equipped with some kind of circuit to combat the effects of interference, primarily of the kind that causes white spots to appear on the picture. It has already been explained that by a suitable choice of aerial, and its siting and alignment, some alleviation of interference can be secured. One of the main sources of this trouble is the ignition circuits of the ordinary petrol engine, the high-voltage spark discharge of which causes white spots or flakes on the screen, often referred to as " snow ".

When this is bad, the impulses picked up by the aerial not only cause a white spot, but by driving the tube grid well beyond the normal 100 per cent modulation point (" peak white ") cause defocusing of the spot, and produce large white patches.

The proper remedy is suppression at the source, by fitting a resistance suppressor in series with the lead from the ignition coil to the distributor of the offending vehicle. Special screw-in or plug-in types are available for this purpose, and can be fitted without difficulty in a matter of moments. While it will be a long time before all interference of this kind becomes

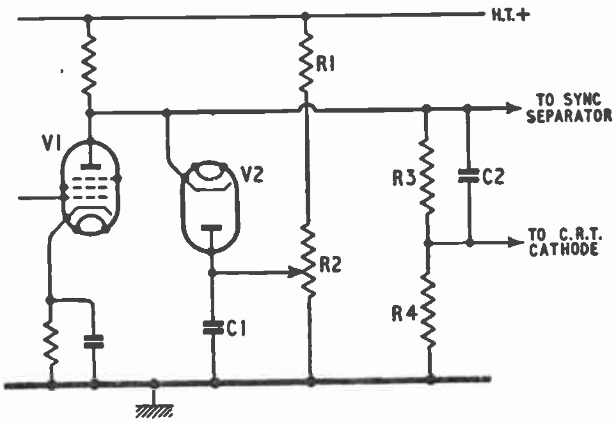


Fig. 49—A common type of vision interference limiter comprises a diode V2 and its reservoir C1 shunted across the output of the video amplifier V1. R2 provides a means of adjusting the level at which V2 conducts

suppressed at the source, it is now compulsory for all new cars to be fitted with suppressors.

In the receiver some improvement can be made by the use of limiter circuits. If the interference impulse can be limited to the " peak white " level, it shows on the screen as a sharp white dot which is much more bearable than a defocused splash.

A simple interference limiter circuit is shown in Fig. 49. It consists of a biased diode valve V2 connected across the output circuit of the video amplifier V1. If the video output is negative-going for application to the cathode of the C.R. tube, as shown here, the cathode of the diode is connected to the V.F. valve anode, while its anode is connected to the slider of a potentiometer in an H.T. potential divider R1, R2.

The slider is adjusted until V2 anode voltage is equal to V1 anode voltage at peak white signal level so that for signals up to this level V2 cathode (V1 anode) is more positive than its anode, under which conditions V2 will not conduct. When a large interference pulse occurs, peak white level is exceeded, and V1 anode goes further negative than the bias on V2 anode, and V2 conducts because its anode is positive with respect to its cathode; or, alternatively, because its cathode is negative with respect to its anode, which means the same thing.

V2 and C1 are thus shunted momentarily across the video output, tending to short-circuit the signal for the duration of the pulse and preventing the signal voltage applied to the C.R. tube from exceeding peak white. All that is seen on the screen is a sharp white dot each time a pulse arrives, instead of a large defocused splash. If the video output is positive-going, the circuit is similar but the diode connections are reversed.

The same type of circuit is sometimes connected in the vision detector diode circuit (or V.F. control grid circuit) instead of in the V.F. anode circuit, but it remains unaltered in principle. If the V.F. amplifier output is negative-going, of course, the diode connections are then reversed as compared with Fig. 49, because the signal at the detector output would be positive-going. Usually when the limiter is connected in the detector circuit a crystal is used as the diode instead of a thermionic valve, avoiding the need for heater supply.

A more elaborate method of combating impulsive interference is to use a triode instead of a diode in a so-called "block-spotter"

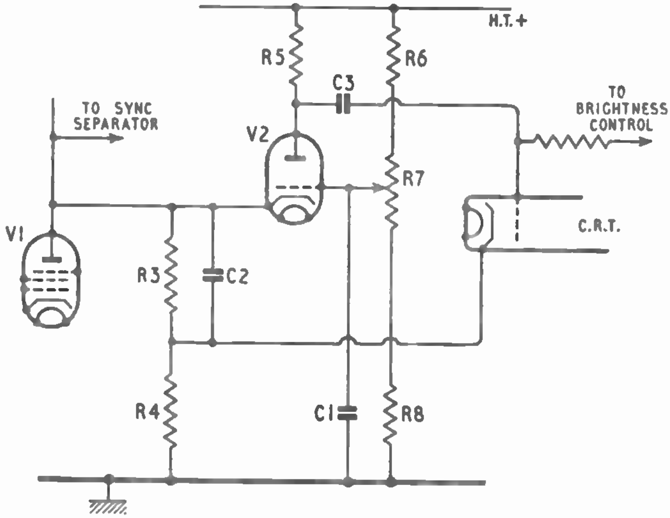


Fig. 50—The principle of the " black spotter " interference limiter is shown in this diagram. V2 inverts the spot, making it black instead of white

circuit as shown in Fig. 50. V1 is the video amplifier again and C2, R3, R4 comprise a network through which the signal is fed to the C.R. tube C.R.T. V2 again is the limiter valve, but it is a triode. Its cathode is connected to V1 anode, and its anode to H.T. positive via R5. Its control grid potential is adjusted by the potential divider R6, R7, R8 so that V2 is cut off for all signal levels up to peak white.

If peak white is exceeded, with a negative-going signal, V2 cathode voltage is driven to a point at which the grid is positive with respect to it, allowing anode current to flow. This happens on each pulse of interference, and consequently the anode current flows in pulses, their magnitude varying in proportion to the voltage of the interference pulse. Each anode current pulse causes a voltage drop across R5, negative at V2 anode, and negative pulses are therefore applied to the C.R.T. control grid via C3 to match those arriving at the C.R.T. cathode. By suitably adjusting the bias at R7 the grid pulses can be made to equal those at the cathode, thus neutralizing them.

In practice it is not as simple as it may sound to neutralize the interference spots exactly, and usually the cancelling pulses are made to exceed them and cut off the C.R. tube beam current, so that instead of a white spot a black spot appears on the screen, making a " hole " in the picture. There is some difference of opinion as to whether black spots are preferable to white spots, but the former have the advantage that they cannot cause defocusing, whereas white spots do cause some defocusing even though it is restricted.

This type of suppressor is directed at a particular kind of interference, that resulting from ignition sparks in internal combustion engines. Another kind of interference that can be alleviated by simple circuitry is what is termed " aeroplane flutter", an oscillation of picture strength resulting from alternate reinforcement and cancellation of the directly received signal by an indirect one reflected from a moving aircraft.

The frequency of the oscillation is very low, varying between, say, two cycles per second and perhaps twenty cycles per second, and it can be attenuated without affecting higher frequency components of the television signal by reducing the D.C. component applied to the C.R. tube. The simple circuitry was shown in Figs. 49 and 50, where it will be seen that the V.F. output is fed to the cathode of the C.R. tube from D.C. potential divider R3, R4.

These resistances are often equal, giving a step-down ratio of 2: 1, and the upper limb is by-passed by a capacitance C2 which tends to by-pass the A.C. component. By a suitable choice of values the flutter component can be reduced almost by 50 per cent while the A.C. component of the picture is virtually unaffected. The D.C. component is halved, however, and this does affect the picture. It is one of the reasons why the viewer feels inclined to get up every now and again to adjust the brightness control during a programme. There are other advantages in using the potential divider, but its effectiveness on aeroplane flutter alone justifies its use, and it is incorporated in practically all modern receivers. Certain types of aerial are more susceptible to aeroplane flutter than are others, and one of these was mentioned in Chapter 1.

THE SOUND CHANNEL

Apart from auxiliary circuits we have now covered the basic vision receiver, but we have by-passed the sound channel from the point at which the manner in which it is extracted from the composite signal was mentioned. It is so similar in principle to the ordinary sound radio receiver that little more need be said about it. It has two features, however, which are quite different from radio practice. One is the high frequency involved in the I.F. (or T.R.F.) channel (which has tuning coils very much like those of the vision channel), with its much greater band-width, and the other is the almost universally adopted series interference limiter.

The greater band-width is interesting because usually quite high audio frequencies are transmitted, and it is thus possible to obtain much higher quality on television sound than it is on an amplitude modulated radio transmission. It must be observed in passing, of course, that transmitted quality is probably no better on television sound than it is on V.H.F. radio, which is frequency modulated. If the standard of audio quality is no better in a television receiver than it is in an A.M. radio receiver, that is because the price at which the television receiver is sold does not permit it to be.

This is no place to discuss audio quality or V.H.F. radio, but it should be explained that television receivers are now on the market which tune not only to television transmissions in Band I and Band III, but also to the V.H.F. radio transmissions in Band II. Arrangements are made for the A.M. detector circuit to be switched over automatically to a ratio detector discriminator circuit for the rectification of the F.M. signal. Attention is usually given to audio quality in such receivers and this inevitably raises the price in proportion to the standard attained, but the result is a complete radio/television receiver of very neat design. This system is described fully in Chapter 14.

The interference limiter is required for the same purpose as it is in the vision receiver: to combat ignition interference. Similarly, it operates by limiting the effect, not by suppressing it, but it operates on a different principle. Whereas the vision limiter discriminates between signal and interference on a basis of amplitude, the sound limiter discriminates on the basis of frequency. (The correct expression is "rise time", but frequency is easier to understand.)

The basic circuit of the sound channel limiter is shown in Fig. 51. V1 is the diode detector which rectifies the output from the I.F. amplifier at L1. The rectified output appears across R1, C1 and is passed via C2, V2 and C3 to the volume control R4, after which it follows a conventional path. The signal passes through V2, which is the interference limiter, because the valve is maintained in a conductive condition by the potentials resulting from its inclusion in the H.T. potential divider R3, V2, R2. The resistance values are in the order of several megohms.

The time-constants of the circuits R1, C2, R2 and R3, C3, R4 are important. The circuit works as a limiter because these time-constants, while allowing the audio frequency range to

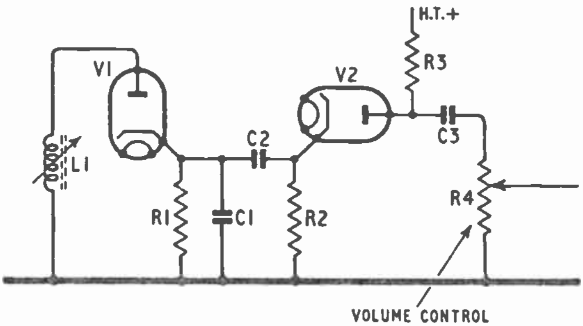


Fig. 51—This illustrates the principle of the series diode limiter, which is used almost universally in the sound channel of the modern television receiver

pass without interruption, cut off the current to V2 when an interference pulse occurs.

To understand this it is necessary to know that whereas the audio signal is made up of sine waves, the nature of a pulse is not. A pulse is a sudden voltage rise that " shocks " its way through the tuning circuits, and it has an almost vertical "wave front", rising suddenly from zero to a very high value and falling away again immediately afterwards to zero.

When such a sudden change of signal voltage appears across R1 it is applied via C2 across R2 and, of course, to V2 cathode. Because V1 output is positive-going, the pulse will be positive-going and will carry V2 cathode with it. If it is fast enough and high enough, it will make V2 cathode more positive than the anode, and conduction will cease, cutting off the signal altogether. This is what is meant by "rise time". Whereas the pulse has a very high rate of rise, the audio signal rises and falls gradually, and its voltage changes are never fast enough to drive V2 cathode positive faster than the anode voltage can follow.

R3, C3, R4 form an H.T. potential divider, and when V2 cuts off C3 begins to charge up. If left like this it would go on charging until the voltage across C3 equalled the H.T. supply voltage, but the time-constants of the circuits are so adjusted that V2 remains cut off only for the duration of the pulse. As C3 charges up V2 anode becomes increasingly positive, and the point is soon reached at which it is more positive than the cathode, even before the pulse has died away completely, and conduction recommences.

All that is heard in the speaker is a faint click as the sound ceases and starts again, so the interference is limited and not entirely suppressed. V2 is connected in series with the signal path, and for that reason is called a series limiter. If the connections of V1 were reversed, giving a negative-going output, V2 would be reversed also, its anode and R3 going to C2, and its cathode and R2 going to C3. Thus either the two cathodes are coupled by C2, as shown in Fig. 51, or the two anodes. If the detector load resistance R1 were connected between L1 and chassis, as it often is, that would have the same effect as reversing V1.

The series limiter is fitted almost universally in the sound channel of television receivers, and apart from the variations just mentioned it is almost always as described. In rare cases it is inserted between A.F. amplifier (where one is used) and the output valve, and even more rarely a different type of circuit is used to combat ignition interference. These are either so rare or so old as to be almost negligible, and they do not justify the space necessary to describe them here.

Chapter 9

THE CATHODE-RAY TUBE

Principles of Magnetic Type – Focusing and Deflection – Projection Tubes

THERE IS A FAIRLY good analogy between the cathode-ray tube and a loud speaker. In the same way that the loud speaker converts an electrical synthesis of the sound fed into the transmitter at the studio back into audible sound again, the cathode-ray tube converts an electrical synthesis of the scene in the studio of a television transmitter back into a visible picture. There is, however, a big difference in the way in which they work.

A moving coil loud speaker needs to be supplied only with a static magnetic field and some power from the output valve of the receiver, and it will reproduce the sound. The cathode-ray tube requires no power from the output valve (which is the video amplifier) in the receiver. It requires only a voltage, and it operates in very much the same way as a valve. It has a heater, a cathode, a grid and an anode, and in its simplest form it is a triode. These electrodes are very different in shape from those of a valve, but like a valve, the tube is operated by applying the signal between its control grid and cathode.

The manner in which its electron stream operates is also very different. Instead of being attracted to an anode which absorbs it, the electron stream is attracted *past* the anode and made to impinge on the fluorescent screen which coats the inside of the glass at the large flattened end of the tube, where it produces an illuminated glow. In order to permit this glow to be used to trace fine detail on the screen, the stream is focused electrically into a fine beam which tapers off to a small spot at the point where it meets the screen.

The brightness of the glow from the impact depends upon the density of the beam and the velocity of the electrons travelling along it. The beam velocity depends upon the anode voltage, and in order to obtain a bright image this must be very high, and instead of being called H.T. it is called E.H.T.: extra high tension. The higher the E.H.T. voltage, the brighter the picture, but in order to produce variations of light and shade, which are the essence of a picture, the density of the beam is varied (modulated) by the control grid, to which the output signal from the video amplifier is applied, in the same way as it is in a valve.

What this signal is, how it is derived, and where it comes from we have already seen in our review of the receiver circuits. We know also that it can be applied equally well to the grid or the cathode, so that either can act as the modulating electrode, and that in fact it is the common practice to apply it to the cathode, so that the tube operates very much like an "earthed grid" or "grounded grid" valve. But from what we have seen so far we cannot make our modulated beam trace a picture.

How it is made to do this was indicated earlier in Fig. 16, which explained how the picture was scanned to produce a picture area on the screen called a raster. This and other features of Chapter 2, such as Figs. 17 and 18, explain how the small spot of fluorescence scans the raster line by line, varying in brightness as it goes along until it has traced the complete rectangle, imprinting on it the required degrees of light and shade to make a picture.

The means by which the beam is made to scan the screen entails quite a complicated section of electronic circuitry called a scanning generator, or a time-base. In fact, there are two time-base circuits, one swinging the beam from side to side, and the other up and down. In making a complete raster the beam must be swung approximately 400 times horizontally from side to side while it goes down and up again twice. All this is part of the C.R. tube in so far as it is analogous to a loud speaker.

In the very early days of television, cathode-ray tubes were made that performed all the functions just described, with the exception of the actual circuitry, within themselves. They contained very complicated electrode assemblies, several inches in length, comprising the heater, cathode, control or modulating electrode, focusing electrodes and final anode and "deflecting" plates that swung the beam for scanning, in a long succession of plates and cups located in the neck of the tube. All were voltage-operated, and it was called an " electrostatic " C.R. tube.

Such tubes are still used for oscilloscopes, but never for television receivers. Modern television C.R. tubes always employ magnetic scanning, the scanning coils which produce the beam deflection being mounted outside the tube, on its long narrow neck. In most of them focus is also magnetically applied from an external magnet, usually a permanent magnet. The forerunner of the modern tube was purely a triode, but its modern successors are becoming more electrostatic and more complicated. Most of them are tetrodes at least, with a " first " and " second " (final) anode, and some pentodes and heptodes, containing focusing electrodes. Most use ion traps. The one consistent feature of them all is that they use magnetic scanning.

This form of deflection greatly simplifies the internal construction of the tube, owing to the elimination of complicated deflector plate systems inside the envelope. The latter systems need very careful construction and alignment when the tube is made, and in short they do not lend themselves very well to quantity production at a low cost. It is only fair to indicate, however, that electromagnetic tubes necessitate the use of carefully designed deflector coils outside.

A typical " magnetic " (that is, electromagnetic) triode tube is shown diagrammatically in Fig. 52. The electrode system

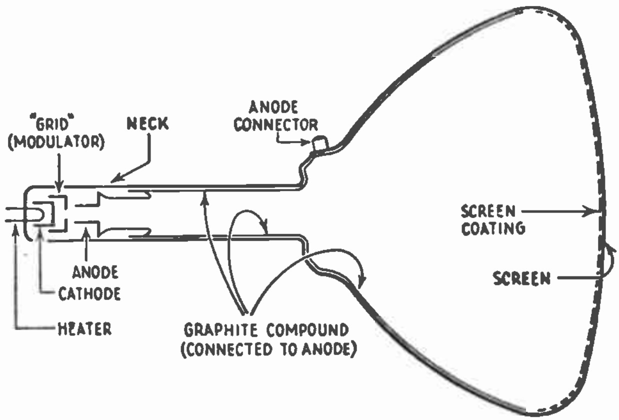


Fig. 52—Sketch showing the principal features of the triode cathode-ray tube of the early type with a deflection angle of 50–60 degrees. The size of the electrodes is exaggerated to show them clearly

comprises, first of all, a heater and cathode assembly which provides the electron stream. Next comes a cylindrical electrode, closed by a disc at the far end in which there is a circular orifice. The electron stream passes through this orifice, and is controlled in intensity by the voltage applied to the electrode. In this way, therefore, the electrode resembles the control grid of an ordinary receiving valve, though its physical construction is quite different. It is commonly referred to as the " grid " of the tube, by analogy, and is furnished with a negative standing bias, like a valve.

Increasing the negative bias reduces the density of the electron stream emerging from the "grid", and eventually cuts it off altogether; reducing the bias increases the stream, and therefore the intensity of the spot on the tube screen. A variable bias control is usually provided, and is termed the " brightness " control. As a rule it comprises a potential divider across the H.T. circuit, one element of which is a variable potentiometer, and its slider goes to the grid of the C.R. tube. It is usually tied down to chassis with a 0·1 μF capacitor.

The video signal from the television receiver, in the form of a varying voltage, is also applied to the "grid", or at least between grid and cathode, and modulates the intensity of the spot on the screen, thereby providing the light and shade of the picture.

The next electrode is the anode, or accelerator, which is used to speed up the electron stream leaving the "grid", so that it strikes the screen with adequate velocity to cause fluorescence of the screen material. The anode is usually a pierced disc, often with a tubular extension towards the "grid", through which the electron stream passes. The whole assembly, comprising heater, cathode, " grid " and anode, is known as the "gun", for fairly obvious reasons.

In addition to the anode as described, modern tubes have the inside of their glass envelope coated with a graphite deposit which is internally connected to the actual anode. This deposit extends from the inside of the neck of the tube, close to the anode, almost up to the screen material, and amongst other things provides a return path for slow-moving electrons which are the secondary products of the impact of the cathode beam striking the screen material.

The anode is provided with a high positive potential, usually ranging from 10,000 to 15,000 V in modern receivers. The higher the voltage, the higher will be the velocity of the electron beam, and therefore the brighter the picture for a given setting of the "grid" voltage control. In order to avoid having to connect the extremely high anode potential via the base of the tube, where it would be difficult to obtain adequate insulation, a connector is fitted to the conical portion of the envelope of the tube, which is in contact internally with the graphite coating, and hence with the anode of the tube.

In tubes that have two anodes, the first anode will have an operating voltage considerably lower than that of the second anode, and its connection will be brought out at the base of the tube. This voltage is usually of the order of three or four hundred volts, and is sometimes taken directly from the H.T. positive line.

Tubes with a single anode are referred to as "triodes" and those with two anodes as "tetrodes".

THE CATHODE-RAY TUBE SCREEN

The screen of the tube, which ideally would be flat, in practice is usually slightly curved for reasons of strength. However, some modern tubes are made with flat screens by means of a special method of bulb construction. So-called "metal" tubes are also available, having a metal conical portion with a flat glass face-plate on which the screen is deposited.

Tubes with circular faces are being displaced by "rectangular" types, in which the glass face (and hence the screen) is shaped in accordance with the picture raster, i.e., it is rectangular and in the ratio of 4 to 3, which is called the aspect ratio.

The inside of the screen of the tube is coated with a film of material which becomes fluorescent when the electron stream strikes it, and this forms the actual screen on which the picture is seen. The colour produced depends on the screen material and a very close approach to a black and white image is obtained by the use of suitable mixtures of chemical compounds.

In the case of early types of tube it was necessary to view the picture in the dark, or at least semi-darkness, owing to limitations of screen brightness. The introduction of better screen materials and the use of increasingly higher E.H.T. voltages, giving brighter fluorescence, has partially removed this limitation, and recently there has been another screen development which makes it possible to view in ordinary room light with a reasonable degree of picture contrast.

This development is the aluminized screen, in which a very thin film of aluminium is deposited on the back of the fluorescent screen, as indicated in the enlarged section shown (not to scale) in Fig. 53. The beam of electrons is able to penetrate the aluminium film, and energize the fluorescent material, but the film prevents the light produced being dissipated back into the tube. Instead, the aluminium film acts as a reflector, and enhances the brightness of the screen, as seen from the front. At low anode voltages, some loss occurs due to the energy lost by the electrons in penetrating the aluminium film, but above about 7,000 V this effect disappears, and the brightness increases, compared with an ordinary tube using the same E.H.T. voltage.

Another development that is designed to permit viewing in high ambient lighting is the use of a so-called " dark " screen.

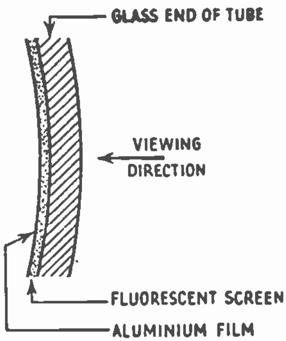


Fig. 53—Enlarged section of a portion of an aluminized tube screen

This originally consisted of a sheet of transparent material, tinted a faint blue or grey, which was laid over the front of the tube screen, so that the picture was viewed through it. Later, the idea was taken up by set makers, who incorporated it in their receiver cabinets, and later it was adopted by the tube manufacturers, who can now supply tubes with or without the colour filter actually incorporated in the glass of the screen.

The theory underlying the use of a filter screen of this type is that the effect of ambient lighting is reduced by half. " Black " in a picture is in fact an unilluminated part of the screen, and it is actually the same colour as the screen is when the set is switched off. Thus "black" is a relative term, looking black only in comparison with the brightness of the fluorescent parts of the screen which, when the set is switched off, looks like white in ordinary room lighting.

However, the light from the fluorescence has to pass only once through the light filter, whereas ambient lighting must pass through it twice before it is seen by the viewer, and relative to the picture, therefore, its effect is reduced by half. It follows, of course, that to obtain a picture of the same brightness as a plain, unfiltered screen, the picture on the screen itself must actually be brighter.

FOCUSING

The beam of electrons leaving the anode of the tube tends to spread out from the axis of the tube, with the result that at the screen there is a diffused fluorescence, covering a large area of the screen. This is unsuitable for television, and it is necessary to adopt some means of concentrating the electrons into a narrow, dense beam, which will produce a bright spot of very small area on the screen. Unless a small spot is obtained. the detail of the picture will be lost.

In view of the analogy with the light passing through a lens, this concentration of the electron beam is termed "focusing", and it is necessary to be able to adjust the electronic lens so that exact focus is obtained at the fluorescent surface of the screen.

In the electromagnetic type of tube which we are considering, focusing is usually carried out by causing a uniform magnetic field to be produced with its lines of force running parallel with the axis of the tube. The effect of this, if the direction of the lines of force is correct, is to cause the path of the electrons in the beam which diverge from the axis of the tube to be bent back, or refracted and, by suitably adjusting the strength of the magnetic field, the electron beam can be accurately focused on the screen.

In order to produce the requisite field, a circular "ring" magnet, capable of being slipped over the neck of the tube, and of being accurately adjusted in position so that its field is parallel with the tube axis, is employed. The magnet may be of the permanent or of the electromagnetic (energized) type. The former is convenient, and needs no current supply from the

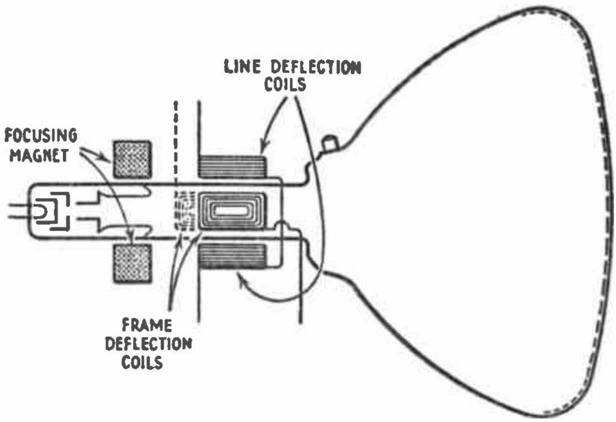


Fig. 54—Sketch showing approximately the disposition of the focus magnet and deflection coils on the neck of an electromagnetic cathode-ray tube. The further frame deflecting coil is displaced slightly to the left so that part of it can be seen. In practice the coils are shaped to fit snugly round the neck of the tube and flare, and they are pushed as far forward as they will go

receiver, but its field is not readily adjustable; the latter permits adjustment of the field to be made very conveniently by varying the direct energizing current which flows through it. This is usually achieved by passing the H.T. current through the magnet winding, but the current changes as the receiver warms up and the focus drifts.

In practice, a combination of the two is sometimes used. Either there is a permanent magnet with a subsidiary electro-magnet so arranged that it will affect the field of the permanent magnet sufficiently to provide the correct range of focusing, or the permanent magnet is made with a self-contained winding to provide the variation in focus required. The most common arrangement today, however, is to use either a permanent magnet or an electrostatically focused tube. Where a permanent magnet is used, its field is adjusted either by means of a magnetic " shunt " or by dividing the magnet into two rings whose mutual proximity can be varied. A shunt is a piece of iron which, by a mechanical adjustment, makes slight variations in the field of the permanent magnet.

In Fig. 54, which shows an electromagnetic tube in diagrammatic form, the focus magnet is drawn in section. Its position can be mechanically adjusted to some extent by sliding it along the neck of the tube. Since the speed of the electrons in the beam of the tube depends on the anode voltage, the strength of the focusing coil or magnet required also depends on the anode voltage, since it needs a stronger magnetic field to "refract" fast moving electrons than slow ones.

With a fixed magnetic field employed to concentrate the electron beam, fine adjustments may also be made by varying the anode voltage of the tube through a small range. This method has actually been used commercially.

DEFLECTION

Having focused the beam into a spot of small dimensions, it is obviously necessary to find a method of deflecting it in such a way that the "raster" of the picture can be produced. At this stage we shall not consider the form of the current or voltage required to do this, but we will see how a suitable deflecting current or voltage can be applied.

In an electromagnetic tube, deflection is produced by electromagnetic means, that is, by a current of correct waveform flowing through coils suitably disposed. The sketch in Fig. 55 indicates diagrammatically how deflection of the spot in one direction (in this case vertically up or down) can be achieved. It is a section through the neck of the tube, at right angles to the axis (shown by the concentric circles), and through two coils placed one each side of the tube neck with their planes parallel to each other.

If a current is passed through the two coils connected in series as shown, a magnetic field, indicated by the fine broken lines, will be produced. As will be seen, these lines, where they pass

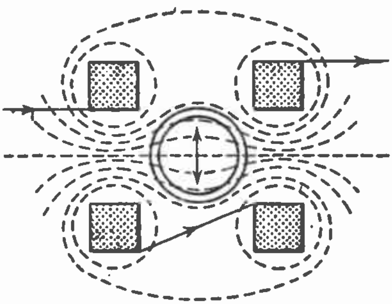


Fig. 55—Diagram of a section through two vertical coils, one on each side of the neck of the tube, showing how the electron beam is deflected vertically by a horizontal magnetic field

through the tube, are roughly parallel, and fairly uniform. In practice, means are provided to improve the uniformity of the field.

By applying the well-known laws of a current (that is, the electron beam in the tube) in a magnetic field, it will be obvious that, depending on the direction of the field, the electron beam will be deflected up or down, and a field which alternates in direction will deflect the beam alternately up and down and will produce the effect of a vertical line, of length depending on the field strength, on the screen of the tube.

This, then, is the elementary principle of electromagnetic deflection. By employing two more coils at right angles to those shown, and producing *vertical* lines of force, it is possible to deflect the electron stream *horizontally*.

The disposition of the vertically deflecting ("frame") coils, and the horizontally deflecting ("line") coils, is shown in Fig. 54, where it will be seen that the coils are towards the end of the neck of the tube. In practice, it is not convenient to mount coils as shown, and the coils used in commercial receivers are of rectangular formation, shaped so that they fit snugly round the neck of the tube, and of such a size that the sides of each pair which are parallel to the axis of the tube practically touch each other; the frame coils are generally fitted over, and outside, the line coils, and the gaps between pairs of line and pairs of frame coils are, of course, displaced from each other by 90 degrees, to make the two directions of deflection exactly at right angles to each other.

The arrangement described helps to secure a more uniform field in each direction, but this object is further achieved and the field strength increased by embedding the coils in magnetic material, usually a ferric oxide ceramic which can be moulded to intricate shapes. The complete deflector coil assembly, or scanning coil assembly as it is sometimes called, is mounted as close to the bell-shaped flare of the tube as possible. Otherwise, at the points of maximum deflection the beam hits the shoulder at the end of the neck, causing "corner shadows" to occur on the picture.

The design of C.R. tubes for television has been changing gradually since the end of the war, and the most marked change recently has been in the size of the picture that can be produced on the screen. Originally the most popular size was nine inches, this being the outside diameter of the face of a circular tube. As public confidence was gained, the greatest demand was for a twelve inch tube, which was easily achieved by lengthening the flared portion of the tube. To make this quite clear it is illustrated in Fig. 56.

The demand then arose for a still larger picture, and 14 inch and 15 inch circular tubes were produced. With them also were produced 14 inch and 17 inch rectangular tubes, whose flared portions were shaped to produce a rectangular screen. On these latter the measurement was made diagonally from opposite

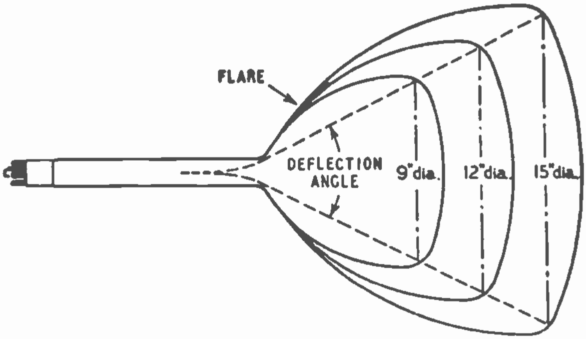


Fig. 56—This drawing illustrates how, with a given angle of deflection, the length of the flared portion of a cathode-ray tube is proportional to the screen diameter

corners. The purpose in making them rectangular was to permit them to be accommodated in smaller cabinets than those required for circular tubes of the same picture size and still show fully the corners of the picture. The largest tube size at the time of writing is 24 inches diagonally across a rectangular tube.

The constant demand for larger and yet larger pictures could not be satisfied by further extending the flare of the tube, because the overall length then became unwieldy and demanded an inconvenient depth of cabinet. The alternative method was to increase the screen diameter (or diagonal) without increasing the length of the flare; in other words, to increase the angle of the flare.

This is a very simple method of increasing the diameter without increasing the length, but it involves increasing the angle of the flare, and while this may not present a difficult problem to the manufacturer, it entails a similar increase in scanning deflection if the picture size is to increase at the same rate as the screen.

In the early tubes the scanning angle, that is to say the angle between the extremes of angle over which the beam must be swung, was about 50 degrees. The maximum deflection occurs at the corners of the picture, so the beam swung 25 degrees from its axis in one direction to reach one corner, and then eventually

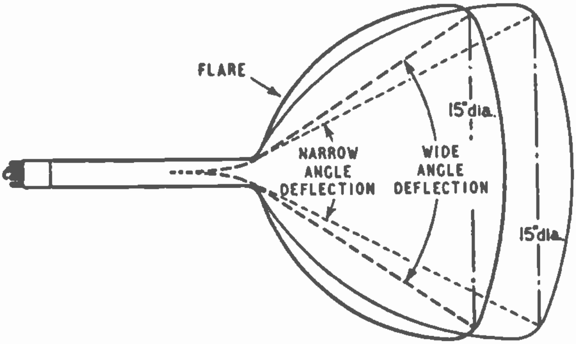


Fig. 57—The screen diameter can be increased without increasing the length of the flare if the angle of deflection is increased

25 degrees in the opposite direction from its axis to reach the diagonally opposite corner.

This is shown diagrammatically in Fig. 57, and together with it is shown how the increased screen diagonal is obtained by increasing the angle of deflection, in so-called "wide angle" tubes. Considerably increased scanning power is necessary to swing the beam over the extra few degrees necessary in these wide angle tubes, and much research and ingenuity have gone into devising suitable scanning circuits to provide the necessary power, but it has been achieved. Scanning angles in modern tubes vary between 90 and 110 degrees. This refers to the maximum deflection during the scan which occurs, as we said before, in the corners of the raster.

ION TRAPS

Apart from general deterioration of the fluorescence of the screen, which occurs when a tube has been in use for a long time, there is another form of deterioration which takes place after

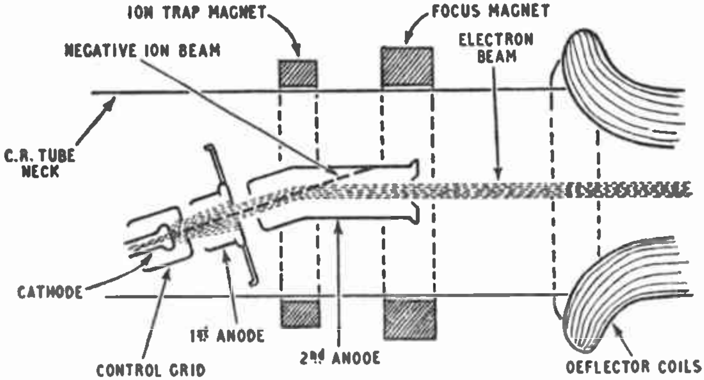


Fig. 58—Cross-section drawing of an electrode assembly, or electron gun, with a " bent gun " ion trap. The drawing is not to scale, and in practice the ion trap magnet is further back

lengthy use. It shows itself as a circular patch of sub-normal brilliance in the centre of the screen, and is due to ions which are present in the tube, despite careful de-gassing of the envelope. These ions, which, compared with an electron, are heavy, are not appreciably deflected by the magnetic fields of the scanning coils, and therefore they impinge on the centre of the tube screen and eventually cause a deterioration in fluorescence in a roughly circular patch on the screen. This effect is less marked in aluminized tubes, but it is becoming a common practice with tube manufacturers both to aluminize their tube screens and to incorporate an " ion trap " in the electron gun assembly. The commonest type is called the " bent gun " ion trap, but there are two general types and these are shown in Figs. 58 and 59.

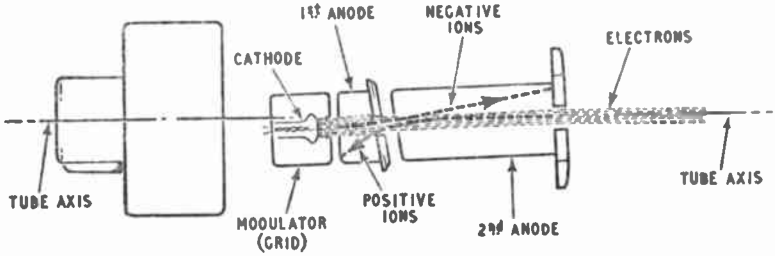


Fig. 59—Another type of ion trap electrode assembly, in which the axis of the "gun" is slightly off-set from the axis of the C.R. tube

In the " bent gun " ion trap which is shown in Fig. 58 the electron gun is set at an angle to the axis of the tube, so that the electron stream is directed obliquely into the anode of the electrode assembly which, however, is bent so that it finally lies on the axis of the tube.

An ion trap magnet which is clipped on to the neck of the tube causes the electron stream to bend as it enters the anode (first anode where two are used) so that the focused beam lies on the axis of the tube.

Because the relatively heavy ions are not influenced by the magnet, they continue straight on in the oblique line until they hit the side of the anode cylinder, where they are harmlessly absorbed.

In the other type of ion trap shown in Fig. 59 the principle is the same but the method is different. The complete electrode assembly is slightly oblique to the axis of the tube, but the orifice at the outlet end lies on the axis, as did the other one. The gap between the first and second anodes is set at an angle, and the effect of that on the electron stream is to bend it so that it endeavours to take up a direction at right-angles to the plane of the gap.

This in effect is electrostatic deflection, which influences both electrons and ions. An iron trap magnet is then introduced in the same manner as it was in the previous example to bend the electron stream back into line with the axis of the tube.

Because the ions do not respond to the influence of the magnet, they continue in a straight line until they hit the wall of the cylinder.

The adjustment of the ion trap magnet is effected by sliding it along the neck and around the neck until the brightest picture is obtained, but its position is critical and it is important that it should be accurately adjusted. If it is not adjusted properly, electrons impinge on the orifice of the anode with very great force and vaporize it, producing gases that may easily shorten the life of the tube.

Before leaving the subject of the tube itself, it should be pointed out that failure of the scanning units can result in a stationary spot of fluorescence, of high intensity, being produced. This, if allowed to continue, will " burn " the screen at the point where the beam impinges on it, with the result that the fluorescent material will no longer be active at this point, and a permanent black spot will be produced.

OPTICAL PROJECTION

Although there is no intention in this book to deal extensively with projection television systems, it is believed that, since a fairly large number of domestic receivers of the projection type have been sold, a brief description will not be out of place.

The projection system that is in general use is a modification of the Schmidt system, employing an optical system of mirrors and a correcting lens so that the light beam can be "folded" into a cabinet of reasonable proportions. The picture is first formed on the screen of a special projection C.R. tube, which has a diameter of about $2\frac{1}{2}$ inches and operates with an E.H.T. voltage of about 25 kV. The receiver, scanning and synchronizing arrangements are in general similar to those used with an ordinary direct-viewed tube, with the exception that in order to protect the tube from serious damage should one of the time-bases cease to function, special safety circuits are incorporated which bias up the tube to beam cut-off if either line or frame scanning deflection fails. With 25 kV on the anode, a line would otherwise be burnt into the screen in a very short time.

The arrangement of the special projection unit used by a number of manufacturers is shown in Fig. 60. The picture on

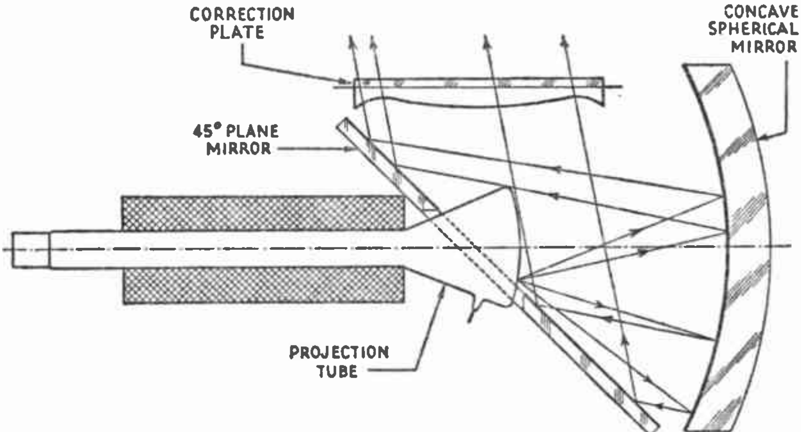


Fig. 60—Sketch showing the optical system in a television projection unit as used in domestic receivers. The paths of the light rays are indicated by arrowed lines

the end of the tube is reflected by a concave-spherical mirror, on to a 45-degree plane mirror through which the tube projects. From this mirror the rays pass through a special correction plate or lens, which corrects the spherical aberration caused by the concave mirror.

By placing a screen of the ground-glass type in the path of the reflected rays, and at the correct distance, the magnified picture is formed on the screen. The size of the picture in early models of this type was about 16 inches by 12 inches, and therefore corresponded to that obtainable from a direct-viewed tube of about 20 inches diameter, but much larger screens than this have been used.

For convenience in layout, the rays, after passing through the correction plate, may again be reflected by a plane mirror before reaching the screen, the actual arrangement depending on the size and shape of the cabinet. This is obviously a "back" projection method, as compared with the front projection arrangement of, say, a home ciné equipment. However, the same system can be used for front projection if desired, and in this way pictures up to 4 ft by 3 ft in size are obtainable.

Chapter 10

TIME-BASE OSCILLATORS

Production of Saw-tooth Waveforms for Magnetic Line and Frame Deflection

ON PAGES 24 TO 27 we saw how the television picture is built up from a series of equidistant lines, of which there are 405 in a complete scan, although quite a number of them are omitted from the raster on which the picture appears. In order to produce this raster, the fluorescent spot on the screen of the cathode-ray tube has to be swept across the screen from left to right by the line scanning generator at a high speed, and at the end of each line it has to return, at an even higher speed, to the left-hand edge, ready to commence the next line. At the same time the frame scanning generator is moving the spot vertically downwards, but at a slower speed, so that each successive line is slightly below the previous one. Although the lines so produced appear to be horizontal, they actually slope downwards to the right very slightly.

We have already seen that with interlaced scanning as used by the B.B.C. there are 25 complete pictures per second, consisting of 50 frames of 202½ lines each, alternate frames being interlaced. The total number of lines " drawn " per second is thus 10,125 which is therefore the frequency of the line scanning unit. The frame scanning unit has a frequency of 50 per second.

Fig. 61 shows diagrammatically the type of current waveform needed in the scanning coils to move the spot on the tube in

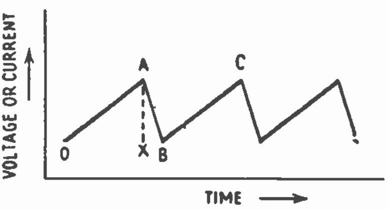


Fig. 61—The ideal saw-tooth waveform

order to produce a raster as described. Both line and frame scanning units must provide this waveform, though at different frequencies. From its appearance, it is usually referred to as a " saw-tooth " waveform.

Assuming we are dealing with the line scanning unit, point O represents the beginning of the first line. As the current rises, the spot moves across the screen until point A is reached. This completes the first line. Ideally, the voltage would now fall instantaneously to zero, ready for the commencement of the second line; in practice, however, this is not feasible, so that instead of the ideal AX, the voltage drops back along the line AB. Thus the flyback occupies a finite time interval, represented by XB, and this interval has to be kept short compared with that represented by OX. On arrival at B, the current begins to rise again, along the line BC, tracing out the second line, and so on.

Owing to the fact that the cathode-ray spot moves much faster during the flyback than during the tracing of the actual line, the flyback trace on the screen would in any case be faint compared with the line trace. However, as the flyback takes place at a period when the line signals are at black, or " blacker than black " level, its trace is effectively prevented from appearing on the screen.

It is important that the increase in current produced by the scanning unit should be regular over the whole of the sweep, that is, OA in Fig. 61 must be a straight line. If this is not so, the picture will suffer distortion due to non-linearity.

We may now consider the types of circuits which can be used in scanning units to provide a current flow with this waveform. There are a great number of these, but basically the majority of scanning units depend on the charging and discharging of a fixed capacitor, although some of the line circuits are inductive. Apart from this, the main differences lie in the methods of ensuring a regular charging current and a speedy discharge.

If a resistor and a capacitor are connected in series and a steady voltage is applied across the combination, initially the voltage across the capacitor will be zero, but as the charging current flows through the resistor, the voltage on the capacitor will rise, at a speed determined by the value of the capacitor (the larger the capacitance, the slower the rise in voltage) and by the value of the resistor (the larger the resistance, the slower the rise in voltage).

If when the voltage has risen to the value required the capacitor is short-circuited, the voltage across it will fall almost instantaneously to zero. It would therefore appear that by adopting some form of automatic switch across the capacitor, operating at the correct speed, we have a means of producing the type of voltage wave form shown in Fig. 61.

There is, however, one difficulty to overcome. When a capacitor is charged in the manner described above, the voltage rise is *not* linear. Actually, the charging rate, and therefore the rate of voltage rise, falls off, at first gradually, but later with increasing rapidity as the voltage across the capacitor more nearly approaches the applied voltage. The curve actually produced is exponential in shape, as shown in the "oscillator" curve in Fig. 62, and if applied to the tube without correction would produce a picture which was compressed on the right-hand side, and at the bottom.

Fortunately, however, the first part of the capacitor charging curve is in practice almost straight, and if we work on this part of the curve only, the resulting waveform of the scanning unit will not differ appreciably from that of Fig. 61. In order to secure this result, the voltage to which the capacitor is charged each time should not exceed about 5 per cent of the applied voltage.

This means, of course, that unless a very high applied voltage is used, some form of amplification of the voltage across the capacitor will be needed. This is not a serious disadvantage, and in any case, where magnetic tubes are used, the voltage waveform must be changed to a current waveform with which the deflecting coils are fed. As an amplifier is necessary, there is no reason why another form of correction should not be used, since it is not necessary that each part of the circuit should be linear, provided that in the final result the spot scans the tube at uniform speed.

In Fig. 62, the top curve represents the output from the scanning unit oscillator, in which the voltage has been allowed to rise and produce part of an exponential curve. If this is followed by an amplifier having a response to a true inverse saw-tooth curve as shown in the middle curve, then the resulting effect of the two together is that the distortions tend to cancel out, producing the corrected curve shown at the bottom of Fig. 62.

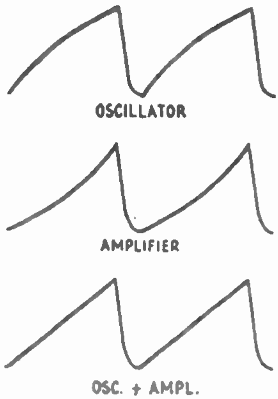


Fig. 62—Showing how two forms of distortion can be made to neutralize each other

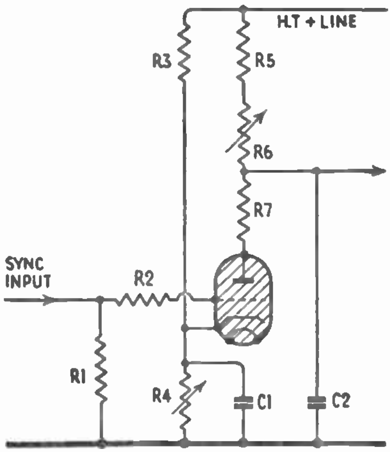


Fig. 63—A typical sawtooth oscillator circuit employing a gas-filled triode relay valve, and forming part of a complete scanning unit

In this way the charging of the capacitor can be carried on up to a voltage representing about 15 per cent of the applied voltage, which reduces the amplification required.

Another method of obviating the exponential charging curve of the capacitor in a scanning unit is to charge the capacitor not through a normal resistor, but through a constant current-device such as a diode valve operating under saturated conditions, or a pentode or tetrode.

THE THYRATRON VALVE

The switching device used in early receivers for charging and discharging the capacitor was a gas-filled triode valve, known as a "thyratron", which is a gas relay triode valve. The valve is filled with an inert gas, such as neon, helium or argon, the latter two being most suitable for television use. Although the use of this device is now infrequent in television receivers (it is also used in oscilloscopes), it is interesting to examine the method by which it operates.

The action of the gas relay is quite different from that of the conventional vacuum triode valve, though the electrode structure is similar. In use, if the grid of the valve is given a certain negative potential, and the anode voltage is gradually increased from zero, no anode current flows until a certain critical " striking " voltage is reached. At this point ionization of the gas inside the valve occurs and a heavy anode current flows. It continues to flow until the anode current is cut off, but is not controllable by the grid.

If now the anode voltage is gradually reduced a point is reached at which ionization ceases, and the valve again becomes non-conducting. This " extinction " voltage is much lower than the " striking " voltage, and it is due to the existence of a difference between the two voltages that the gas triode can act as an automatic switch. Following up the switch idea, the switch is " open " when the valve is non-conducting, and " closed " when the ionization is present.

Although the grid has no control on the valve when the latter is in the conducting condition, it can influence the operation of the valve, in the following way. As the negative grid bias is raised, a progressively higher anode voltage is needed before the valve will " fire "; in other words, the striking voltage increases with increase in negative grid voltage.

A typical thyratron time-base oscillator circuit of the kind used to control the charging and discharging of a capacitor in a scanning unit is shown in Fig. 63. The shading inside the valve envelope indicates that it is gas-filled. C2 is the capacitor which is charged and discharged. It will be seen that C2 is virtually connected from anode to cathode, though R7, a comparatively low value resistance of a few hundred ohms, is interposed to limit the maximum current.

This is necessary because when the valve " strikes " it almost short-circuits C2, and if there were no limitation of discharge current the valve cathode would be damaged. R7 must not be too large, however, otherwise the discharge will be too slow and the flyback of the trace will occupy too much time.

C2 is charged from the H.T. positive line of the scanning unit through R5 and R6, which are in series with the anode circuit of the valve. The total charging resistance can be varied over a certain range by making R6 variable.

In order to provide variable bias for the grid of the gas relay, the cathode is connected to the tap on the potentiometer R3, R4, across the H.T. supply. R4 is made variable, and is shunted by C1. The bias is applied to the grid in the usual manner via R1 and R2. R1 is a grid resistance which really forms part of the sychronizing input circuit; R2 is provided to limit the grid current of the valve, which might otherwise reach a high value and heat up the grid.

This is how the circuit operates. On switching on the H.T. supply, C2 charges through R5, R6 until the anode voltage of the valve reaches the critical value for the particular grid bias in use. The valve then suddenly ionizes, and C2 becomes practically short-circuited and therefore discharges rapidly. When the anode voltage (that is, the voltage across C2) has fallen to the extinction value, the ionization suddenly ceases, the valve becomes non-conducting, and the voltage across C2 starts building up again.

The whole sequence is repeated indefinitely at a frequency depending on the values of C2; R5, R6; and R3, R4. Normally, in a television scanning unit, C2 is fixed in value, and the adjustment of the unit is carried out by varying R4 and R6.

If we consider a free running (that is, non-synchronized) circuit, an increase in R4 increases the negative bias of the grid, and therefore the striking voltage of the valve increases, which means that the voltage of capacitor C2 can build up to a higher value before discharge occurs. This means that the deflection voltage available is increased, and the spot moves farther across the tube screen. In other words, the amplitude of the raster (picture width or height) is increased.

R4, therefore, can be regarded in a free-running circuit as an amplitude control, through it also affects the frequency of the circuit, since as the voltage across C2 can now rise to a higher value, the time required for this is increased, and the frequency of charge and discharge is reduced unless R6 is altered to compensate for it. R6 obviously controls the rate at which C2 charges, and therefore it is primarily the frequency control, though, as mentioned above, it is affected somewhat by R4.

In a television scanning unit we rely on the synchronizing pulses to fire the gas relay at the exact moment and at the exact frequency, and in these circumstances R4 and R6 have less effect on the circuit. It must be realized that however accurately we adjust R4 and R6, the scanning generator will not run sufficiently accurately to obtain a picture without synchronizing. The sync pulses, described later on in Chapter 12, are fed to the grid of the gas relay in such a way that each pulse applies a small positive bias (that is, it reduces the standing negative bias provided by R4).

With the controls set to give a free-running frequency slightly lower than the correct one, each sync pulse arrives at the grid just before the anode voltage of the valve reaches the striking value. The pulse suddenly lowers the negative bias, which lowers the striking potential and therefore causes immediate ionization of the valve.

It is clear that the sync pulses not only regulate the frequency of the scanning unit, but that they also time the commencement of each line, or frame, very accurately.

The frequency at which the circuit operates, when synchronized, is higher than when it is free running, and the amplitude is smaller. This follows from the fact that the sync pulses cause the valve to strike earlier than it otherwise would, as is explained in more detail in the chapter on Synchronizing. It can be demonstrated by listening to the note from the line scanning unit which can be heard by most people when a signal is being received, and then unplugging the aerial. The note will fall in pitch.

R4 has little effect on a synchronized generator, while R6 mainly affects the amplitude. However, a large change in value of R4 which alters the natural frequency of the generator seriously causes loss of synchronization. R4 therefore becomes the line or frame " hold " control.

THE BLOCKING OSCILLATOR

The gas triode type of circuit at one time was commonly employed in television scanning generators, but in modern receivers evacuated or " hard " valves are more generally employed, and there are many different circuits which may be used to obtain the desired results.

The simplest form of hard valve time-base employs a single triode valve in the circuit shown in Fig. 64. This is a " blocking " oscillator, in which inductances in the anode and grid circuits of the valve are tightly coupled so that the circuit oscillates strongly. At each positive peak on the grid, grid current flows round the grid circuit and charges up C1, which has the effect of making the mean grid potential more and more negative.

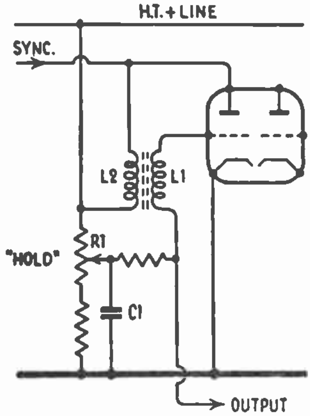


Fig. 64—Simplified circuit of a blocking oscillator time-base oscillator, using a triode valve. The second triode of the double valve shown would be used in some other part of the receiver, possibly in the other time-base

After a time this cuts off the anode current to such an extent that oscillation ceases, and the charge on C1 begins to leak away through R1. As this goes on, the negative potential on the grid falls, and a point is reached at which the circuit bursts into oscillation again, and the whole process continues indefinitely.

The saw-tooth voltage in this circuit is found between the top of C1 and chassis. The scan occurs when C1 is discharging through R1, and the flyback when the circuit oscillates and C1 charges. The value of R1 obviously controls the speed of discharge, and hence the frequency of the oscillation, and becomes the " hold " control.

Fig. 64 shows a simplified practical arrangement using one half of a double-triode valve, the other half of which might be used for some other purpose, possibly the other time-base since there must be two in every receiver. The valve might be a triode-pentode, the pentode operating perhaps as the sync separator. It will be seen that the sync pulses are applied directly to the anode of the blocking oscillator valve and that the " timing " circuit C1, R1, is shown in the bottom of the control grid circuit. The sync pulses may just as readily be applied to the control grid, however, and the timing circuit might be in the anode circuit, the grid circuit, or there might even be one in each. When the sync pulse is applied to the grid its polarity is reversed.

It was at one time quite common to find a pentode valve used as a blocking oscillator, using a circuit based on the one shown in Fig. 65. Here the triode oscillator circuit uses only the cathode grid and screen of the pentode, the screen grid operating as the triode anode, and although this part of the circuit differs in Fig. 65 from that in Fig. 64, that merely indicates some of the variations that are found in such circuits, and basically it is the same.

The method of producing the saw-tooth is different, however, because it follows more nearly the method used in a thyratron circuit. While the triode is acting just as it did in Fig. 64, the pentode anode charging capacitor is charging up (during the stroke) at the same time as C1 and discharging (during the fly-back) when the valve conducts violently. The saw-tooth output is then taken from the top of C3, the coupling capacitor C4 going to the output valve.

THE MULTI-VIBRATOR

Another and quite different type of hard valve scanning circuit that has gained considerable popularity in recent years is one that is called a multi-vibrator, probably because it produces a very wide range of harmonics. It always involves the use of two triode valves, and basically they are connected as shown in Fig. 66 (a), and the system is characterized by the symmetrical cross-connections between the two valves. In practice the

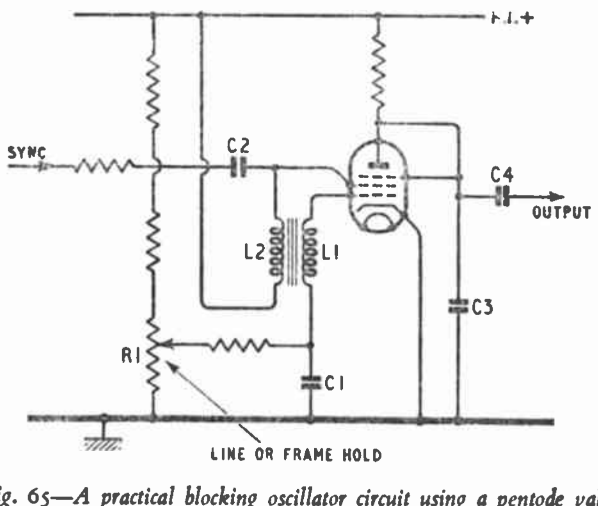


Fig. 65—A practical blocking oscillator circuit using a pentode valve instead of a triode. The oscillator circuit is still a triode and is basically the same as that in Fig. 64

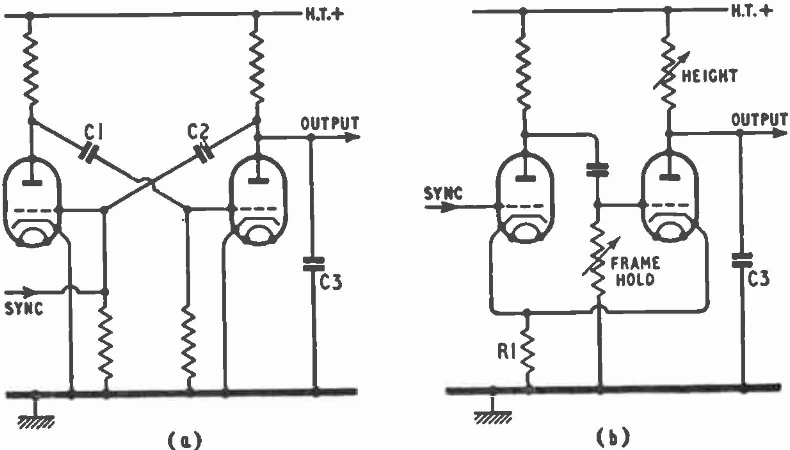


Fig. 66—Two basic forms from which most multi-vibrator time-base oscillators are derived. The symmetrical circuit (a) *is resistance-capacitance back-coupled; the less symmetrical one at* (b) *is cathode-coupled by R1*

pattern is varied quite a bit, and sometimes the second valve forms part of a pentode output valve, the screen grid acting as the anode of a triode. When two triodes are used, they might both be in the same envelope, or they might both be the triode (or even pentode) sections of other multiple valves.

Another form which the multi-vibrator can take is shown in Fig. 66 (b), where instead of coupling the two triodes back to each other by coupling capacitors, like C1 and C2 in (a), they are coupled by a common bias resistance R1, which may or may not be by-passed by a small capacitor. In either circuit a violent half-cycle of oscillation occurs suddenly, producing a sudden change in anode voltage. There is then a pause, until suddenly a change occurs in the opposite direction.

The suddenness of the change is due to the very tight coupling between the two valves with positive feed-back, and the pause between each half-cycle is due to the time it takes for the capacitances in the circuit to charge or discharge. The result is a square oscillation cycle, and the saw-tooth waveform is obtained from the charge that develops across C3 during the pause, followed by the flyback when the sudden oscillation occurs.

There are many varieties of the multi-vibrator oscillator, but they are all characterized by the employment of two valves (or two separate sections of a double valve). Often the cross-coupling shown in Fig. 66 (a) is omitted, and coupling between the two valves consists of what looks like conventional amplifier coupling. Feed-back, or the coupling back to the first valve from the second, then takes place, as explained in Fig. 66 (b). Such arrangements are recognizable from the fact that the cathodes of the two valves go to a common " bias " resistance, which is usually not by-passed by a capacitor. The charging capacitor is then usually connected between the anode of the second valve and chassis, and the sync pulses are fed in to the grid or the cathode of the first valve.

The most difficult circumstances in which to recognize a multi-vibrator circuit in a diagram occur when the second valve also forms the time-base output stage, especially if it is in the line time-base, because often the back-coupling is taken from some point on the line output transformer, and it then loses the characteristic cross-connection. In fact it often looks like an amplifier and output valve combination. It can be recognized by the fact that no other kind of oscillator circuit is present.

It was stressed earlier that the flyback time should ideally be zero, that is, the scanning spot at the end of a line should return to the beginning of the next line instantaneously. In practice this is not possible, but it is the aim of the designer to keep the flyback time as short as possible. It is interesting to realize that the incoming signal cannot force the cathode-ray spot to be back at the commencement of a line just as the line signal starts, and if it is not there when the picture signal commences the left-hand edge of the picture will be lost, or folded over, if it is in the line time-base that the flyback is slow; or at the top of the picture if it is in the frame time-base.

The distance between frame flyback lines is not equal all the way up the screen, but it varies in a regular manner, usually decreasing from bottom to top. If the interlace is correct, the flyback of the even frames, superimposed on that of the odd frames, should still result in a regularly changing spacing between successive lines. With an interlace which is not accurate, " pairing " of the lines of each frame sometimes shows up clearly by the flyback lines, which will also tend to pair.

Chapter 11

TIME-BASE OUTPUT CIRCUITS

Line and Frame Deflection

IN EARLY RECEIVERS IT was the normal practice to use an oscillator, usually one of the types described in the previous chapter, to generate the saw-tooth waveform, and to pass on its output to an amplifier which operated as an output valve and fed the scanning coils with deflection currents, very much after the fashion in which an A.F. amplifier is followed by an output valve in a sound radio receiver.

The practice is still followed in most receivers in the frame time-base, but in the line time-base it is quite common to combine the functions of oscillator and output valve in a single pentode designed specially for the purpose. The circuits then become very complicated and varied, seldom there being found two line output circuits that are exactly alike in different models.

In early receivers, employing 50 degree deflection tubes or thereabouts, the line output circuit was just a conventional pentode or tetrode heavy current power amplifier valve, step-down transformer—coupled to the deflector coils. Anode dissipation might be in the region of 20 W, say 60 mA at 300 V. One reason for the employment of transformer coupling is to step down the impedance of the scanning circuit, because owing to the highly inductive nature of the load, and the sudden changes of current resulting from a saw-tooth waveform, very high back E.M.F. voltages occur at the flyback, running into thousands of volts. Another reason is that a transformer keeps the D.C. anode current out of the deflector coils. When it is present it imposes a permanent deflection of the beam.

A simple circuit of the early type is shown in Fig. 67. The sudden collapse at the flyback is controlled by R3, C2, which damp the circuit, restricting the over-shoot which would otherwise occur in such a highly reactive circuit. R3 was adjusted until

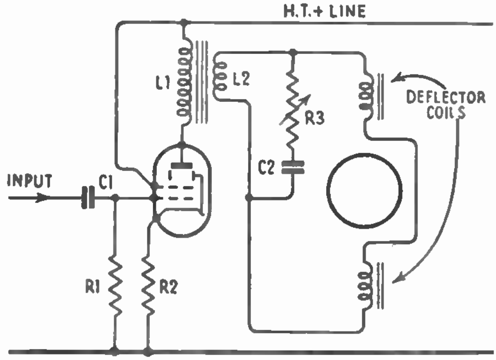


Fig. 67—A power output valve, transformer-coupled to the line deflection coils, as used in early receivers. The circuit is simplified for clarity

its value was such that the inductive field died away without overshoot, and because its setting was critical it was referred to as a "critical damping" device. Since it controlled the rate of decay of the magnetic field, it determined the flyback period, and its control knob was labelled "line linearity", because it controlled the start (left-hand side) of the lines.

The load imposed by this damping device was very heavy, however, because it was present during the forward stroke as well and consumed several watts of power. An alternative device was to shunt a diode across the circuit in its place, and to

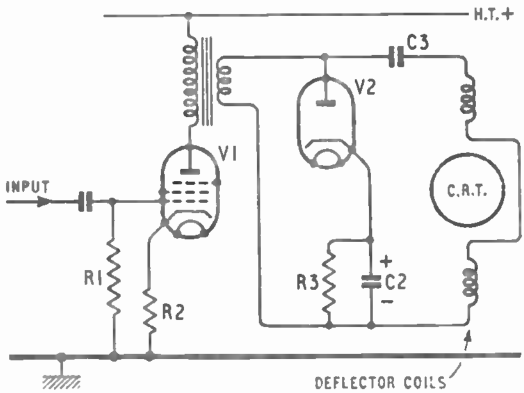


Fig. 68—This diagram is the same as that of Fig. 67 with the exception that the economy diode valve V2 and C2, R3 replace the damping resistance R3. C3 prevents D.C. current from flowing through the deflector coils

arrange its polarity so that it conducted immediately after the flyback, damping the circuit and preventing oscillation. Such an arrangement is shown in Fig. 68, where the diode, labelled V2, was known as a "damping diode". It conducted on the forward stroke, which for reasons that cannot be gone into here meant that it charged up by absorbing the over-shoot at the beginning of the stroke, and absorbed practically no power from the circuit afterwards for the rest of the stroke.

On the flyback it ceased to conduct, until the completion of the first stroke of the flyback, when the polarity reverses to complete one cycle of oscillation. The polarity then is the same as for the forward stroke, and V2 conducted, charging up C2. In the absence of damping, the inductive circuit would continue to oscillate at a decaying amplitude, but instead it charges up C2, which absorbs power and thus prevents the oscillation from taking place. R3 discharged C2 at such a rate as to ensure that at the end of the next flyback V2 was able to conduct again. Thus power was still wasted in R3, but it was less than was wasted previously. In both cases the power absorbed by R3 was dissipated in heat.

This device was used as it is shown in very few receivers, but it was the first step towards the modern highly efficient and highly complicated line output circuit which is used in one form or another in every domestic television receiver. It was realized that power was still wasted, and with a stroke of real ingenuity a way was found to use the energy stored in C2 to raise the voltage of the H.T. supply to V1, allowing V1 to use the power previously dissipated in R3. V2 was then referred to as an "efficiency" diode, and the additional H.T. voltage was called the "boost" voltage.

The reason for this inspiration was economic rather than academic. Early receivers had always been available for operation only from A.C. mains, because it was necessary to step up the mains voltage in order to obtain H.T. supplies of high voltage to run a time-base properly, but there was a wide demand for receivers that could be operated from D.C. mains. From the manufacturers' point of view it was desirable to supply this market with sets, but it was also desirable to make TV sets that would operate from A.C. or D.C. mains, for the following three reasons: (*a*) because mains transformers were bulky and also dear; (*b*) because receivers could then be used in areas supplied only with D.C. mains; and (*c*) because one type of receiver could be manufactured for use in A.C. or D.C. areas. Such sets were originally described as "transformerless" receivers.

The way in which it was done is shown in Fig. 69. The negative side of C2 is connected to H.T. positive, and the H.T. positive end of the primary winding of the line output transformer is taken to the positive side of C2. Thus the H.T. supply

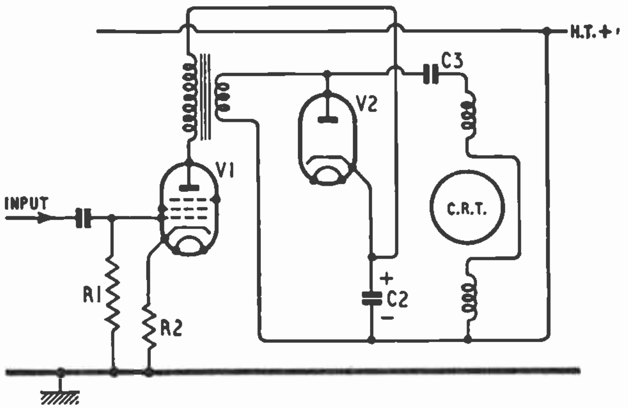


Fig. 69—By connecting C2 of Fig. 68 in series with the H.T. circuit, the energy stored in C2 is made to "boost" the H.T. voltage to the line output valve

voltage to the anode of the line output valve is increased, or boosted, by the voltage developed across C2. Infrequently, instead of connecting C2 as shown in Fig. 69, its positive side is connected to chassis, and VI cathode (the bottom of R2, if present) is connected to its negative side. This gives the same increase in voltage, but in the negative side of the circuit, taking the cathode down below chassis potential.

In early examples of this device the gain was about 30 V, and an electrolytic reservoir capacitor of about 2 μF was employed, but in modern receivers much higher boost voltages in the neighbourhood of 150 V are obtained; and the reservoir capacitance is probably somewhere between 0·1 μF and 0·5 μF.

The gain in H.T. voltage is only half the story, because the efficiency diode circuit is made to produce practically half of the line scan in addition to increasing the H.T. supply voltage. To understand this it is necessary to realize that in an undamped highly inductive circuit the flyback voltage can be very high, running into thousands of volts, and that the circuit will oscillate freely when the inductive field is allowed to collapse suddenly. Quite substantial currents can be made to flow in circuits connected externally to the output transformer.

Instead of damping the line output circuit and making it "lossy", the modern tendency is to keep the losses in it low.

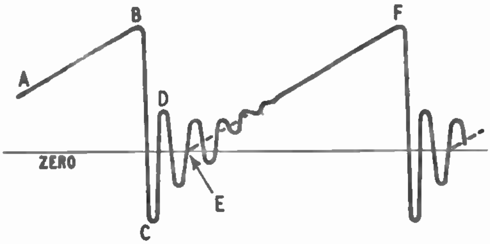


Fig. 70—An undamped high efficiency line output circuit would produce oscillations something like those shown here after the flyback B, C, causing changes in the beam scanning rate. The full permissible flyback period is from B to E, when the valve begins to drive again

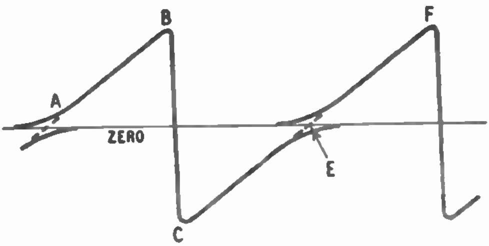


Fig. 71—When an efficiency diode is used the oscillation following the flyback is arrested at point C and made to form the first part of the forward scan

Thus it has a high efficiency factor, or high "Q", and it will oscillate very well, with a high flyback amplitude. The resulting current waveform in the deflector coils is shown in Fig. 70, where A–B shows the end of the forward stroke of one line of scanning current, and B–C represents the sudden collapse of the inductive field at the flyback, when the line output valve suddenly ceases to drive the circuit.

The current on the forward stroke reaches a maximum at B, then suddenly reverses for the flyback and falls away to zero, but owing to the inductive nature of the circuit it then over-shoots zero, continuing on to C. It then reverses its direction again, over-shoots zero again, and rises to D, where it completes one cycle of oscillation. It would go on doing this, with reducing amplitude at each cycle, even when the output valve begins to drive again at E, and would modulate the speed of the beam as it traced the line across the screen of the C.R. tube. When this happens, vertical striations, or alternate light and dark bands, appear on the left-hand side of the raster.

The efficiency diode prevents this oscillation from taking place. Its polarity is such that it conducts only on the forward stroke, and it follows therefore that it conducts shortly after the point C in Fig. 70, at the bottom of the first down-stroke of the flyback, as the current begins to rise towards D. The current it passes charges up C2 which, once it is charged, biases up the diode and permits it to pass sufficient current only to keep it charged.

The diode circuit is so designed as to accept current from the over-shoot at C at the same rate as is required by the deflector coils for the beginning of the scan, with the result that instead of going back to D in Fig. 70, the " free " flyback current is made to drive the scanning beam for almost the first half of its deflection on each line, as shown in Fig. 71. Here the oscillation is seen to be absent, and D is eliminated, the return stroke from C being made to follow the line C–E. At E it falls away to zero, having charged up C2, and power from the line output valve takes up the drive.

Thus the line output valve is in operation for only a little more than half the scanning period E–F, and considerable economy is effected. This complicates the circuitry to some extent, because it is necessary to ensure that the time-base is properly adjusted to bring the output valve into operation at the correct point. If it is incorrectly adjusted it is possible to damage the output valve seriously.

Whereas in early receivers the H.T. power dissipated in the anode circuit of the output valve might be in the neighbourhood of 20 W, in modern receivers it is likely to be nearer to 35 W, running perhaps at 350 V and up to 100 mA. This despite the greatly increased efficiency of the circuit, owing to the much greater power necessary to drive the modern wide-angle C.R. tubes.

It is the increasing demand for higher power in the scanning circuits to drive the beams of larger C.R. tubes with wider deflection angles to-day that dictates the need for highly efficient "efficiency" diode circuits. Although most receivers are designed for A.C./D.C. mains operation, which in itself requires the efficiency diode, A.C. mains receivers would also use the line output valve and efficiency diode combination kind of line output circuit purely on account of its efficiency.

Both valves work very hard, and although the rectifier is usually described as a diode, which one instinctively associates with signal circuits rather than power circuits, its function is much more like that of a heavy-duty mains rectifier. Apart from the large current it has to handle, it must withstand very high peak voltages, and if its cathode is connected to a high potential part of the output transformer, as it usually is to-day, it must withstand them between its cathode and heater. This has led to the design of special boost rectifiers with 6 kV heater/cathode insulation. Owing to this feature, involving wide spacing between heater and cathode, some of these valves take about 3 minutes to reach operating temperature after being switched on.

The foregoing description applies to line time-base output circuits equally whether a separate oscillator valve is used or the output valve itself acts as the oscillator. When it is also the oscillator, some part of the output circuit is coupled back to the control grid circuit of the valve to make it oscillate, and this arrangement is referred to as a single-valve time-base. The output valve might operate with another valve as a transitron oscillator, but this is really the same thing as a single-valve, or at least single-stage, time-base, because the output stage is not driven from a separate oscillator circuit.

The reader has been warned that the modern line output circuit is complicated, but it is beyond the scope of this book to go into greater detail than this, because it is still regarded as complicated even by people who are familiar with it. The output transformer is almost always an auto-transformer, and only in some cases is a D.C. isolating capacitor used to keep D.C. current out of the scanning coils.

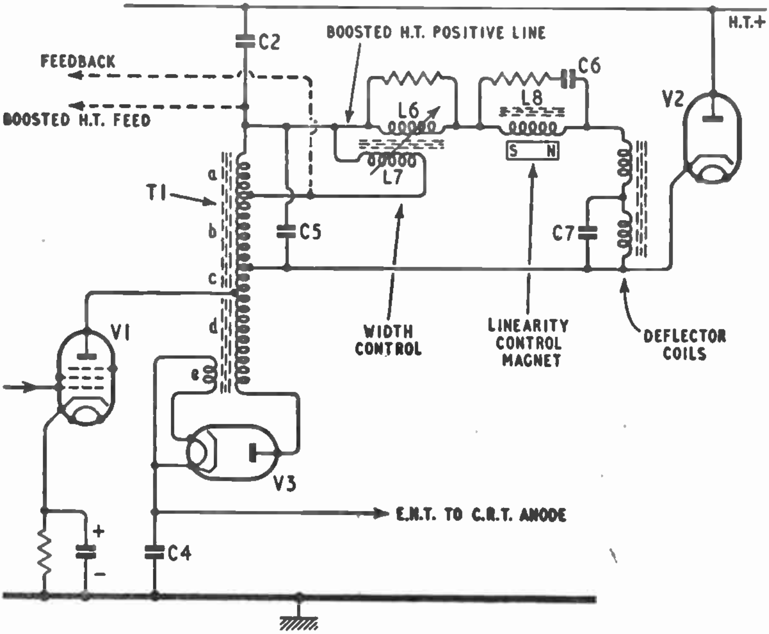


Fig. 72—Representative diagram of the simpler type of line output circuit as it is in modern television receivers. T1 is the auto-transformer coupling the line output valve V1 to the deflector coils. V2 is the efficiency diode, and C2 is the boost reservoir capacitor. The boosted H.T. line voltage might be as high as twice the normal H.T. line voltage or even higher

In order to give the reader some idea of the circuit of a modern line output stage, a fairly straightforward one is shown in Fig. 72. T1 is the auto-transformer output coupling, which has a special core of ferrous oxide material. The primary comprises sections *a* to *c*. The deflection secondary comprises *a* and *b*, which is deliberately tuned to quite a high frequency by C5. Width control consists of a series choke L6 in series with the deflector coils, an adjustable core varying its impedance to control the scanning amplitude. Associated with it is L7, which is shunted across the secondary and shares the same core with L6. As the core is withdrawn from L6 it goes further into L7, so that the load across the transformer remains constant.

The linearity control comprises a second coil L8 in series with the deflector coils. It has a ferrous oxide core, but it also has a permanent bar magnet close to it. The bar is adjusted so that its field, together with the scanning current, saturates the core at a certain point in the scan. C7 is a small capacitor, sometimes of the pre-set type, which balances the circuit and prevents vertical striations from appearing on the left-hand side of the picture. These striations when present have very much the same appearance as those just described (on page 131) as arising from overshoot.

The efficiency diode V2 is shown connected directly to the deflection secondary but it is sometimes connected to some other

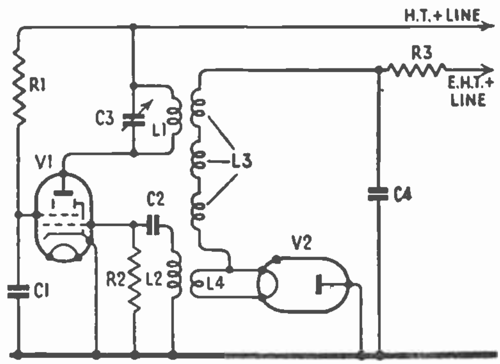


Fig. 73—An R.F. oscillator type of E.H.T. generator that is used in some receivers to supply E.H.T. current to the C.R. tube. It is seldom used in modern receivers

point, although its anode is usually connected to H.T. positive. V2 and its reservoir capacitor C2 are actually connected in series across the secondary, whose output it rectifies just as it would from a mains transformer. The negative side of C2 is where it joins the anode, of course, and as that is joined to H.T. positive, the positive side of C2 supplies H.T. current to V1 anode circuit. The voltage developed across C2 is called the H.T. boost voltage, and it is added to the normal H.T. voltage. In this particular case the H.T. voltage was 191 V, but the boosted H.T. voltage was 416 V, with 225 V across C2.

Frequently the boosted H.T. supply is used to feed other circuits, including the frame time-base, where a high voltage is desirable, as indicated by the broken line. Quite often where a multi-electrode C.R. tube is employed it provides an enhanced H.T. voltage to the first anode. A second broken line shows how a connection might be taken off from the secondary and fed back to the grid circuit of V1, or to another valve operating with it in a transitron circuit, if output and oscillator are combined in one stage.

Another part of the transformer that is shown in Fig. 72 is section *d*. This is a very large winding, and when used as a secondary it develops very high voltages on the flyback stroke, which are rectified by a special type of rectifier V3 and its reservoir C4 to supply E.H.T. current to the final anode of the C.R. tube. This E.H.T. circuit is always associated with a modern line time-base, and can supply up to 16,000 V. The current is very small, and once C4 is charged only the tips of the flyback peaks are rectified, so the flyback is not seriously damped by the system. The separately wound secondary *e* supplies V3 with heater current.

Other types of E.H.T. supply circuit have been used occasionally, but with the exception of projection receivers, which have a specially designed separate oscillator-driven E.H.T. generator, these have been completely superseded by the flyback E.H.T. circuit. In the recent past a simple R.F. oscillator circuit has been used to generate a voltage which is fed into a transformer that steps it up to perhaps 5,000 V or 10,000 V, and the circuit of such an E.H.T. generator is shown in Fig. 73.

In the very early days E.H.T. was obtained from a straightforward mains transformer with a 5,000 V secondary. These were difficult to insulate properly, they were heavy and bulky, they were expensive, and above all they were extremely dangerous in domestic receivers. They were the cause of the fires that threatened to give television a very bad name with the fire insurance companies in the early days of television.

Most of the chapter has been devoted to the line time-base, but it can be seen from the number of duties that it is called upon to perform, that it is a very important part of a receiver. Apart from providing the deflection power for the scanning coils, it must also perform the complicated process of supplying half of the energy needed to drive itself, it often supplies H.T. current at high voltage to other parts of the receiver, and it generates the E.H.T. supply for the C.R. tube.

The frame time-base is far less spectacular. Its design is eased considerably by the fact that it runs at a repetition rate of 50 c/s, whereas the line time-base runs at 10,125 c/s. The same types of oscillator are used in the frame circuit as in the line, but of course their circuit values are very different because of the much lower frequency. Such a thing as a single-valve frame time-base has been known, but it is very rare indeed.

Although they are by no means stereotyped, frame time-bases follow a fairly regular pattern to-day. One of the three oscillators described in Chapter 10 will be used, and it will feed

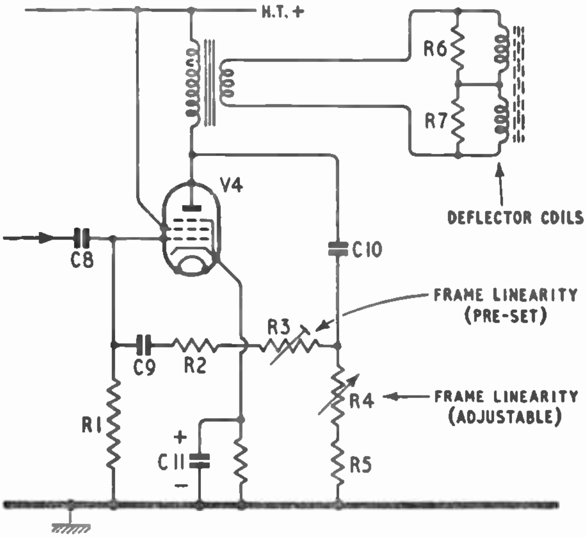


Fig. 74—A typical frame output circuit. C10, R4, R5 and C9, R2, R3 are parts of the negative feed-back circuit from which linearity control is derived

an output valve which is usually transformer-coupled to the deflector coils. The transformer may be double-wound or auto, and occasionally the coils will be driven directly. Generally there is some kind of adjustable feed-back from the output circuit to some point earlier, usually the control grid of the output valve, to provide linearity.

A typical frame output circuit of a fairly simple kind is shown in Fig. 74. The most important feature of it is the negative feed-back circuit which is used to correct non-linearity. In this particular circuit there are two adjustable linearity controls, but often there is only one. One of the two here is pre-set which means it is not adjustable externally. The other, R4, is adjustable from the outside of the set but even then it is one of the external pre-set controls, usually located at the back of the receiver.

The only other feature worthy of remark in the frame time-base is a device called the flyback suppressor. Owing to the increasingly larger C.R. tubes and the increasing E.H.T. voltages, frame flyback lines tend to show up on the screen, and it is necessary in modern receivers to suppress them. This is done by feeding the flyback pulse from the frame time-base to the grid of the C.R. tube.

Where it is taken from varies quite a lot. It may come from the output valve, or from some part of the oscillator circuit, and sometimes it is taken off the actual frame deflector coils. Provided that the video signal is fed in at the cathode of the C.R. tube, however, the pulse is negative-going and is fed in at the control grid.

Chapter 12

SYNCHRONIZATION

Sync Separation – The Differentiator – The Integrator – Flywheel Sync

THE TIME-BASE CIRCUITS IN all modern receivers are self-running. That is to say, once the receiver has warmed up they oscillate and produce a raster on the screen of the C.R. tube whether there is a signal coming in or not. With all kinds of time-base the raster is very different in appearance, when there is no signal, from the steady firm rectangular shape of a synchronized raster, but it is there.

It has already been remarked in an earlier chapter that any time-base when it is free-running (that means unsynchronized) must run at a slightly lower repetition frequency than the synchronized one, in order that it may be controlled by the synchronizing signals when they arrive. This follows from the fact that the slower a time-base runs, the longer each forward stroke takes to complete; when it is synchronized, it still tends to run slowly, but before the forward stroke is completed a sync pulse occurs and " trips " it, initiating the flyback.

If the time-base ran faster, it would complete its forward stroke before the sync pulse arrived, and the flyback would occur too early. The sync pulses control the speed of the time-base only if its free-running speed is such that the flyback is about to occur naturally very shortly after the sync pulse is due to arrive, so that the sync pulse determines the instant at which flyback commences. If the sync pulse arrives just *after* the flyback starts, it has no effect on the time-base at all. It has no effect either if it arrives too early.

This is explained diagrammatically in Fig. 75. The horizontal lines at (i) represent respectively zero oscillator voltage and the voltage at which the circuit trips itself and starts the flyback, as marked. As the unsynchronized oscillator voltage rises on the forward stroke it approaches the tripping level, and when it reaches it at *a* the oscillator automatically initiates the flyback, which is completed at *b*. Then the next forward stroke *b*, *c*, commences, and again the oscillator is tripped automatically when the trip voltage is reached at *c*, initiating the flyback *c*, *d*.

The output of the same oscillator is shown again at Fig. 75 (ii), but this time it is synchronized. The forward stroke commences at *b* as before, but just before it reaches the trip voltage, which it would do at *c*, a sync pulse *e* is superimposed on the oscillator voltage, raising it suddenly to the trip voltage and initiating the flyback just before it would occur naturally. If this happens at the same point on every forward stroke, the time-base in the receiver is kept exactly in step with that at the transmitter.

A sync pulse *e* is shown superimposed on the forward stroke of the waveform in Fig. 75 (i) but it occurs at such a position that its peak does not reach the trip voltage. As it is moved farther up the stroke it gets closer to the trip level, and it will trip the oscillator over quite a wide range when it is near the top of the stroke. It is made to approach the top of the stroke by altering

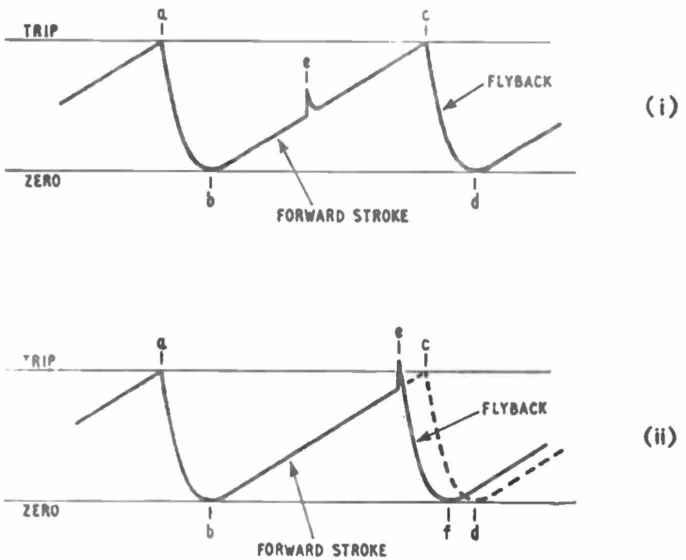


Fig. 75—At (i) *is shown the saw-tooth waveform of a hypothetical free-running time-base with an ineffective sync pulse at* e, *half-way along the forward stroke. At* (ii) *the pulse occurs near the end of the forward stroke and trips the oscillator*

the repetition rate of the time-base with the " hold " control, which is actually a speed, or frequency, control. It derives the name " hold " from the fact that it is used to adjust the time-base speed until the sync pulses occur somewhere within the range at which they trip the oscillator and hold it in step.

As we saw earlier in Fig. 17 in Chapter 2, the sync pulses are sent out with the picture modulation, the complete waveform comprising the video signal. In order to extract the synchronizing signals from the complete waveform they have to be separated by a device called a sync separator. There are numerous circuits for achieving this, but they all have one feature in common: they all operate by cutting off and suppressing the signal above a certain level, or voltage. They are therefore amplitude filters.

It was explained in Fig. 17 that if the maximum signal voltage for peak white modulation is taken as 100 per cent, then black level will occur at 30 per cent, and all the picture modulation voltages would have values between 30 per cent and 100 per cent. Below black level, the signal voltage drops suddenly from 30 per cent to zero (approximately) each time a sync pulse occurs, and because the signal voltage here is lower than black level, it is sometimes referred to as the " blacker-than-black " region.

The direction taken by the picture signals above black level results from an increase in transmitter power, the whiter the picture element at a given instant the greater the power output, and consequently the greater the signal voltage in the receiver. This is described as a " positive " modulation system, because greater signal strength is associated with a brighter picture element. When a sync pulse occurs the transmitter power drops suddenly to (nominally) zero. Some idea of this can be gleaned from Fig. 41 in Chapter 8.

In the same chapter we saw in Figs. 42–50 some of the circuits that handle the demodulated video signal, and it was shown there that their output might be positive-going or negative-going, according to which way round the detector was connected. It must be clearly understood that with a positive modulation system like ours, in which the signal increases for increased brightness, the output from the detector will be greater for increased brightness whether it is positive-going or negative-going, and confusion between positive modulation and the signal polarity must be avoided. A positive-going detector output fed into the grid of the video amplifier of Fig. 45 becomes a negative-going one at its anode, because of the 180-degree phase difference between the control grid and anode of the valve.

It is usual in modern receivers to connect the vision detector for a positive-going output, and it follows from this that when a sync pulse occurs the signal voltage falls from black level to zero, and the sync pulse in a positive-going video signal is therefore negative-going. If a diode valve D2 were connected across the output of the vision detector D1 as shown in Fig. 76,

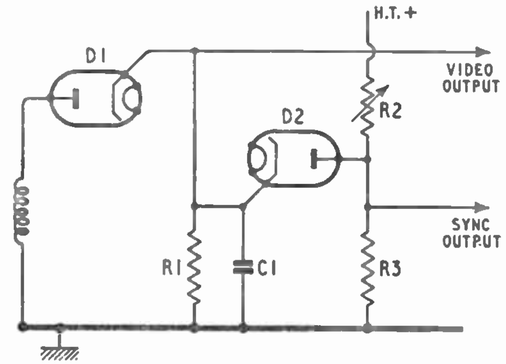


Fig. 76—Diode D1 with R1 and C1 forms a vision detector circuit with a positive-going video output. D2 is biased by R2, R3 to conduct only when the signal voltage falls below black level, and thus it conducts only on sync pulses

where the video output from D1 is positive-going, D2 would act as a sync separator. D2 could be suitably biased by adjusting R2 to conduct only when the signal voltage fell below black level, when a pulse would appear across R3. During picture modulation the cathode would be more positive than the anode, and D2 would not conduct.

This type of sync separator circuit was commonly used at one time. The setting of R2 was not really critical, because if it cut off lower than black level, sync pulses were still obtained, although their amplitude was smaller. If the detector output were negative-going, D2 would simply be reversed. The sync output from it was very small, of course, and it had to be followed by an amplifier if large sync pulses were required.

It is unnecessary to go into old-type sync separators further than this, because Fig. 76 explains the principle and the varieties

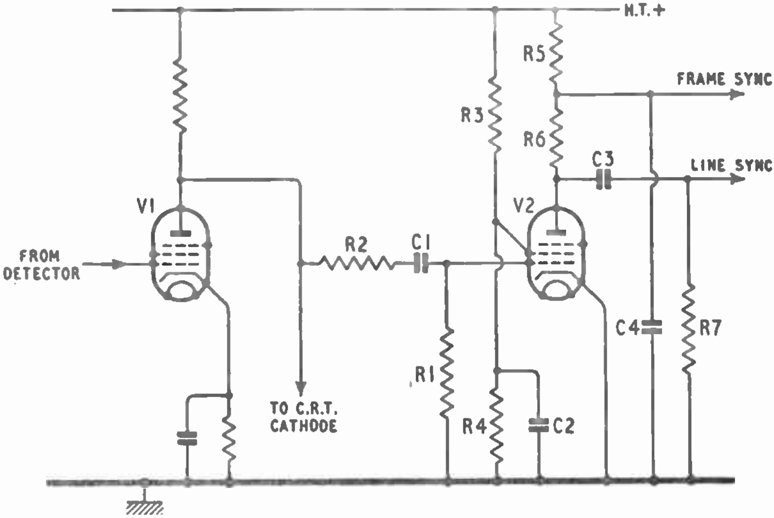


Fig. 77—The now almost ubiquitous pentode sync separator in British television receivers. Here it is V2, and it takes its input signal from the video amplifier V1, and thus it receives the same signal as is fed to the C.R. tube cathode. Occasionally a triode valve is used instead of a pentode

were very numerous. To-day there is virtually only one type of sync separator: the "saturated" pentode leaky grid separator, whose diagram is shown in Fig. 77. It is fed from the anode of the video amplifier, V1 in Fig. 77, and it is always used in association with a positive-going detector output, and it therefore receives a negative-going video signal from the video amplifier—the same signal as is fed to the C.R. tube cathode. Occasionally a triode is used in the same way instead of a pentode.

Since the video waveform that is fed into the control grid of the sync separator of Fig. 77 is negative-going, the sync pulses will be positive-going, because they start at black level and drop to zero. Zero is positive in a negative-going signal because it is less negative than black level. As the signal is coupled to the valve via C1, only A.C. coupling is obtained, and the D.C. component is lost. The waveform will be the same as that shown in Fig. 41 (b) but inverted—in fact it will be the lower waveform of Fig. 41 (a) after rectification. Because it is A.C.-coupled it will tend to dispose itself about zero level in the manner shown in Fig. 46, but again with the polarity reversed.

The first essential of a sync separator is the establishment of D.C. level, because if it is to discriminate between amplitudes it must start from a known datum or base line, and the pentode separator does this automatically. The H.T. voltages applied to its anode and screen are very low, in the neighbourhood of 30–50 V as a rule, and no cathode bias is used. Anode current, therefore, is very small, and so is the "grid base". This means that quite a small voltage range on the control grid will run anode current from cut-off to saturation.

When a sync pulse arrives it drives the grid suddenly positive, driving anode current to maximum (saturation) and causing grid current to flow along R1. R1, C1 act exactly as they do in a leaky grid detector in a radio receiver. C1 charges up negatively, and the time-constant is chosen so that it holds its charge long enough to suit the conditions under which it is to work. Because the signal is negative-going, picture modulation occurs in a negative direction, but the negative charge in C1 is already sufficient to hold the anode at cut-off, and the picture modulation only drives the grid more negative still, and has no effect on the anode.

When the next sync pulse arrives it drives the grid suddenly positive again, and anode current flows. The sync pulse must be large enough to drive the anode current to saturation, so that each time a sync pulse arrives, anode current suddenly shoots up from zero (cut-off) to maximum (saturation). Thus each sync pulse produces an identical change of anode current, which in turn produces an identical voltage-drop across the anode load resistances R5 and R6. At the end of each sync pulse the anode current drops suddenly to zero again.

What is actually happening is that the pentode control grid is acting as a diode anode. The time-constant of C1, R1 determines the bias, and the diode performs the dual function of sync separator and D.C. restorer. The pentode then operates as a D.C. amplifier, developing very large sync pulses of very square shape in its anode circuit. The picture content is completely eliminated.

Two kinds of sync pulses are required, however, and they are both present at the anode. Since all the pulses are now of the same amplitude, they cannot be separated by an amplitude filter. For the separation of the line and frame sync pulses, a fairly simple form of what is known as " pulse technique " is used. The line and frame pulses are of different duration, and they are separated by virtue of their width, or duration.

It is evident, therefore, that sync separation occurs twice: once to separate the sync pulses from the picture signal; and then again to separate line and frame pulses from each other. The pentode sync separator just described provides the most convenient, reliable, and economical method of performing the first separation, and it is quite a strong factor in favour of feeding the C.R. tube at its cathode, requiring as it does a negative-going signal, as shown in Fig. 47.

The separation of the line and frame pulses from the combined output of the sync separator is quite a different process, and is less easy to understand, as it is here that the pulse technique is involved. Discrimination between the two kinds of pulses is achieved by making them of different duration, but the process is complicated by the need to keep the line circuits synchronized during the longer frame pulses.

Each line sync pulse lasts 10 millionths of a second, usually referred to as 10 micro-seconds, or better still 10 μs, and they are going out continuously at the end of each line, that is to say, at a rate of about one every 100 μs. The frame pulse lasts very much longer, actually 400 μs, so there should be no difficulty in discriminating between them.

The task of discrimination, however, is greatly hampered by the fact that if the frame pulse consisted of one long period of 400 μs, the line pulses would have to stop while it happened, because both come in with the signal in a long continuous train, sandwiched in between the picture information. If the line sync pulses were to stop as long as this, the line time-base would get out of step, and several lines might be displaced at the top of the picture while it was catching up again. So the line pulses continue during the frame pulse, breaking it up into four 100 μs parts.

To make matters worse, and certainly very much more difficult to understand, interlacing involves the commencement of the lines in the " even " frame in the middle of a line, as was shown in Fig. 17, and it follows from this that sync pulses for the lines in an " even " frame must fall half-way between those of an " odd " frame.

This does not mean that the line time-base shall start one of its lines in the middle of another, but that the frame time-base shall be triggered half-way through a line. The repetition of the line time-base continues at 100 μs throughout, but each frame pulse commences alternately at the end of a line and in the middle of a line. In effect the frame pulse shuffles to and fro for half a line for " odd " and " even " frames relative to the line pulses, and in order that line pulses shall occur in the right places in both positions, a second set of line pulses has to be inserted in the frame pulse, half-way between the first set. So the frame pulse is now divided up into eight 50 μs sections.

The result of all this is that a train of sync pulses seen on an oscilloscope would look like the waveform shown in Fig. 78.

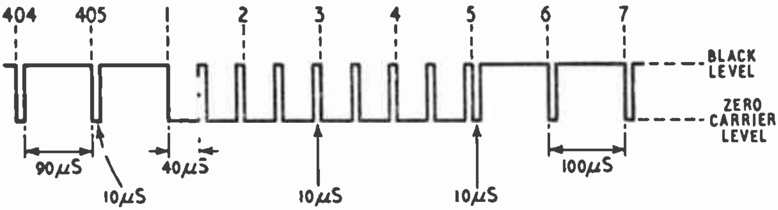


Fig. 78—The pulse train containing the frame sync pulse sequence which initiates the " odd " frame. Line 405 of the " even " frame is shown on the left without any picture modulation on it. The eight half-line framing pulses are followed by lines 5–14 during which picture modulation is suppressed. The lines are numbered 1, 2, 3, 4, etc., here as they occur in the pulse train, but in the raster, of course, the lines of the even frame are interleaved with them

Here it is assumed that no picture modulation is present, and the last two lines of the " even " frame (that is the second one of an interlaced pair), numbered 404, 405, are seen on the left with modulation at black level. The numbers indicate the points at which the sync pulses for the following line occur, tripping the time-base.

It must be explained at this point that the numbers on the arrows in Fig. 78 show the line numbers in the sequence in which they occur in the train of pulses in the signal, and not their sequence on the raster. On the raster, all the lines of the " odd " frame have odd numbers, 1, 3, 5, 7, etc., because those of the "even" frame are interleaved with them in an interlaced raster, as was explained in Fig. 16.

The frame pulse commences at line 1 for the "odd" frame, and arrows show the line pulses continuing through it for four lines, when it finishes. In between these pulses can be seen the second set of pulses which operate the line time-base when the "even" frame pulse arrives and starts in the middle of a line.

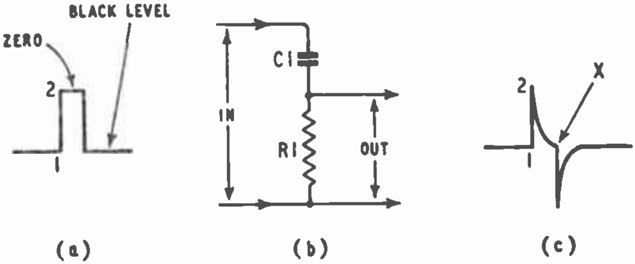


Fig. 79—How a differentiator works. If a square-shaped pulse (a) *is fed into the differentiator circuit* (b), *a very steep-sided double pulse* (c) *comes out. In order to be able to draw it the right way up, the pulse is here positive-going.* X *shows where the input pulse finishes*

Because the line pulses occur at half-line intervals during the frame pulse, they are called half-line pulses.

Each pulse starts from black level, so it is necessary for the waveform to return there before each pulse. In the frame pulse, therefore, it returns in less than 50 μs, because another pulse must occur then. The duration of a pulse is counted from the time it drops down to zero (and this is when it trips the time-base) to the time it rises again to black level. In Fig. 78 it can be seen that a line pulse lasts 10 μs, and each pulse of the composite frame pulse lasts 40 μs, separated from its neighbour by 10 μs at black level.

So 40 μs is the real period by which the frame pulses must be recognized against the 10 μs line pulse period, instead of 400 μs. A 10 μs pulse must trip the line time-base, but a series of 40 μs pulses must trip the frame time-base. We know already that the line time-base is tripped by the down-stroke, or leading edge, of the sync pulse, so it strikes at this point irrespective of the period of the pulse. It is tripped by the leading edge of the 40 μs pulses in Fig. 78. To enable these pulses to trip the frame time-base they have to be added together, or " integrated " to make one large pulse.

It is desirable that the pulses should be very sharp, so that the time-base is tripped at a given instant, and this is best achieved by means of a " differentiator," which despite its high-sounding name consists simply of a capacitance and a resistance connected in series, as shown in Fig. 79 (b). If a square-shaped pulse like that at (a) is fed into it, a voltage waveform like that at (c) appears across the resistance. The " leading " edge of the pulse marked 1, 2 at (a) is required to trip the time-base, and it can be seen at (c) that it is still quite straight and steep in the output, so that no matter at what point (voltage) between points 1 and 2 the time-base is triggered, it still occurs at the same instant.

To obtain the correct output waveform the values for C and R must be correct, and suitable values for the line time-base would be such as to produce a time-constant of 10 μs, but other values can be used. Further, instead of a resistance-capacitance combination the differentiator may take the form of an inductance-capacitance combination, and it may involve a transformer. But always it produces a steep, spiky pulse.

In the frame time-base it is important that the line sync pulses do not affect it. For successful scanning with an interlaced raster it is essential that the frame time-base is tripped only by the frame pulse. Otherwise the resulting lines of the " even " frame in the raster will be traced directly on top of those of the " odd " frame, instead of between them, with a big black gap between successive lines, making a very " liny " picture.

From the foregoing it is clear that the complete train of sync pulses is applied directly to the line time-base, so that it is kept in synchrony during the frame pulse train. To operate the frame time-base the frame pulse train must be made to produce something very different from the pulses that it applies to the line time-base.

This is done by " integrating " the frame pulses, but not the line pulses, and the simplest integrator circuit is shown in Fig. 80 at (b), where it is seen to be an inverted version of the differentiator of Fig. 79. Now, however, the output is taken from the capacitance C1, and when a pulse of voltage is fed into the network, as shown at 1 in Fig. 80 (a), current flows through R and into C1, and it continues to do so until the pulse ceases at 2 in (a).

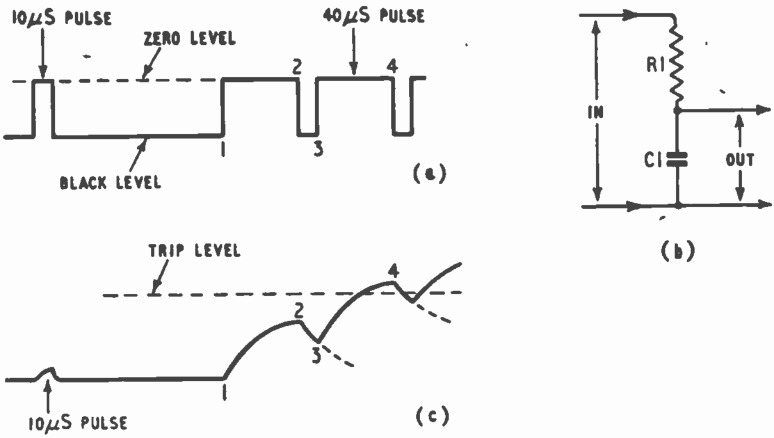


Fig. 80—How an integrator works. If the square-shaped pulse (a) *starts at* 1 *and lasts until* 2, *a voltage develops across capacitor* C1 *at* (b) *in the manner shown between* 1 *and* 2 *at* (c). *A second pulse* 3, 4 *builds up on top of the first pulse. Unlike the pulses in Fig. 78, which were negative-going, here they are shown positive-going in order that the waveform at* (c) *can be shown rising*

In order to show the sync pulses and the integrated output with the same polarity, the sync pulses are shown as positive-going, whereas they were shown as negative-going in Fig. 78.

While the current is flowing, C1 is charging up, with the well-known exponential waveform shown between 1 and 2 in Fig. 80 (c). When the pulse ceases at 2, the capacitor begins to discharge again as shown between 2 and 3 at (c), but the capacitor had been charging for 40 µs, and when it has been discharging for only 10 µs, another 40 µs pulse commences at point 3, and continues up to point 4, when there is another 10 µs rest.

It can be seen from Fig. 80 that successive 40 µs segments of the frame pulse train build up one on top of the other to a higher voltage than that of any one of them, and for comparison with them a 10 µs pulse is shown occurring just in front of the train of 40 µs pulses. It begins to charge up C1 as before, but does so only for 10 µs. The pulse then ceases, and the charge in C1, which is, as it were, only 10 µs high, has a 10 µs rest in which to discharge again, and the effect of the short pulse is negligible and it does not affect the time-base. If a string of them went on indefinitely they would never build up on one another.

How many segments of 40 μs frame pulses are needed to trip the frame time-base depends upon the design, but usually the second or third one is high enough to do it. A trip level is indicated in Fig. 80 (c), where it can be seen that the first pulse is not sufficient to reach it, although the second one is.

A differentiator and an integrator of the types just described constitute the simplest methods of discrimination, and they are seldom used just as they are described in a modern receiver. Sometimes, however, they form the beginning of the triggering system, and are followed by so-called "pulse shaping" circuits whose purpose is to ensure that the pulse that reaches the oscillator shall be steep and clean. They can actually be connected directly together, however, as shown in Fig. 81.

Such circuits, when they are used, usually involve an additional valve or so, although it may be a diode, when a crystal might be used. If a triode (or two triodes) is used, it is biased up so

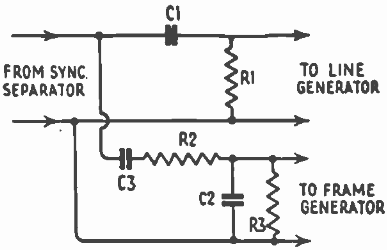


Fig. 81—Combined line and frame sync pulse separating circuit, comprising a differentiator and an integrator, in its simplest form

that only the tip of the pulse causes it to conduct, and then it rapidly reaches saturation, very much after the manner described for the pentode sync separator. When a diode is used, it is biased up, usually from an H.T. potential divider, so that it does not conduct until the sync pulse has built up to a predetermined height, and then again a sudden burst of current flows and sends a sharp pulse on to the oscillator.

These circuits are used in both time-bases, but they are more common in the frame time-base, especially the diodes. They have a very special application there if an integrator is used, because as can be seen from Fig. 80 (c), the integrated pulse has a very gradually rising wave-front, not a steep one like the differentiated pulse. A pulse-shaping circuit, sometimes called a "clipper", can, by suddenly producing a sharp pulse of current when the integrated pulse reaches the level, say, of the trip line in Fig. 80 (c), turn a blunt pulse into a steep one.

Most oscillators can be triggered with a positive-going or a negative-going pulse, according to whether it is fed in at the anode or the grid, but the choice is a matter for the designer. Both polarities are used quite liberally, and the decision as to which is used may depend upon the convenience of the sync circuit or that of the oscillator. To obtain the opposite polarity may require an additional valve in the sync circuit, simply to reverse it. On the other hand, the oscillator may work better with a pulse at the anode than at the grid, or vice versa.

To get over this difficulty, many sets employ more elaborate frame pulse separating circuits, not necessarily of the integrator type. One interesting circuit makes use of the intervals between successive frame pulses and converts them to positive pulses of the same duration as line pulses, and with almost vertical leading edges, the first of which is used to trigger the frame generator.

Development is continually taking place in the design of sync separating circuits, because the securing of an accurate and stable interlace between the two frames of a complete picture is of considerable importance. The effect of loss of interlace is to make the line structure of the picture more noticeable, while at the same time considerable detail in the vertical direction is lost.

Some of the first receivers to be produced in this country suffered from complete or partial lack of interlace, but modern receivers are rarely deficient in this respect. However, it is found in some receivers that if the line or frame hold controls (or both) are badly adjusted so that the picture is only just stable, the interlace sometimes fails or becomes intermittent. It pays, therefore, to set the hold controls about midway between the ends of the range over which the picture is stable, if only to ensure a satisfactory interlace.

FLYWHEEL SYNCHRONIZING

Another problem which is being successfully tackled in many modern receivers is the retention of accurate synchronizing in the face of severe interference. One of the worst effects of interference in "fringe" areas of low signal strength is the erratic effect of line synchronization when interference pulses arrive. This gives a "tearing" effect on the picture, and

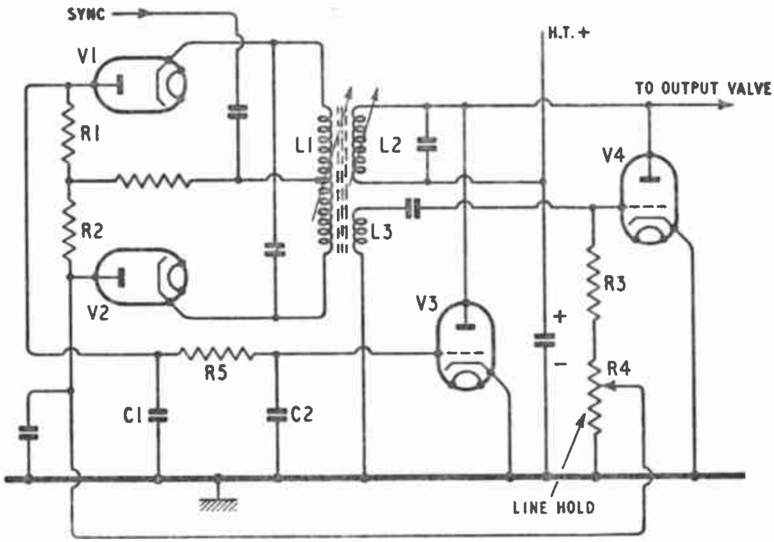


Fig. 82—Simplified diagram of a sinusoidal flywheel synchronizing time-base as used in some British receivers. V4 is the oscillator, and V3 the reactance valve

sometimes even causes complete displacement of groups of lines. By the use of special scanning generator circuits which give a " flywheel " effect, a temporary loss or displacement of the sync signal has no visible effect, the line generator holding the sync accurately until the sync signal is again correctly restored.

The essence of flywheel synchronizing is that the time-base responds only to a regular procession of pulses, and not to individual pulses as does a normal triggered time-base. Thus an extra pulse, which might result from some kind of interference, would be ignored, while the omission of one pulse in perhaps a dozen would not be missed. It is as though synchronization has momentum, like a flywheel. It does not respond to jerks, whereas the normal time-base depends on a separate pulse for each line.

In general these circuits are rather complex and difficult to understand, but probably the simplest to explain is one that uses a sinusoidal oscillator. A simplified diagram of one of these is shown in Fig. 82, where a sinusoidal oscillator V4 acts as the time-base oscillator, with reaction coupling between its tuning coil L2 and the grid coil L3. The frequency of oscillation is adjusted by means of an iron-dust core to exactly the line frequency, 10,125 kc/s. It will be remembered that saw-tooth time-bases must run slower than line frequency.

Thus from the anode of V4 the sinusoidal output is fed to the line output valve, which is biased so as to chop it up into a square waveform by slicing off the tops of the waves. Provided that the frequency is properly adjusted and does not change, there is a complete time-base, without synchronization.

Left to itself, the frequency of oscillation would change, of course, owing to drift, and in any case the repetition frequency of the transmitted pulses is not always precisely 10,125 kc/s, although it may average out exactly to that figure over a period. Some kind of synchronization is essential, to keep the oscillator in step with the signal. In this circuit this is achieved by the use of a discriminator circuit and a reactance valve, which operate in the same way as in an A.F.C. circuit in a radio receiver.

In Fig. 82 the reactance valve is V3 and it is shunted across the oscillator tuning coil L2. Coupled to L2 is a discriminator coil L1, to the ends of which are connected the cathodes of diodes V1, V2. On each cycle of oscillation which is induced in L1 from L2, the ends of L1 are of opposite polarity, as shown in Fig. 83 (a), and on one half-cycle V1 conducts, while on the other half-cycle V2 conducts, as their cathodes are driven negative in turn. Thus half-cycles of rectified current flow alternately in their load resistances R1, R2, but as their polarities are connected in opposition the potentials neutralize each other, and the total voltage across them is zero.

Sync pulses are applied to the centre of L1 and thus equally to both cathodes, so they cause equal currents to flow in the diode circuits simultaneously, again cancelling each other out and producing zero total voltage across the load resistors R1, R2. When the time-base is properly adjusted, the oscillator voltage in L1 is just crossing the zero line on each cathode when the sync pulses arrive, as shown in Fig. 83 (a), and equal currents again flow in R1 and R2.

If sync pulses and oscillation half-cycles occur together, however, as they do in Fig. 83 (b), the diode with a negative half-cycle on its cathode will conduct a larger current than the other, because the second one is receiving a positive half-cycle of oscillation, which biases it against the negative-going sync pulse.

If the oscillator frequency differs from the line frequency, the oscillator voltage at the time a sync pulse arrives drifts away from zero, and unequal currents flow, giving a total voltage across R1 and R2 which is not zero. This will be positive or negative with respect to chassis according to whether the frequency is higher or lower than line frequency. The resulting voltage is applied as bias to the grid of the reactance valve V3, which alters the oscillator frequency in the desired direction to bring it in step with the sync pulses.

Fixed bias for V3 can be taken from the oscillator grid circuit, where grid current flows through R4, and as V3 bias controls oscillator frequency, R4 becomes the line hold control. C1, R5, C2 store up and smooth the pulsed correcting voltage from the discriminator, their time-constant determining the rate at which correction can be made. Thus here is the actual flywheel effect. To set up such a circuit manually, the oscillator frequency is

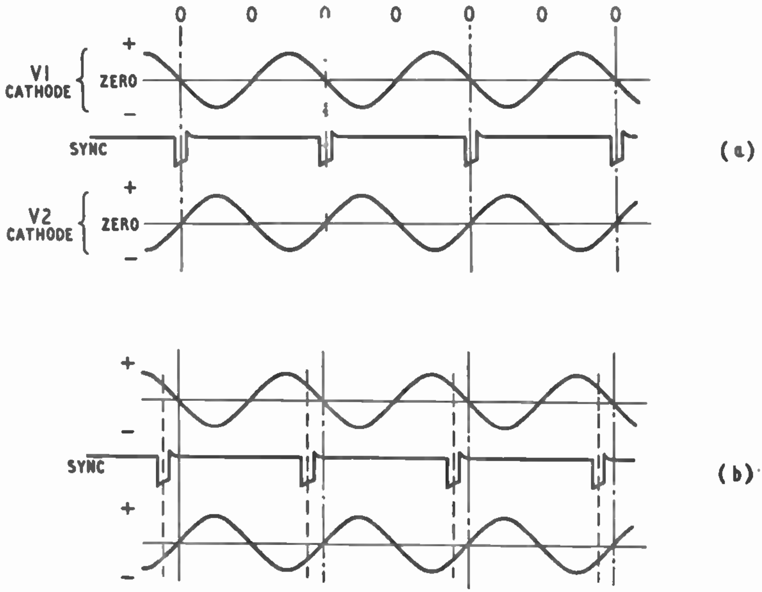


Fig. 83—Waveforms at the cathodes of the discriminator diodes V1 and V2 in Fig. 82. The opposing sine wave voltages are seen either side of the sync pulse voltages. Correct phase conditions are shown at (a), *incorrect phase conditions at* (b). *Noughts indicate points of zero oscillator voltage*

adjusted while receiving a picture with sync pulses suppressed, and when it is working properly no difference occurs when the sync pulses are restored. If the core of L1 is then adjusted, phase displacement will cause the picture to move about horizontally within its raster.

In another system of flywheel sync, which uses a conventional sawtooth time-base such as a multi-vibrator, " sampling " pulses are taken from a special winding on the line output transformer on the flyback strokes of the scanning waveform and " compared " through the medium of a discriminator with the incoming sync pulses.

As before, the ends of the sampling winding at the time of the flyback are of opposite polarity, and they are connected to the diodes of the discriminator, but the net output from them is zero. The 10 μs sync pulses are also applied to the discriminator as before, but they are differentiated and thus have the waveform shown at (c) in Fig. 79. This is symmetrical, in so far as it is equally positive and negative, and the net output from it is zero also.

When the time-base is synchronized with the signal, the sampling pulse occurs exactly at the point of zero voltage in the middle of the differentiated pulse, marked X in Fig. 79. If the time-base gets a little out of step, the sampling pulse occurs on one side of X or the other, one of the diodes conducts more current than the other, and a difference voltage appears in the load circuit. This is used to charge a capacitor, and the voltage of the capacitor is applied as bias to the oscillator valve of the time-base, speeding it up or slowing it down according to the error.

The time-constant of the capacitor circuit determines the rate at which the frequency can change, but quite a number of pulses would have to be out of step before the voltage changed appreciably, and that provides the flywheel effect.

Chapter 13

AUTOMATIC GAIN CONTROL

Simple Vision and Gated Vision Systems – Gating Diode

THE PRINCIPLE OF AUTOMATIC gain control, A.G.C. for short (or A.V.C. as it was in the early days), will be quite familiar to those who understand radio receivers, because all domestic receivers have used it for many years. Until the advent of multi-channel tuning with alternative programmes it was not necessary to use A.G.C. in television receivers because they worked from a single station, usually within a few miles' radius of it, where fading was not experienced. A.G.C. of the conventional kind found in radio receivers was occasionally used in the sound channel to counteract fading in fringe areas.

With the introduction of an alternative programme, however, some method of adjusting the gain is required when changing from one channel to another, because the relative strengths of the two may differ widely. Further, as the alternative channel is located in Band III, fading is likely to occur where it might not do so in Band I.

When a tuner unit is added to an existing receiver that is not equipped with A.G.C. it is usual to incorporate in it some form of gain control that is switched from one position to another with the channel switch. Once the two positions have been adjusted to give the same signal strength at the vision detector for both channels, the viewer has no further adjustment to make when channel-changing. Otherwise he must readjust his contrast control when changing channels.

A drawback to this method is that the gain controls are then located in the R.F. amplifier, which precedes the frequency changer, so that the full gain of the I.F. stages follows and amplifies mixer " noise " as much as the signal, sometimes giving a grainy picture. Normally the contrast control governs the I.F. amplifier gain, *after* the mixer, so that the full signal strength is applied to the mixer and the gain is reduced after it, together with the mixer noise.

When a receiver is designed for multi-channel operation it is usual to provide it with an A.G.C. circuit to take care of the difference in signal strengths between the two channels, and the A.G.C. acts as the contrast control on the I.F. amplifier. A.G.C. has the advantage that it does not need setting up for each installation, that it counteracts fading, that it accommodates changes in signal strength if the transmitters are moved or modified, and the difference between the strengths of transmissions (within limits), that it controls the I.F. amplifier, and that it helps to reduce the effects of aeroplane "flutter". It would still operate if a third programme were introduced.

The attainment of an A.G.C. voltage from the signal is not as simple in a television receiver as it is in a radio receiver. It is complicated by the fact that with an amplitude modulated signal, the strength, or voltage, of the signal varies with picture brightness, unlike a sound radio signal, whose average value is the same irrespective of modulation depth.

There are two general methods by which A.G.C. is derived in television receivers, one quite simple and the other rather

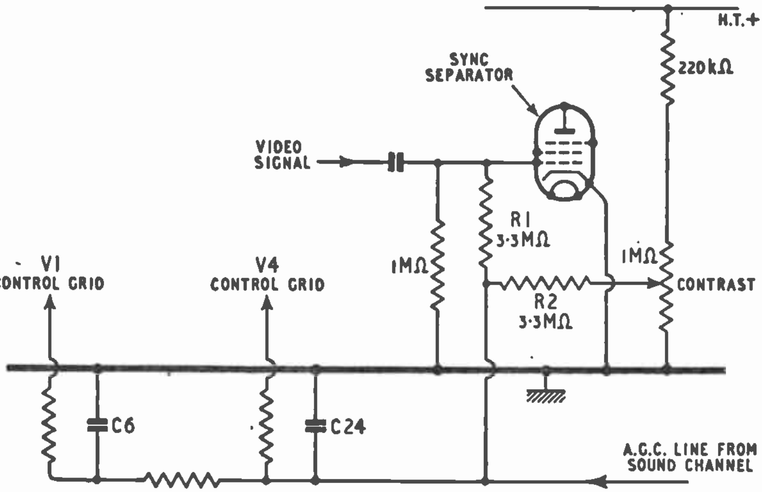


Fig. 84—The simplest type of vision A.G.C. circuit, using the negative voltage on the sync separator grid as bias. Only the essential features are shown, but this circuit is taken from a commercial receiver

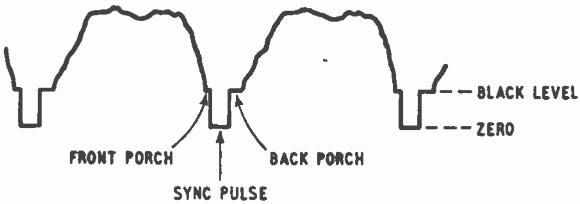


Fig. 85—Two complete lines of video waveform with their sync pulses and the accompanying front and back " porches "

complex. The simple one consists of tapping off from the grid leak of the pentode (or triode) sync separator, which we have already seen is used almost universally to-day, some of the negative potential developed along it, and using that as an A.G.C. voltage.

One method of doing this is shown in Fig. 84, but there are many variations of it, including delay in some cases, and often the grid leak is actually divided to provide a tapping. In Fig. 84 a separate tapped network is provided by R1, R2. How negative the A.G.C. will be with a given strength of signal is determined by the position of the slider in the H.T. potential divider, which thus forms the contrast control. The secondary A.G.C. line from the sound channel is quite commonly connected to the vision A.G.C. line to provide a source of bias when sound is radiated without vision.

This system operates from the average strength of the vision signal and is thus not truly accurate in its compensation, because it will increase the gain of the I.F. amplifier if a signal is sent out which is darker than the average picture, and vice versa for over-bright picture modulation. This, however, has a distinct advantage in many cases, because it brightens up the very dark picture, and it prevents defocusing on a very bright picture.

The alternative method is called a " gated " or " keyed " vision A.G.C. system. The only feature of constant value in the television signal is the height of the sync pulses, which is the same as black level, and to overcome the inaccuracy of the average or mean system just described, it is necessary to measure the voltage of black level in the signal, which is constant irrespective of modulation, and derive a control voltage from that.

This is where the complexity comes in, because a method has to be devised by which the television signal voltage can be " sampled " while it is at black level. The word " sample " might give the reader a clue to the method adopted, because it was used a short way back in the last chapter when describing the flywheel sync circuits. Usually a sampling pulse is taken from the line time-base, either from a winding on the line output transformer or at some other part of the line time-base. It may be taken from the same point for both flywheel sync and A.G.C.

There are so many circuit variations that it would not be helpful to show a circuit diagram of any one system to represent the various types of gated A.G.C. systems, but the principle is shown in the diagram in Fig. 86. Usually the signal is "sampled" at the output of the video amplifier, which means that by some kind of switching device the video amplifier anode is connected from time to time to the A.G.C. system while the signal is at black level.

In Fig. 85 are shown two complete lines of video modulation, with their sync pulses. On either side of the middle sync pulse are indicated the front and back porches, which are actually short intervals at black level to separate the picture modulation from the pulses. The front porch is short (about 1·5 μs at present) and the back porch is relatively large (about 6·5 μs). These are always at black level signal voltage, irrespective of picture

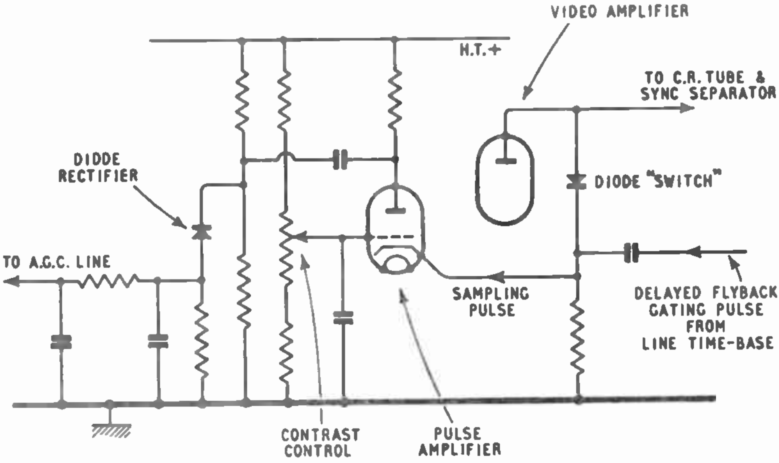


Fig. 86—One example of a gated vision A.G.C. circuit. Only the essential features are shown. Although there are numerous variations, this diagram is representative of the general principle

modulation, and thus they always represent the signal strength at the anode of the video amplifier. If the signal weakens, black level voltage falls; it if increases, black level rises.

The switching device consists of a diode (valve or crystal) that is biased back by a potential divider so that it does not conduct on any part of the picture waveform. To the diode is then applied a " gating " pulse from the line time-base, neutralizing the bias momentarily and allowing the diode to conduct, so that the video amplifier anode is momentarily connected via the diode to the A.G.C. system. The diode acts like a switch.

This is the gating, or keying, process. The gating pulse actually occurs on the fly-back stroke of the time-base, but it is delayed so that it strikes the diode a few microseconds later, during the back porch period. Thus at this critical moment the A.G.C. is able to take a " sample " of the black level voltage once every line, and the current through the sampling diode is proportional to the strength of the signal.

The samples are taken as short " pips " or pulses, of course, and as there is only one very short pulse during each line period, the output voltage is very small. It is usually amplified by a triode or a pentode A.G.C. amplifier, whose output is rectified by a diode and smoothed by a resistance-capacitance network before being fed to the A.G.C. line of the I.F. amplifier. Contrast control consists of a gain control on the A.G.C. amplifier.

There is one system in particular which deviates from the foregoing generalized description of vision A.G.C. circuits, and that is one in which the black level sample is taken from the signal during the frame sync pulse period, when there are 14 lines of black level signal without picture modulation. One big difference in this method is that the sampling diode remains conductive for a very much longer period than before, but it is also non-conductive for a much longer period. Precautions have to be taken with all A.G.C. systems to prevent valves from over-running themselves in the absence of a signal, and from being over-run by the signal soon after the set is switched on but before the time-base, and thus the A.G.C., is working, which might be as long as three minutes. The biggest danger is in over-running the video amplifier with a strong positive-going output from the vision detector before the A.G.C. system is working, but that is taken care of in different ways by different manufacturers.

Chapter 14

TV/F.M. RECEIVERS

Radio/TV Combination — V.H.F. Radio — Adaptability of the Turret Tuner — Selectivity and Choice of I.F.

SINCE RADIO AND TELEVISION are both broadcast media for domestic entertainment it is logical to associate them with each other and to provide both forms of entertainment in a single receiver. From time to time numerous methods have been adopted to achieve this end, but until the introduction of F.M. (frequency modulated) radio transmissions in the V.H.F. (very high frequency) range the combination was found only occasionally, as a " luxury " feature in a television receiver.

With A.M. (amplitude modulated) radio on the M.W. (medium wave) and L.W. (long-wave) bands the greatest saving in cost in combining it with a television receiver, as compared with buying separate receivers, is in the omission of the cabinet of the radio receiver. The audio frequency amplifier and loud speaker can also be saved, as can the power supply unit, because the radio receiver can use those already in the television set, but what saving is achieved in that direction is off-set in the additional complication that is imposed in the design of the television receiver, particularly in the matter of radio/television switching.

M.W. and L.W. tuning circuits are so different from those in a television receiver that the radio section of a combined receiver must contain a complete circuit of its own up to the detector stage. If the output from the detector is taken to the volume control of the television set, there is usually sufficient gain in the TV audio amplifier to load up the TV speaker adequately. There is also adequate power available in the H.T. and heater circuits of a TV receiver to supply the radio receiver with its needs, provided that one or two valves in the TV set are switched off.

In practice it is necessary to switch off parts of the TV circuit in any case when receiving on radio, because otherwise the time-base and synchronizing waveforms cause interference. This makes switching necessary, and it is then usual to switch off all the purely TV circuits, including the I.F. amplifier, video stage, and time-base circuits and cathode ray tube, but then it is necessary to make some adjustment to the power supply circuits, now relieved of a very heavy load, to prevent their voltages from rising unduly.

Thus such a combination becomes quite a complicated piece of circuitry, and in addition to its cost it provides more scope for breakdowns, as does anything that is complicated. Some manufacturers in the past have found it preferable to use completely separate receivers with the exception of the loud speaker, thus simplifying design and construction, and mounting them in the same cabinet. In all such cases, of course, separate aerial systems are necessary in combined receivers for each receiver.

With the introduction of radio transmissions at V.H.F. the proposition of a combined radio and television receiver is completely revolutionized, and as a result, today the foregoing description of combined receivers can be regarded as being written in the past tense, except that unwanted sections of the TV receiver are still switched off for radio as before.

As was explained in Chapter 6, the tuning circuits in what is often called the "front end" of a modern television receiver have to cover a wide section of the V.H.F. range of frequencies, from 40 to 70 Mc/s and from about 170 to 220 Mc/s. Where a turret tuner is employed it is only necessary to insert the appropriate pair of "biscuits" to tune to any channel in these ranges, and it would be just as simple if desired to do the same thing for channels in between these two ranges, say for instance at 100 Mc/s, because they are all within the V.H.F. range, which the tuner covers completely. An incremental tuner could if required be made during manufacture to do the same thing.

Now the B.B.C. F.M. transmissions are radiated in the V.H.F. range, each having a channel some 200 kc/s wide allotted to it at a frequency between 85 and 100 Mc/s which range of frequencies is referred to as Band II, and since the television tuner includes this frequency region in its range, Band II signals can be tuned by it, and that is why V.H.F. radio transmissions have simplified the design of combined radio and television receivers.

Such a combination is usually described as a TV/F.M. receiver. There is a minor drawback in the reception of these transmissions on a TV receiver in that they are frequency modulated, while the television signals are amplitude modulated. This complicates the detector stage considerably, but the difficulty is overcome very ingeniously by clever circuit design.

Frequency modulation is very different in many respects from amplitude modulation, but the differences are too wide to be explained here. Readers who would like to understand more about the subject could read it up quite quickly in a small booklet written by the co-author of this book, *F.M. Explained*, by E. A. W. Spreadbury and in greater detail in *Principles of Frequency Modulation*, by B. S. Camies. He would also obtain a better understanding of the combination of F.M. and A.M. circuits if he read another book by the authors of the present volume, *Radio Circuits*, by W. E. Miller and E. A. W. Spreadbury.

The much wider bandwidth of the F.M. radio signal (200 kc/s) than that of an A.M. radio signal (9 kc/s) offers no difficulty to the tuning circuits of a television receiver, whose signal bandwidth is over 4 Mc/s in the " front end " circuits, and at least half a megacycle wide in the sound channel I.F. circuits. If suitable biscuits are inserted in the drum of the turret tuner of a normal Band I/Band III TV receiver, therefore, it will tune in the F.M. signals, convert them in the frequency changer to the sound intermediate frequency, and thus pass them on to the I.F. stages of the sound channel of the receiver.

As was explained earlier, the detector stage for F.M. signals is different from that of the normal TV sound receiver, which is designed for the detection of A.M. signals, but until the detector stage is reached the signal is passed on quite normally, using the same intermediate frequency as is used for television sound.

The basic circuit of a typical F.M. detector is shown in Fig. 87, together with the normal type of circuit for a TV sound detector circuit, which we saw earlier in Fig. 51. It will be seen that it employs two diodes D1, D2, which might be thermionic valves (as shown) or crystal diodes. Two diodes were used in Fig. 51, but whereas one of them was a noise limiter, in the F.M. detector circuit of Fig. 87 both diodes are necessary for the actual detector circuit itself.

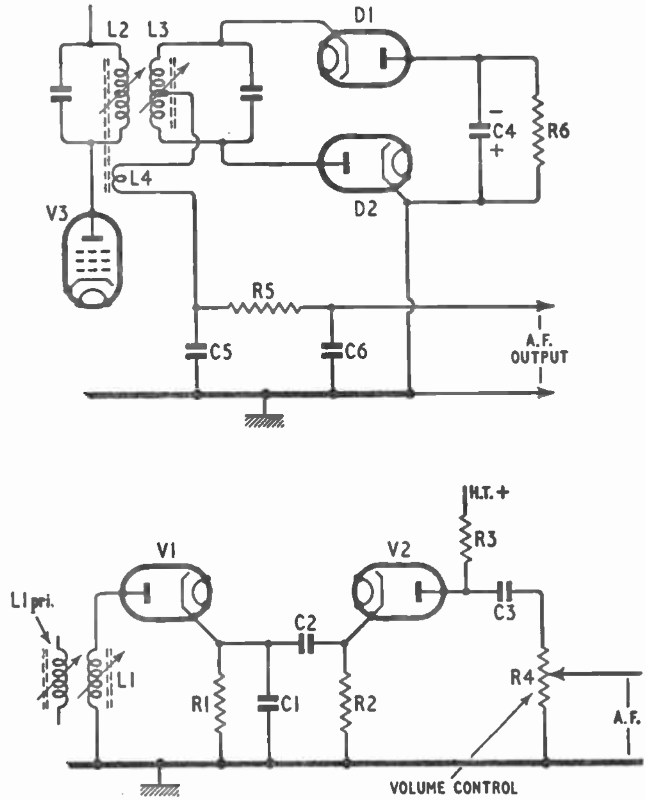


Fig. 87—A typical F.M. ratio detector circuit (top) compared with a typical TV sound channel A.M. detector circuit (below) which is redrawn from Fig. 51, but with the primary winding L1pri, which with L1 constitutes an I.F. transformer, added

There are several types of F.M. detector circuit, or discriminator as the F.M. detector is often called, and the one shown in Fig. 87 is known as a ratio detector because of the manner in which it functions. Another well-known type is called the Foster-Seeley discriminator, after the men who invented it. The ratio detector is distinguished by the connection of its two diodes in series with each other, instead of being connected in opposition, like a push-pull pair. Both of these types of discriminator are used in TV/F.M. receivers, but the ratio detector is by far the commoner, and our explanation will be confined to it.

In a frequency modulated signal, the modulation causes the *frequency* of the carrier to vary instead of its *amplitude*, and it is from this that the term F.M. is derived, as distinct from A.M. The corresponding detector circuit must therefore be sensitive to changes in frequency, and must produce an output signal that is proportional to the frequency variation of the carrier.

In Fig. 87, L2, L3, L4 are the windings of a rather special kind of I.F. transformer, and V3 is the final I.F. amplifying valve, and it is actually in the transformer that the discrimination takes place, while the two diodes work differentially as the detector, the ratio varying with the A.F. output signal.

Unlike the A.M. detector, however, their D.C. load resistance R6 does not also act as the A.C. load, or A.F. load, resistance, but is actually shunted by an electrolytic capacitor C4 of between 2 μF and 10 μF capacitance to prevent any audio frequency appearing across it. The A.F. load is provided by the capacitance of C5, and it is across this capacitor that the A.F. output signal is developed.

Amplitude modulation can be superimposed on an F.M. signal, but it interferes with the proper F.M. signal and is therefore undesirable, and measures are usually adopted in the receiver to prevent it from occurring. The electrolytic capacitor performs this function to a considerable extent, and other methods, such as biasing a valve (usually V3) so that it limits the amplitude of the carrier, are often employed as well.

One of the advantages of F.M. is its freedom from interference, and limiting the carrier amplitude assists the attainment of this end. Another device is to give the modulation what is called a " rising characteristic " at the transmitter, which means that as the frequency of the modulation rises the strength, or amplitude, of the A.F. signal is increased. This is known as " pre-emphasis ".

If the modulated sound signal were reproduced like this it would sound very shrill, but it is not, because the signal is " de-emphasized " in the receiver. Much of the noise that clutters up a signal is in the upper audio frequencies, and pre-emphasis helps the high notes in the signal to compete with it. When the signal is subsequently de-emphasized in the receiver, the high-pitched interference is reduced in intensity at the same time as are the high notes in the signal, and an improved signal/noise ratio is achieved. The de-emphasis is performed by a simple resistance-capacitance network, R5 and C6 in Fig. 87, and the A.F. output from the complete detector circuit is taken from C6.

The variety of detail in the F.M. detector circuit in different makes of TV/F.M. receivers is considerable, and in many circuit diagrams the only recognizable feature is the pair of diodes connected to the ends of the last I.F. transformer, but basically they can all be related to the circuit of Fig. 87 when closely investigated, unless they use the Foster-Seeley discriminator, when the circuit works on a slightly different principle. Then the detector circuit can still be recognized by the presence of the two diodes, but they are connected the same way round with respect to each other, whereas in the ratio detector each is connected the opposite way round with respect to the other.

How the ratio F.M. detector and the TV sound A.M. detector can be combined is shown in Fig. 88, which again is a basic diagram, omitting several possible refinements which are used in considerable variety by different set makers. The only essential change in the ratio detector circuit as compared with Fig. 87 is the introduction of the switch S1 in series with the electrolytic capacitor C4. When S1 is closed, the detector circuit is suitable for F.M.; when it is open, the circuit becomes suitable for A.M., or television sound.

When S1 opens for A.M. detection the two diodes D1, D2 become series-connected rectifiers, and so far as the signal is concerned they work just as would a single valve. Either could be short-circuited and the circuit would still work. What was the D.C. load resistance R6 becomes the A.M. signal diode load resistance, taking the place of R1 in Fig. 51.

The output from R6 is then connected by S2, which is closed for TV, to the series diode limiter valve V2 which is still connected as before between the H.T. potential divider resistors R2 and R3. Although the limiter circuit might look different in Fig. 88 from that in Fig. 51, actually it is not, except that the valve is reversed. The reason for this is that it must always be connected in opposition relative to the diode detector. Thus in Fig. 51 V2 is connected so that its cathode "faces" the cathode of V1, but if V1 were reversed (and this would make no difference to the rectification of the signal) V2 would have to be reversed also.

In Fig. 88 D1 is connected the reverse way round to V1 in Fig. 51, so V2 must be reversed also. The presence of D2 might confuse the issue a little, but it can be regarded merely as an earth connection for L3, and it could be short-circuited without affecting the working of the circuit on TV sound (A.M.).

Having accepted the fact that the A.F. signal appears across C5 on F.M., and across R6 on A.M. (or TV), it can be readily appreciated that if S1 and S4 are closed, while S2 and S3 are open, the circuit will work as an F.M. detector and the A.F. signal will be applied via C3 to the volume control R4; or that if the switch positions are reversed the circuit will work as an A.M. detector and the A.F. signal will again be applied via C3 to the volume control.

The change-over mechanism is mounted on the turret tuner and ganged with the channel selector control, so that when the turret drum is turned to an F.M. radio position the switch unit is automatically operated. In some receivers there is only one position for F.M., the fine tuner being used to tune in each of the three F.M. stations manually. In others there are three separate positions on the drum, each having a coil biscuit for one station. The same switch unit also disconnects other parts of the receiver that are not required when radio is being received.

Thus the combined circuit will work on TV or F.M. signals, and as the rest of the receiver can accept F.M. signals on Band II without any difficulty, the TV/F.M. receiver looks a very simple proposition. Even the same television aerial can be used, although it is very desirable to add to it a pair of horizontal elements to act as an F.M. aerial. This seems to have a negligible effect on the aerial's TV performance and of course it permits the same feeder cable to carry the F.M. signal to the set.

When the idea of the TV/F.M. receiver just described was first put into practice it worked very satisfactorily, but later developments, although they did not completely spoil this excellent combination, complicated it seriously. At the time of the introduction of this ingenious scheme the intermediate frequencies of TV receivers were not standardized, but the most common values were 16 Mc/s (vision) and 19·5 Mc/s (sound). The optimum intermediate frequency for F.M. was considered to be 10·7 Mc/s, and that was the value used in most A.M./F.M. radio receivers, and it still is regarded so.

Subsequently, however, for other considerations connected mainly with the development of TV services in Band III, it

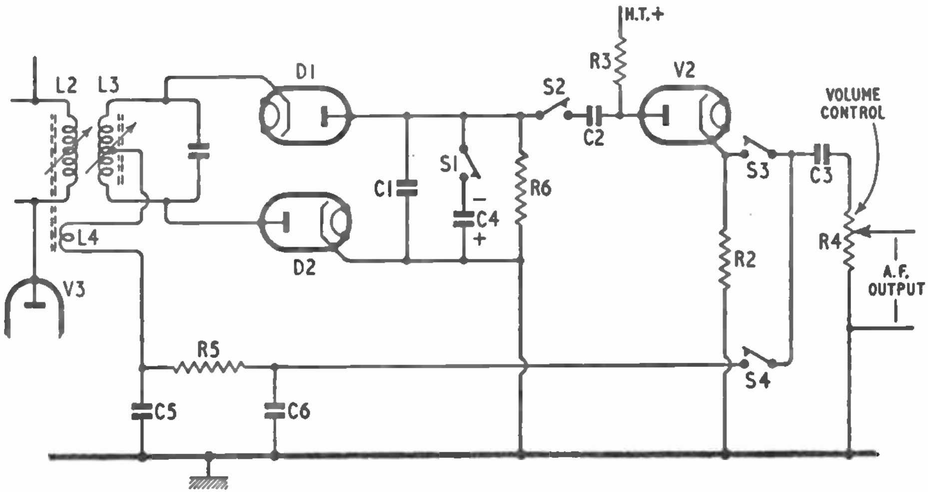


Fig. 88—Showing how the F.M. and A.M. circuits of Fig. 87 can be combined to make a single dual-purpose A.M./F.M. detector circuit. The component reference numbers are the same in all three diagrams. Note the polarity of C4, positive to chassis

became necessary to standardize TV I.F.'s at a much higher frequency to avoid the possibility of whistles occurring as a result of interference between receivers working on different TV channels, and the recommended standard, which has since been adopted almost universally, was 34·65 Mc/s (vision) and 38·15 Mc/s (sound).

The selectivity of a tuning circuit is very closely bound up with frequency, the selectivity becoming poorer as the frequency is raised, and whereas the F.M. system would work quite well with TV sound channel I.F. circuits at 19·5 Mc/s, which is just under twice the optimum frequency, it was unsatisfactory when the TV sound I.F. was raised to 38·15 Mc/s, which is nearly four times the optimum frequency. The selectivity was so poor that where the simple TV/F.M. combination we have described was used, other F.M. services such as fire and police interfered with the programmes. Some receivers were so unselective that the fine tuning knob failed to separate one F.M. channel from the next, 2·2 Mc/s away.

Several different methods have been used to overcome this difficulty. One manufacturer goes so far as to use a conventional TV tuner, with its usual frequency changer, and then pass the sound channel through a second frequency changer, both on TV and F.M., changing the sound intermediate frequency to about 6·5 Mc/s while leaving the vision I.F. at 34·65 Mc/s. He is therefore able to use the same I.F. circuits for F.M. and TV sound, and his frequency is so low that he can adjust the selectivity to suit his requirements.

Other manufacturers keep to the TV sound I.F. for F.M. signals but introduce additional tuned circuits, usually with band-pass characteristics, to achieve greater selectivity, but the most common answer to the problem today is to use the recommended standard intermediate frequencies for both services. This means that the I.F. amplifier must respond to 38·15 Mc/s for TV sound signals, and to 10·7 Mc/s for F.M. radio signals, which can be achieved by connecting two sets of I.F. transformers in series, as it is done in A.M./F.M. radio receivers, although there is a variety of other methods.

One method is to use the same valves for both services, TV and F.M., with dual pairs of tuning coils, tuned to TV and F.M. I.F.'s respectively, but to connect them in parallel, or a rather intricate series-parallel arrangement. In any of these cases, the F.M. coils respond to the 10·7 Mc/s signal, and the TV sound coils respond to the 38·15 Mc/s signal, and neither of them responds to the other's signal frequency, yet both signals will pass through the amplifier. Another method still is to use a separate I.F. amplifier for the F.M. signal, with its own valves, taking its signal directly from the output of the tuner unit.

In all cases where the recommended standard I.F.'s are used for TV sound and F.M., however, a separate detector circuit is necessary for each service. Then, of course, all complications are disposed of, because it is unnecessary to use a combined TV/F.M. detector, and two separate circuits like Fig. 51 and Fig. 87, can be used, the primaries of the two I.F. transformers (L2 and L1pri) being connected in series with each other in the anode circuit of V3.

The output from each detector circuit then goes to a two-way change-over switch like S3, S4 in Fig. 88. The signal from the TV sound detector is taken from, say, C3 in Fig. 87 to S3, and that from the F.M. detector from R5, C6 in Fig. 87 to S4. Thus the signal passed to the volume control R4 comes from the appropriate detector circuit, according to which switch is closed.

Often the normal TV aerial will pick up a sufficiently strong F.M. signal to permit the TV/F.M. receiver to work without modification to the aerial, but this is bad practice, because the advantages of F.M., particularly that relating to freedom of interference, may be lost. F.M. signals are all horizontally polarized, and the TV aerial is vertically polarized in most parts of the country. Where the TV aerial is vertical, it is advisable to have a pair of horizontal F.M. elements fitted to the Band 1 TV elements, right close to the centre, where the feeder is taken off. This does not noticeably affect the TV aerial, and ensures a good F.M. signal. Where the TV aerial is horizontal to start with, an additional fitment may be unnecessary except in near-fringe areas.

Chapter 15

RECEIVER INSTALLATION AND OPERATION

Location of the Set – Initial Adjustment of the Controls – Attenuators

FOR THE BENEFIT OF those who are not familiar with the installation and operation of television receivers it is now proposed to touch upon a few points which may be helpful to the non-technical user.

Dealing with installation, the first point that arises is the location of the receiver. There will probably be little, if any, choice as to the room in which it is to be used, but it is worth giving a certain amount of thought to its position in that particular room.

With a television receiver more than with an ordinary sound receiver, there are obviously good and bad positions.

Unsuitable positions are, for instance, those with the screen directly facing the main window; or close to the door so that every time anyone enters or leaves he or she has to walk in front of the screen, and possibly allows a stream of light to fall on the screen when the door is opened; or in a corner of the room such that a complete rearrangement of seating has to be made when the set is in use.

There is a good deal to be said for placing the set close to the window. In this way the picture can often be clearly seen in daylight without having to draw all the curtains. This is certainly possible with receivers incorporating the latest aluminized tubes, high E.H.T. voltages, and dark filters.

Due respect must, of course, be paid to the position of the electric point from which the set is to operate, but it is better to place the set correctly, even if a long mains lead has to be used, than to let the electric point dictate the receiver position. The correct plan is to have an electric point installed near the receiver. The distance from the point at which the aerial feeder enters the room is immaterial, since any reasonable increase in feeder-length will have no ill effects; on the other hand, as the feeder will usually enter via the window, the positioning of the set near, and with its back to the window, helps in making an unobtrusive feeder run.

Sufficient was said in the first chapter of this book regarding aerial systems to make it unnecessary to deal with that subject again here, and it will be assumed that an efficient aerial system has been installed, and that the receiver end of the feeder has been fitted with a plug which is suitable for the special aerial socket of the receiver in use.

In general, the non-technical member of the public is not expected to know more about the operation of a receiver than to be able to adjust the few variable controls provided, with a moderate degree of intelligence. The more technical user, and the dealer who supplies the set (or his service engineer) will want to know how to handle not only the fully variable controls, but also the pre-set ones, which do not normally need adjustment once the set has been installed at a particular site.

The first thing to do with a new receiver, which one assumes is supplied with its tube and valves *in situ*, is to make certain that none of the valves is loose in its holder, and that all top cap connectors (where fitted) are firmly in position. The tube mountings should also be examined to verify that the tube has not shifted in transit, and that it is firmly fitted in its holder and is not damaged.

It is important that the voltage adjustment on the mains transformer should be correctly set for the voltage of the supply. It is sometimes advisable to check the mains voltage by means of a meter, as the voltage in some localities may be well off the rated value, and certain receivers are somewhat critical with regard to voltage input.

The mains socket should be of the 3-pin type and the plug should be correctly wired with the lead from the receiver, especially if the A.C./D.C. technique is employed in the set. This is highly important in the interests of safety. Fig. 89 shows how the mains lead should be wired to the plug, and in the same sketch are indicated the correct connections for the socket

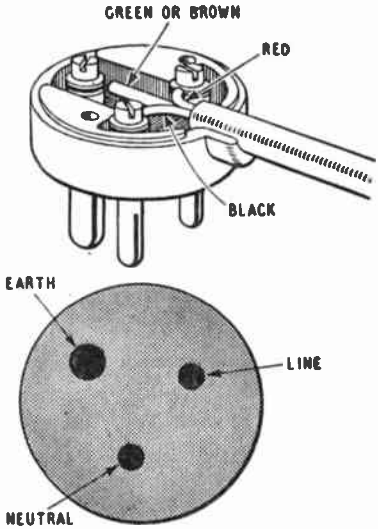


Fig. 89—This sketch shows the correct method of connecting the mains cable from a receiver to a 3-pin wall plug. It is very important for safety that the plug (and the wall socket) are correctly wired. This sketch applies equally to plugs with round pins, as shown, and the 13 amp plug, which has flat pins

if one is being fitted specially for the receiver, in a house where 2-pin plugs are normally used, for instance.

The " Earth " socket should go to a good reliable earth, such as a main water pipe, and if the socket is properly wired, the full mains voltage should be present between the right-hand socket (marked " Line " in the sketch) and the Earth socket. The full mains voltage also exists between the Line and the " Neutral " socket, of course, but no voltage, or at the most a very low voltage, should be found between Neutral and Earth sockets.

The foregoing explanation applies to A.C. mains only, and it is important that its directions should be observed, because if either the plug or the socket is wrongly wired, the chassis will become " live " to the mains. The connections should be made and checked only by somebody who is technically competent and reliable, because electrical shocks are possible if the leads are connected to the wrong side of the mains. Commercially made receivers as they are bought in a shop are thoroughly well protected against electrical shock, even when a 2-pin plug is used with them, but there is always the possibility of somebody leaving the back cover of the set insecurely fastened, or even the remote chance of a fault developing in the course of time.

If an existing A.C. 3-pin socket is used, that should be checked to ensure that it was correctly wired in the first place. On D.C. mains, of course, the leads must be connected so that the polarity of the mains is correct to suit the receiver, and you have no alternative as to the polarity of the leads. A 3-pin plug is still helpful, however, because the earth connection will provide some protection, and in any case the plug cannot be reversed, applying the mains in reversed polarity to the receiver.

Needless to say, any adjustments inside the receiver, apart from actual controls, should be made with the set disconnected from the mains. It is important to remember that some points in the set are at a potential of several thousand volts to earth, and at such potentials actual contact with a live point may not be necessary before a severe shock is received. Also, even when the set is switched off, do not immediately handle any previously live parts, for they do not necessarily lose their high potential immediately. When in doubt, the point to be handled may first be shorted to chassis with a long-handled and well-insulated screwdriver.

It is obviously not possible to give detailed instructions for the preliminary adjustment of every receiver, but the following general hints will be applicable to most types. There may, however, be cases where a different procedure will give the best results more quickly. Wherever detailed instructions are supplied by the receiver manufacturer, they should be followed rigidly.

First, remove the aerial plug temporarily if a transmission is coming in; this is not necessary if the station is not transmitting at the time. Switch on the set, and wait until all circuits are operating correctly. Turn the " brightness " control (tube bias) clockwise until the raster is visible on the screen, then turn the same control anti-clockwise until the raster just, but only just, disappears.

With many modern television receivers, in particular those that employ the mean level system of vision A.G.C., this proposal cannot be carried out, because when there is no video modulation on a carrier the A.G.C. system automatically turns up the contrast, because the average signal voltage is low. Conversely, when the signal contains a lot of bright light, the A.G.C. turns the contrast down. Therefore the best way to adjust the brightness control is to adjust it in conjunction with the contrast control for the best reproduction of all shades of grey, from " black " to white while receiving a picture, and the best picture for that purpose is Test Card C. The process is described in Appendix I, section 7, on page 181.

Having made this preliminary adjustment of the " brightness " control, the aerial may be plugged in again, if it was previously removed, and an attempt made to adjust the other controls on an actual transmission. For this purpose it is best to wait until one of the test patterns is being transmitted, since these are far more suitable for the preliminary adjustments than any normal moving scene, or even a still picture. The best one is Test Card C which is shown opposite page 1.

The first thing to do is to turn the " contrast " control (signal gain) clockwise until there is a visible picture of some sort on the screen. It may be broken up, and slipping either horizontally or vertically, but so long as something appears, the receiver is obviously picking up the signal. If nothing (except, perhaps, bright interference splashes) is visible, it may be that the receiver is not tuned to the station.

Modern receivers have a variable tuning control (C8 in Fig. 33, Chapter 6) in addition to the multi-channel switch, and both of these controls must be adjusted correctly. The variable tuning control should be adjusted accurately for maximum sound, especially on Band III signals, and it may require resetting each time the channel switch is operated. There may also be an R.F. gain, or sensitivity, control.

The reason for adjusting the variable tuning control for maximum sound is that it is extremely difficult to tune in a television receiver manually by watching the picture, whereas on the sound channel the tuning is relatively sharp. If the oscillator frequency is correct it will produce the correct I.F. output for the sound channel and the vision channel, but although the receiver will work with an I.F. signal of not quite the correct frequency, the sound rejectors in the vision channel, which are sharply tuned, will not reject the incorrect sound intermediate frequency, and sound-on-vision effects will appear in the picture.

In the case of older receivers, most of them have no variable tuning control, but there may be a pre-set control which forms one of a group of subsidiary adjustments. If so, this should be adjusted, keeping the " contrast " control (and the R.F. gain, if any) well advanced, until some sort of picture appears. Manufacturers' instructions regarding tuning (if provided) should be followed.

The usual recommendation given is to tune to maximum sound, which will give the optimum (though not necessarily maximum) vision setting. In a receiver with a multi-channel switch, the switch knob and tuning knob are usually concentric.

If a sensitivity control is provided, it should be adjusted for optimum picture contrast with the contrast control set to the mid-point of its track. The purpose of a sensitivity control is to prevent overloading on a very strong signal.

We will assume that a picture of some sort is now obtained, and the next thing is to synchronize it by means of the " line hold " and/or " frame hold " controls. If the picture appears to be stable in a vertical direction (that is, if it is not slipping up or down) it may only be necessary to adjust the line hold control; vertical movement of the whole picture, however, indicates lack of frame synchronization.

When adjusting the two " hold " controls, it will be found that there is a small range of movement of each control over which synchronization holds; the control should be adjusted to the centre of this range in each case. These controls are usually classed as subsidiary ones, and will be found grouped with others at the back of the receiver, or otherwise concealed from view.

Having stabilized the picture on the screen, the next thing to do is to focus it accurately, if a focus control is provided. The focus control, when fitted, is usually isolated from the rest at the back of the cabinet, and its adjustment is fairly obvious. The individual lines of the picture should be sharp and distinct.

If it is found that the picture is not equally sharp over its whole area, it is usually advisable to arrange for maximum sharpness to be at the centre of the raster. Modern receivers do not use a focus magnet, and they have no external focus adjustment at all. This applies to all receivers that use electrostatically focused tubes.

Naturally, the lines of the raster must be horizontal, and this will normally be found to be the case unless movement of the deflector coil assembly has occurred since the set left the works. If, however, the lines are off horizontal, resulting in a tilted picture, it will be necessary to rotate the deflector coil assembly one way or another until the picture is level. In most cases some sort of clamp will have to be loosened, and subsequently tightened up again, after performing this operation.

Another possibility, but one that does not normally occur unless the receiver has been badly handled in transit or otherwise disturbed, is that the picture may not be centred on the tube face. In receivers that use magnetically focused tubes, centring is often performed by adjusting the plane of the focusing coil or magnet relative to the axis of the tube. The focusing unit is usually arranged on an adjustable mounting for this purpose.

Almost all modern receivers, and many older ones, are provided with magnetized plates or rings which are fitted very close to the deflector coils, and rotation of these rings shifts the picture about. In some receivers a D.C. current is passed through the deflector coils and its density is varied to move the picture in either direction. This method is called electrical "shift", and the control knobs are usually referred to as vertical and horizontal " shift " controls.

Having levelled and centralized the picture, there is now the possibility that it is too large or too small for the aperture in the tube mask, or that its proportions are not correct. Adjustment for these faults is made by two further controls, usually labelled " picture width " and " picture height " respectively. By adjusting one or both of these, it is possible to get the size and proportions of the picture correct. The size should be such that the " dotted " border of the test pattern is just visible at the edges of the mask; the proportions are correct when the ring at the centre of the test pattern is truly circular. Incorrect proportions will change this circle into an ellipse.

One other fault may appear in the picture, and that is lack of linearity, resulting in either a spreading out or a closing up of the picture in a horizontal direction (in the case of line linearity) or in a vertical direction (in the case of frame linearity) in one part of the picture. A subsidiary control, usually marked " line linearity", or "frame linearity", is provided for adjustment, which is best carried out using the test pattern border as a guide. The black " dots " should be of equal size and spacing from one side of the picture to the other.

It will be found with some receivers, on carrying out the various adjustments described above, that to some extent they are interdependent. For instance, adjustment of the picture height and width may disturb the synchronization; adjustment of the line linearity control may necessitate a further adjustment in picture width, and so on.

Since the subsidiary controls are often at the rear of the cabinet, and it is necessary to see the picture when making adjustments, a mirror is a very useful accessory to have available.

If it seems impossible to reduce the picture strength sufficiently, even with the " contrast " control at its minimum position, the signal strength is obviously too great, and the R.F. gain control, if provided, should be reduced. If this is not adequate, or is not provided, the signal input will have to be cut down by means of an attenuator (*see* Appendix II).

With the signal input correctly adjusted it should be possible, by the aid of the " contrast " and " brightness " controls, to secure a picture of acceptable quality. Some changes in the settings of these two controls will be necessary if the level of general lighting in the room changes. Light should never be allowed to fall directly on the face of the tube, otherwise the picture quality will be poor.

On pages ix–xvi are reproductions of actual photographs showing the effects of maladjustments of the television receiver controls. These should be studied in conjunction with the instructions given in previous pages of this chapter.

Having got the receiver controls correctly adjusted to give a steady, properly focused and levelled picture, the final adjustment, and one that might frequently require attention, especially upon changing from one programme to another, is that of the fine tuner, which we have so far adjusted only for maximum sound. Maximum sound may be a good enough setting for it, but at its correct setting the resolution of the detail in the picture, and not necessarily the brightness, will be at a maximum. The only way to check this with accuracy is to do it while Test Card C is being transmitted, and then study the effect of the tuning control, bearing in mind the instructions in section 2 of Appendix I, which will be found on page 180. The brightness and contrast controls should be adjusted after reading section 7 of Appendix I.

Appendix I

TELEVISION TEST CARD "C"

THE TELEVISION TEST CARD "C", which is radiated by the B.B.C. and I.T.A. services daily during the morning trade period, can be of great value in the setting up of a television receiver, and also in obtaining useful information on its visual performance. A photograph of the test card is reproduced on page xvi.

The card was introduced as a result of close liaison between the British Broadcasting Corporation and the British Radio Equipment Manufacturers' Association. This happened before the introduction of an alternative programme, but the I.T.A. transmitters also radiate the test card.

It was designed jointly by the two organizations to overcome the limitations of the original test card "A" from the point of view of those concerned with the design, development and maintenance of television receivers. The following explanatory notes will permit the maximum benefit to be obtained from the card:

1—GENERAL

The pattern approximates in mean signal to that of the average picture. The general background of the whole pattern is made mean grey to enable both positive and negative high frequency overswing, and similar effects, to be observed at the correct setting of the brightness level and in the form in which they are usually most noticeable on picture transmissions.

Areas of mean grey background are left between all sections of the test pattern to enable "following" effects to be observed and to avoid, as far as possible, interference between different tests.

The main frequency and contrast range tests are confined to the area of the pattern within the central circle where the focus quality should be a maximum. Subsidiary focus tests are provided in the corners of the pattern.

An outer border of black and white sections similar to that on the tuning signal pattern forms the edges.

The individual test sections and their uses are dealt with in more detail below.

2—HIGH-FREQUENCY RESPONSE

The two frequency test patterns within the centre circle consist of five frequency gratings corresponding to fundamental frequencies of 1·0, 1·5, 2·0, 2·5 and 3·0 Mc/s. They are arranged vertically for ease of intercomparison and are provided with white reference areas at the top and bottom to aid in assessing the reproduced level of modulation in the grating. The two patterns are reversed vertically relative to each other to reduce effects of non-conformity of cathode-ray tube focus and effects arising from other parts of the whole test pattern.

In use in receiver checking, referring to the left-hand pattern, the top three frequencies, 1·0, 1·5, 2·0 Mc/s, should certainly be resolved, and, in the later designs of receiver, the 2·5 Mc/s pattern also, although with reduced intensity of modulation. It is unlikely that significant resolution of the last pattern will normally be obtained.

3—FOCUS UNIFORMITY

Additional diagonal frequency gratings are provided in the corners of the pattern and extend over that part of the picture area where focus variation is most significant. The equivalent horizontal definition of these gratings corresponds to a fundamental frequency of about 1 Mc/s and should be well within the response of the amplifier circuits. The variation of cathode-ray tube focus over the picture area can, however, still be judged by observation of the sharpness of the lines of the gratings.

4—LINEARITY OF SCAN

The majority of the pattern is covered by a white square grid on the grey background. This provides a means of judging scan linearity over the major part of the picture area for both directions of scan. In addition, a more critical test of linearity over the central area is provided by a central circle.

For perfect linearity of scan the circle would be accurately circular and all the grid meshes square and equal in size. A close approximation to this can usually be obtained with present receivers (see also section 5 below).

5—PICTURE ASPECT RATIO

The pattern is surrounded by a border of alternate black and white sections, the length of each section being half that of the mesh of the linearity grid. The outer edges of this border represent the boundaries of the transmitted picture, and therefore now have an aspect ratio of 4 to 3. Under correct scan amplitude adjustment these outer edges should just fill the receiver mask. In practice it may be found that it is not possible to fulfil this condition exactly with optimum linearity in the centre of the picture, as judged by the circle. In this case it is probably preferable slightly to overscan in either the horizontal or the vertical direction in order to maintain central linearity.

In the case of receivers sold before April, 1950, the tube mask will have been made suitable for the original aspect ratio of 5 to 4. When such receivers are correctly adjusted according to the new 4 to 3 aspect ratio, a small gap will be present at the top and bottom of the picture, provided the border just comes within the sides of the mask. These gaps are quite normal. Receivers issued since April, 1950, will, of course, have masks suitable for the 4 to 3 aspect ratio, within the limits imposed on them by the shape of the modern rectangular tube.

6—SYNCHRONIZING SIGNAL SEPARATION

The black and white border sections on the right-hand side of the picture, immediately preceding the line synchronizing impulses, afford a critical test of separation of synchronizing impulses from picture signal.

Incorrect adjustment of the synchronizing separator or limitation of frequency response in the vision channel will tend to cause horizontal displacement of parts of the picture information; for example, the contour of the circle, corresponding to the positions of the black and white sections down the height of the pattern.

7—CONTRAST RANGE

The central contrast wedge provides five tone values varying between full white at the top and black at the bottom. It is not possible to specify the brightness of the intermediate tones exactly, but with satisfactory receiver operation they should all be reproduced as definite steps in brightness.

For satisfactory receiver operation the brightness and contrast controls should be adjusted so that the scan is just not visible on the black square, while the white square represents the maximum brightness available from the tube at satisfactory focus quality.

If one of the intermediate tones is missing, or the grading appears unequal, it will, in general, be necessary to reduce the contrast, and reset the brightness to give the correct black level.

8—PULSE RESPONSE AND SPURIOUS ECHOES

Two vertical bars, one white and the other black, of about 0·25 microsecond width, are provided on either side of the central circle. These provide in effect a pulse test of the whole system and enable the response to isolated detail approaching the maximum resolution of the system to be judged.

In addition, these bars provide a means of checking the presence of spurious reflection signals such as those arriving at the aerial by multipath transmission.

9—LOW-FREQUENCY RESPONSE

Amplitude and phase distortion at the low-frequency end of the video spectrum give rise to background shading over the picture area in the form of horizontal streaking effects. Such effects, however, are infrequent as a form of receiver distortion and could only occur where one or more stages of video amplification with unsuitable L.F. time constants are employed; such effects may also be caused by faulty D.C. restoration. The fault is, however, more likely to occur at the transmitter, due to the difficulty of maintaining accurately a perfect L.F. response of the transmission system.

An adequate test for practical purposes is provided by the black bar on a white ground above the central circle, and in addition, the black and white areas on either side of the central circle.

10—MISCELLANEOUS POINTS

The grid pattern has been made to correspond to a full white signal in order to provide an additional check on the variation of focus quality over the picture area at maximum cathode-ray tube modulation. For this purpose, the lines of the grid have been made as narrow as permissible without appreciable introduction of the interference effects on horizontal lines, inherent in the line scanning process.

It will be realized from the above description of the features of the "C" test card that its use enables a very good idea of the performance of a receiver to be obtained merely by inspection of the reproduction of the card on the screen. Since the card is transmitted intermittently each morning, ample time is available to make adjustments to a receiver and to note their results. The ordinary tuning signal, transmitted for five minutes before each programme, is obviously not so useful in this respect, and is only intended to give time for setting up a receiver by means of its normal controls.

Appendix II

FIXED ATTENUATORS

A FIXED ATTENUATOR CAN be made very simply from three resistors, as indicated in Fig. 88, which shows the well-known T-type attenuator arrangement. The two series resistors,

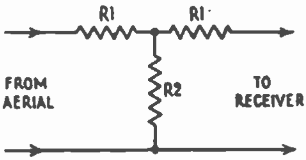


Fig. 90—A simple T-type attenuator for reducing signal input

R1, are of equal value, but R2, the shunt resistor, is different, its value being lower than that of R1.

If we assume that the impedance of the feeder and of the aerial input circuit to the receiver is 80 ohms, and if N represents the attenuation factor required, then—

$$R1 = 80\left(\frac{N-1}{N+1}\right)$$

$$R2 = 80\left(\frac{2N}{(N+1)(N-1)}\right)$$

Suppose we wish to cut the signal input down 20 times, then N = 20, so that—

$$R1 = 80\left(\frac{19}{21}\right) = 72 \text{ ohms approx.}$$

$$R2 = 80\left(\frac{40}{21 \times 19}\right) = 80\left(\frac{40}{399}\right) = 8 \text{ ohms approx.}$$

There is, of course, no need to employ resistors of extreme accuracy, but they should be non-inductive types.

ABBREVIATIONS

A.C.	Alternating current
A.C./D.C.	Alternating or direct current
A.F.	Audio frequency
A.F.C.	Automatic frequency control
A.G.C.	Automatic gain control
C.R.T.	Cathode-ray tube
c/s	Cycles per second
D.C.	Direct current
I.F.	Intermediate frequency
kV	Kilovolt (thousand volts)
L.F.	Low frequency
Mc/s	Megacycles per second
Megohm	Million ohms
pF	Picofarad
R.F.	Radio frequency
V	Volt
V.F.	Video frequency
μF	Microfarad
μs	Microseconds
V.H.F.	Very high frequency
F.M.	Frequency modulation
A.M.	Amplitude modulation
M.W.	Medium wave band
L.W.	Long wave band

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