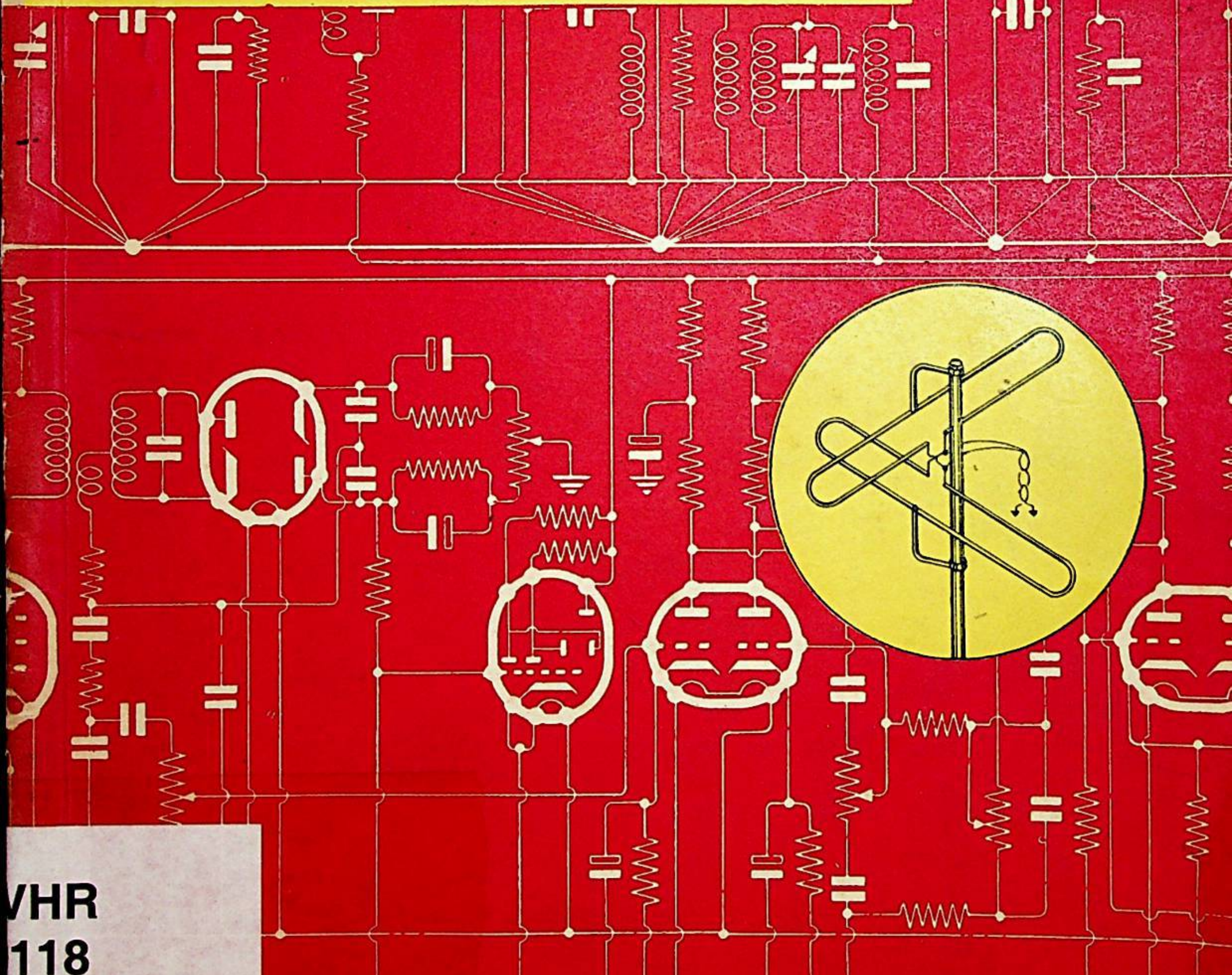
PRACTICAL F.M. CIRCUITS FOR THE HOME CONSTRUCTOR

By R. Deschepper.

AM & FM CIRCUITS



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FOR THE HOME CONSTRUCTOR

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R. Deschepper

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THE FREQUENCY MODULATION ERA

From its infancy Broadcasting has been considered to fulfill the primary function of conveying to very large audiences the sounds produced in front of the microphone or held in store in the form of recordings. In the early days, the possibility of picking up distant stations appealed strongly to the first amateurs. Long distance records used to be claimed on all sides, and the "last word" in 1925 was to "receive America." Although in this way sensitivity came into the foreground among the principal qualities demanded from a receiver, the density of the traffic through the ether soon brought up the critical problems of selectivity.

However, up to 1930, radio remained the privilege of a small group of enthusiasts, since the installation, maintenance and control of a receiver layout (comprising, besides the receiver itself, a frame aerial, a loud speaker, a filament battery together with its charger, and an H.T. battery eventually to be replaced by a "battery eliminator") necessitated a certain amount of technical knowledge and more than a little patience.

With the advent of "ganged tuning" and, above all mains operation, radio starts its astounding career. Its technical aspects and its "miraculous" nature cease to engage the listener. For him, the radio set is primarily a box producing music. And this music has to be good, that is, to differ as little as possible from the sounds captured directly by the microphone. From then on the drama of high fidelity begins to unfold.

Recourse is made to all kinds of artifices, and so it becomes impossible to transmit music without distorting it. This arises, as much from the intrinsic properties of the mode of transmission, as from the limitations imposed by virtue of the excessive number of transmitters. The maximum frequency separation between two transmitters of adjacent wavelength is 9000 cycles per second. Under these conditions the frequency spectrum transmitted must be limited to 4500 c/s. In this way a large proportion of the harmonics indispensable to faithful reproduction of musical notes and transitory sounds is lost.

On the other hand, with the system of amplitude modulation, the range of relative sound intensity must be compressed to avoid drowning the "pianissimo" passages in the background noise.

Finally, atmospherics and interference, being of the same nature as amplitude-modulated waves, make themselves evident as irritating noises which nothing will eliminate.

In order to transmit music while retaining intact its entire range of frequencies and its quality, without, in addition, polluting it with unwanted noises, it has been necessary to give up the advantage of long-distance transmission and to have recourse to the domain of metre waves where, in practice, nothing limits the width of modulation bands. For example, at wavelengths between 1 and 2 metres, we have available a bandwidth of 150,000,000 c/s. let us say space sufficient for more than 16,000 narrow-band transmitters.

In this band then, frequencies may be allocated to substantial numbers of wide-band transmitters. This is all the easier when the same frequencies may be used by stations well separated from each other, in view of the limited range of metre waves.

Since the use of these waves serves to avoid painful limitation of the range of frequencies transmitted, it becomes possible (but not without difficulty) to cover the necessary "dynamic range" (range of intensity) without even giving up the amplitude-modulation principle. By adopting frequency modulation, a further benefit is derived because it then becomes possible to eliminate response to interference.

A frequency-modulation detector produces no output from noise and other forms of amplitude modulation. Interference cannot reach the loudspeaker to spoil the realism of the programme.

Certainly these remarkable advantages possessed by frequency modulation have to be paid for dearly; it is necessary, in order to derive benefit from them, to set up a suitable receiver which is generally more complex than those used for amplitude modulation. In addition, when account is taken of the limited range of transmitters, it becomes necessary to establish a closely-linked network in order to cover the entire territory of a country with adequate zones of reception.

Such networks are in course of installation in various countries, including Great Britain and Northern Ireland, where they will exist side by side with the present long-distance transmitters operating on wavelengths between 10 and 2000 metres. Furthermore, in certain systems of television, the sound accompanying the vision is emitted as frequency modulation.

This means that the time has come for all radio technicians to make themselves familiar with this new system of modulation. In order to make good the absence of practical books devoted to this subject, we have asked our friend R. Deschepper to write one. No one could, indeed, be better qualified than he to undertake this task and to have every expectation of success. Over a long period, in his laboratory at Brussels, he has developed numbers of constructional prototypes which have been carefully designed and have achieved remarkable performances. A selection of these tested designs, which have already been proved by exhaustive trials, will be found by the reader in this book.

But, before tackling these designs, the reader will be able to study, without difficulty, the indispensable theoretical groundwork which R. Deschepper presents clearly ,concisely and in a manner which characterises the essential qualities of all the works of this well-known author.

We wish to thank him for the trouble which he has taken to place at our disposal, a reliable and pleasing guide book which explains clearly and in simple terms, the mysteries of frequency modulation.

E. AISBERG.

PREFACE

The alarming overcrowding of the frequency bands allocated to broadcasting, on long wavelengths as well as on medium and short wavelengths, has led to the adoption of the range 87.5-100 Mc/s (metres waves). As has been happening in the United States since before the war, the various European broadcasting organisations are establishing chains of V.H.F. transmitting stations, which are intended to supplement the service given by existing high-power transmitters, by providing high-quality transmission over a relatively restricted area. Too much importance need not, however, be attached to these last words, for, in favourable conditions, metre waves are able to carry more than 200 miles.

Frequency modulation has generally been adopted for these transmissions in preference to the classical system of amplitude modulation, because of the great advantages which it confers. It is, however, only available on very short wavelengths because of the bandwidth required for its transmission.

The employment of frequency-modulated metre waves has brought to birth a new technique in the construction of radio receivers, which is of a somewhat disturbing nature for technicians and constructors used to classical methods.

It is for their sake, as well as for that of the many high-fidelity enthusiasts, that this introduction to the new field in radio has been written.

The first part of the book is devoted to a description and theoretical explanation of the operation of the special circuits required for the reception of frequency-modulated V.H.F. The basic principles outlined in it will be readily understood.

In the second part, the practical sphere of activity is covered by the description of various F.M. adaptors and AM/FM receivers. At the end, an appendix gives practical winding details for the construction of the coils.

We hope that this book will be of service to all professional engineers who have not yet had the opportunity to become familiar with frequency modulation. It may also assist them in television, since metre wave receiver construction uses the same methods and requires the same precautions as a television receiver, because the same family of frequencies is involved.

The Author wishes to thank the following firms : **Philips, Telefunken, Alvar, Supersonic, Visodion** and **Optalix,** who have been kind enough to place their comprehensive technical literature at his disposal.

R. D.

Preface

to the

BRITISH EDITION

For a considerable period, the future of Frequency Modulated transmission in the United Kingdom appeared uncertain, with the result that little of a practical nature has been done to acquaint the constructor with the unique possibilities of this system. Now that the superiority of Frequency Modulation (F.M.) over Amplitude Modulation (A.M.) has been acknowledged, and a concrete programme laid down for covering Great Britain and Northern Ireland with a chain of transmitters working on this principle, the time has come to familiarise the constructor with the particular requirements of this system. Both in Europe and in the U.S.A. frequency modulated transmissions have been in use for some years, thus providing them with considerable and invaluable experience and an undeniable lead in this field.

Bernards (Publishers) Ltd. have approached this problem realistically and by arrangement with Société des Editions Radio are publishing this very excellent and completely practical guide to Frequency Modulation by R. Deschepper. Written by one of Europe's foremost technicians in easily understood terms, this book places the accumulated knowledge and experience of some years at the disposal of readers and constructors in the U.K.

The Publishers particularly wish to thank Dr. G. Mole for his invaluable work in translating this book from the original French.

W.J.M.

London, Jan., 1955.

CONTENTS

PART I—BASIC THEORY

DEFINITIONS.

Modulation is the process whereby the intelligence to be transmitted is impressed upon the carrier signal. This always takes the form of a periodic variation of the carrier.

In amplitude modulation, designated by the initials A.M., the *magnitude* of the carrier is varied. In frequency modulation, or F.M., the *frequency* is varied.

Broadcasting imposes an especially difficult task on modulation in requiring it to follow faithfully all the characteristics of the modulating signal. Now, the latter may be extremely complex, for it often includes steep-fronted impulses or *transients*. These transients or *transitory sounds* are indispensable if the system is to reproduce the full richness of the original sound.

Moreover, in order that the reproduction may be a faithful replica of the sound captured in the studio, it is essential that it should be capable of following all its changes in amplitude, in other words, that it reproduces the original waveform.

Finally, reception must be as free as possible from atmospheric and man-made interference.

ADVANTAGES AND DISADVANTAGES.

Amplitude modulation responds very imperfectly to these requirements. In regard to the latter point, it should be remembered that interference consists of impulses which act on the amplitude of the carrier. Being of the same nature, they mix with it and can never again be separated. The detector incorporates them irretrievably in the audio output.

Reproduction of transients involves reproduction of the very high frequencies of which they are composed and which may extend to 20,000 c/s.

It is known that modulation introduces on either side of the carrier wave, new frequencies which correspond to the fundamental frequency plus and minus the modulation frequency. In order to transmit 20,000 c/s it would be necessary then to have a channel 40,000 c/s wide. Now, in the ordinary broadcast bands, the bandwidth allocated to each station is 9,000 c/s (9 kc/s). In fact, to a large extent, the stations overlap their allotted bands, but without thereby attaining the conditions essential for high fidelity. Furthermore, only listeners located close to the transmitter can profit from this; for other listeners the overlapping of the sidebands makes itself felt as unpleasant interference.

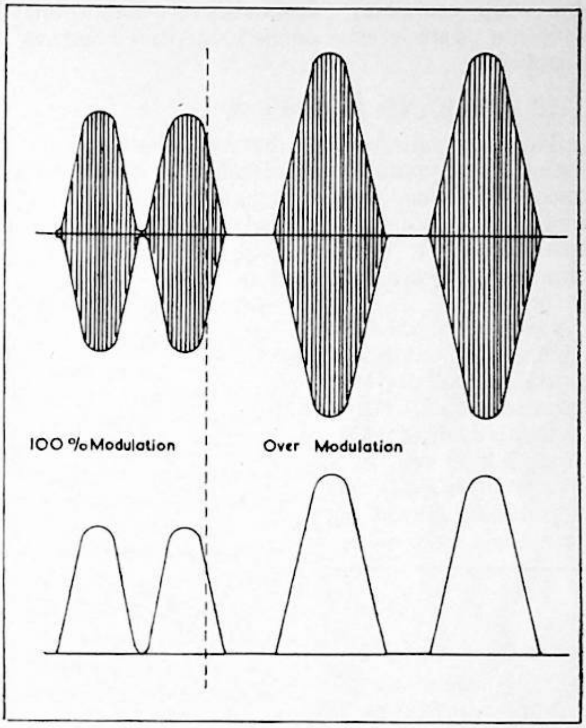


Fig. 1. On A.M., overmodulation produces intolerable distortion of the envelope.

It is evident, moreover, that the maximum possible depth of modulation is attained when the carrier level falls to zero, that is for 100 per cent. modulation, beyond which the transmitted signal loses its shape completely (see Fig. 1).

Now, the ratio between the maximum sound intensity of an orchestra and the " pianissimo " passages is of the order of 10,000 : 1 (40 db). In the course of a simple conversation, the sound fluctuation may be only 10 db. If 100 per cent. modulation were to be made to correspond to the maximum level (which is rarely attained) the mean level would become so weak that it would be lost in the background noise of the receiver and drowned by the least interference. It is thus impossible to avoid compressing the dynamic range of the sound before transmitting it.

In frequency modulation, the carrier wave retains a *constant amplitude*, but its frequency is made to vary on either side about its nominal value. It is the extent of this variation which now represents the percentage modulation. We see immediately that the limit imposed on amplitude modulation no longer exists for, theoretically, the frequency deviation may be as large as desired. It is possible, then, to follow faithfully the wave-form of the transmission.

A receiver for frequency modulated transmissions is designed to detect only frequency variation while remaining uninfluenced by amplitude variation. Interference of all kinds thus becomes inaudible.

THE SIDEBAND PROBLEM.

The reconstitution of the modulating signal without loss requires the reception of all the frequencies included in the sidebands and the retention of their correct amplitude relationship. We have seen that, for amplitude modulation, this requires a pass band equal to twice the highest frequency.

Frequency modulation produces sidebands which extend beyond the deviation corresponding to the modulation frequency and contain many more frequencies than for A.M. It may be shown mathematically that there is an infinite number of these, but in practice consideration need only be given to those adjacent to the carrier, since their amplitude falls off rapidly as the displacement from the carrier increases (Fig. 2).

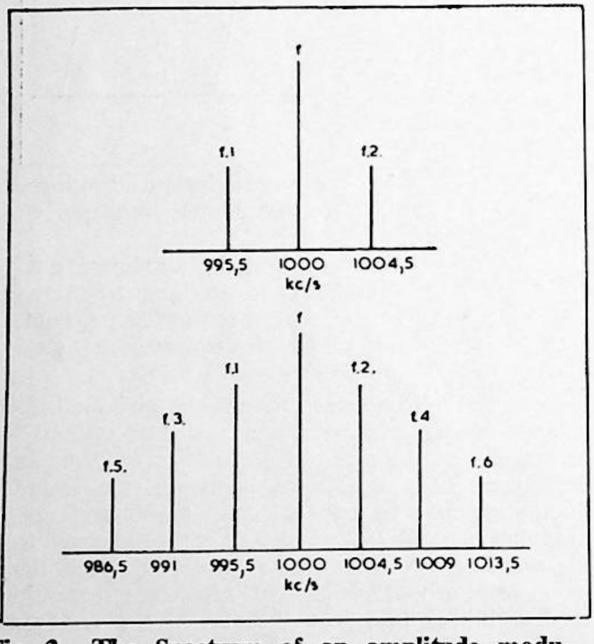


Fig. 2. The Spectrum of an amplitude modulated carrier (above), compared with its F.M. counterpart. In both cases the modulation is by an audio frequency of 4,500 c/s.

Nevertheless, the effective bandwidth is substantially greater for F.M. than for A.M. and becomes greater still as the depth of modulation increases.

Compared with amplitude modulation, this constitutes a disadvantage which excludes all possibility of using frequency modulation in the ordinary broadcast wavebands. It follows that in the medium waveband (520-1620 kc/s) a single F.M. transmitter would occupy more than a quarter of the available space.

By contrast, in the metre waveband (87.5-100 Mc/s), which is more than ten times as wide, nothing prevents the employment of this system which is indisputably superior to amplitude modulation on all other counts.

IMPROVED SELECTIVITY.

Selectivity remains to be considered. Beating between the carriers of two neighbouring stations takes the same form as amplitude modulation and, like it, is detected by an ordinary receiver and becomes inseparable from the A.F. signal. In an F.M. receiver, on the contrary, this interference may be practically eliminated. It has so far been assumed that the interfering transmission is unmodulated. If this is not the case, the situation becomes complicated by the presence of sidebands. It has been estimated that, in order to be insignificant, interference must produce an A.F. response one hundred times lower than that of the wanted signal. This demands, for an A.M. transmitter modulated to a depth of 30 per cent., a ratio of 300 : 1 between the levels of the two signals at the input to the receiver.

Any kind of interference produces, not only an effect on the amplitude of the signal, but also a certain degree of phase shift which is equivalent to a light frequency modulation. An F.M. receiver will eliminate amplitude interference but will remain sensitive towards fluctuations in frequency.

Other conditions being equal, these are always much less troublesome than for A.M., and it is considered that an adequate ratio between the wanted signal and the interfering signal at the receiver input would be approximately 25 : 1, as against the 300 : 1 required in the case of amplitude modulation.

It follows from this fact that frequency modulation ensures excellent reception at a given range while demanding only 25 per cent. of the transmitted power required by A.M.

F.M. RECEIVER CHARACTERISTICS.

Whatever the system of modulation used, the peculiarities of metre wave reception demand a departure from the traditional designs used in ordinary radio.

The *noise* caused by the emission of electrons in valves and by thermal agitation of electrons in conductors is generally inaudible on the long and medium wavebands. It is even unnoticed on short waves in carefully-constructed receivers. But it becomes progressively more difficult to eliminate as the frequency of the signal is increased. The greater part of the noise is that contributed by the valves. The choice of these for use in the VHF amplifier and frequency-changer stages must therefore take into account their equivalent noise resistance, which will be quoted by the manufacturer in the case of types suitable for very high frequencies.

Valve noise is generally more pronounced in multi-electrode valves, and this is why triodes have returned to favour for the reception of F.M. transmissions as well as for television.

A second important consideration is the necessity to avoid, as far as possible, *radiation* of local oscillator signal from the aerial. This is liable to cause considerable annoyance to nearby listeners and, moreover, to upset future television reception over a considerable area, since the second harmonic falls in band III of the wavebands reserved for television.

Very severe legislation has been brought into force to deal with this in certain European countries.

This fact indicates the need to make provision for a V.H.F. buffer stage to precede the frequency changer. The buffering action counts here more than the gain which will always be relatively low.

The *frequency-changing* process requires a certain amount of comment. The triode-hexode (or heptode) mixers used in broadcasting are ill-adapted to V.H.F. frequencies because of their high noise level, their low conversion conductance and their high inter-electrode capacitance which allows oscillator voltage to enter the input circuit. It is for this reason that use is often made of an additive type of frequency changer employing either a triode or a pentode.

The intermediate-frequency stages of F.M. receivers remain of traditional design, but nevertheless have certain special features: the almost universally accepted frequency is 10.7 Mc/s. A frequency as high as this is necessary in order to throw the image frequency outside the 87.5-100 Mc/s band and also to achieve the required acceptance bandwidth without complication. Since the stage gain is reduced because of this, it is necessary on the one hand to have at least two I.F. stages, and on the other hand to use high-slope valves in this section of the receiver.

It is in the detector stage that the most striking distinction between the two kinds of receiver is to be found. The principle of the various available systems consists in *transforming a variation in frequency into a variation in amplitude,* which may then be detected in the traditional manner. It is indispensable also that the system as a whole should be as insensitive as possible to amplitude variation of the incoming signal.

The A.F. stages are no different from those normally used in A.M. receivers, apart from the fact that, in order to take full advantage of the benefits of frequency modulation, they must be particularly well designed. The tone control of the "suffocation" type, which is still too often found in current receivers and which only serves to mask interference, could never be justified here, since interference is practically non-existent.

Such is the general outline of the F.M. receiver.

F.M. TRANSMISSION STANDARDS.

The frequency band allocated to frequency-modulation broadcasting in Europe extends from 79.5 Mc/s to 100 Mc/s and the bandwidth allotted to each transmitter is 200 kc/s. The maximum amplitude of modulation (which may be termed a modulation depth of 100 per cent. by analogy with A.M.) corresponds to a frequency deviation of 75 kc/s on either side of the fundamental. The remainder of the allotted channel serves to accommodate the sidebands and constitutes a margin of safety in the event of overmodulation.

In order to be in a better position to overcome background noise, the depth of modulation is increased towards the high frequency end of the spectrum, a process known as pre-emphasis. This has to be compensated on reception by means of an appropriate low-pass filter following the detector. The time constant of this network must be 50 microseconds in order to match the characteristics of the transmission.

Let us pass now to a rather more detailed study of the various sections of the receiver.

V.H.F. STAGES.

A choice of various circuit arrangements may be made in accordance with the need to achieve maximum gain, minimum noise level, or maximum protection against radiation of local oscillator voltage from the aerial.

A high-slope pentode yields the greatest gain and may be necessary in fringe areas. It contributes, however, a high noise voltage.

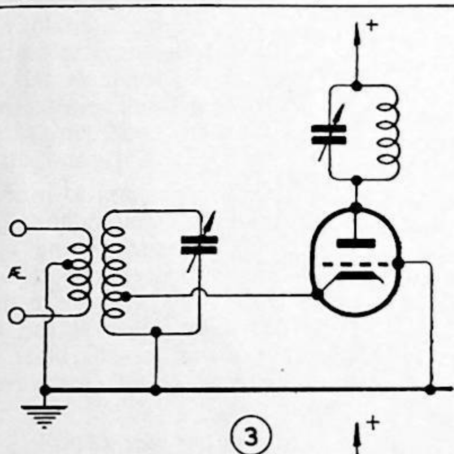
The Q factor of the grid circuit is not critical, because it is always damped by Miller effect as well as by the effect of self-inductance in the cathode and screen-grid leads. It is known that at very high frequencies the damping of the input circuit increases approximately as the square of the frequency. It must be added that at these frequencies the period of oscillation is of the same order of magnitude as the transit time of electrons between the various valve electrodes.

The resulting phase shift between the A.C. grid voltage and the space current has the effect of introducing an additional degree of damping into the circuit.

Finally the aerial is a third source of damping which must be considered.

When these facts are taken into account, it becomes possible to dispense with a variable tuning capacitor for the input circuit and simply to tune it on the centre of the band at about 94 Mc/s. By winding the tuning coil in such a way that the tuning capacitance is made up entirely from its own self-capacitance together with the input capacitance of the valve, it is possible to obtain a pass band of about 12 Mc/s.

If the receiver is provided with A.G.C. (automatic gain control) it is advisable to apply this to the V.H.F. valve rather than to an I.F. stage. In any case, because of the very high frequencies involved, the application of the A.G.C. control voltage will be accompanied by a certain amount of detuning, because it will change the dynamic input capacitance of the valve. This detuning will be particularly pronounced if the grid circuit is sharply tuned; but it will have no appreciable effect if the circuit is heavily damped as in the case considered.



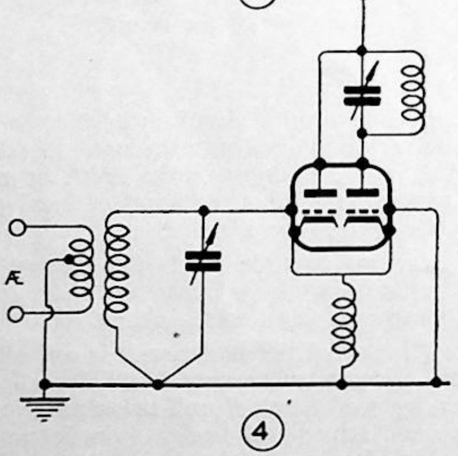


Fig. 3. V.H.F. triode amplifier. The grounded grid forms a very effective screen.

Fig. 4. V.H.F. cathode-coupled stage, a circuit which has a tendency to instability.

The necessity to reduce the noise level has led to the employment of triodes for V.H.F. amplification. By feeding the signal into the cathode, it is possible for the grid to be connected to earth and so to form a very efficient screen between anode and input. The inconvenience of this arrangement is its low input resistance, which is between 300 and 500 ohms, and which consequently introduces considerable damping into the aerial circuit. The difficulty is resolved by tapping the cathode down on the tuned circuit. The gain of such a stage, however, remains low (Fig. 3).

Another solution is to precede the valve by a second triode having the output on its cathode (" cathode follower "). The two cathodes may moreover be connected to a common coupling element (Fig. 4) which permits the use of double triodes with common cathodes (6J6, ECC91). In another arrangement, known under the name *cascode*, the two triodes are mounted in series (Fig. 5).

These arrangements yield an amplification equivalent to that provided by a pentode but with much lower noise level. The adjustment is, however, more critical.

Certain constructors still remain faithful to the pentode because triodes do not readily lend themselves to control by an A.G.C. voltage.

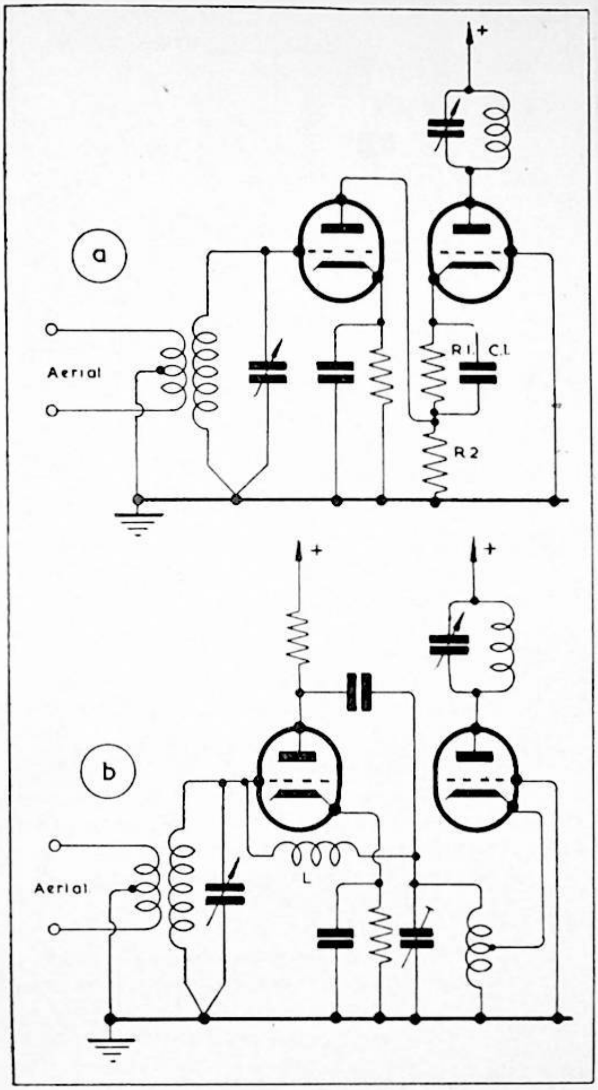
FREQUENCY CHANGERS.

The important consideration here is to obtain an adequate conversion conductance. That of conventional triode-hexode or heptode valves falls rapidly as the frequency rises, and at 100 Mc/s does not have more than a tenth of its normal value.

For this reason, frequency changers of the *multiplication* type, where the two signals are fed to separate grids following one another in the cathode-anode space, are being replaced more and more by *additive* circuit arrangements, where the two signals are fed to the same grid.

Besides its weak response to very high frequencies, the first system requires very careful adjustment of the oscillator voltage and always has a fairly high noise level. Finally, thermal frequency drift is more pronounced. Because of this last fault, it is necessary to readjust the oscillator tuning repeatedly during the first few minutes of operation.

Figures 6 and 7 show two modern additive circuit arrangements. The use of a separate oscilla-



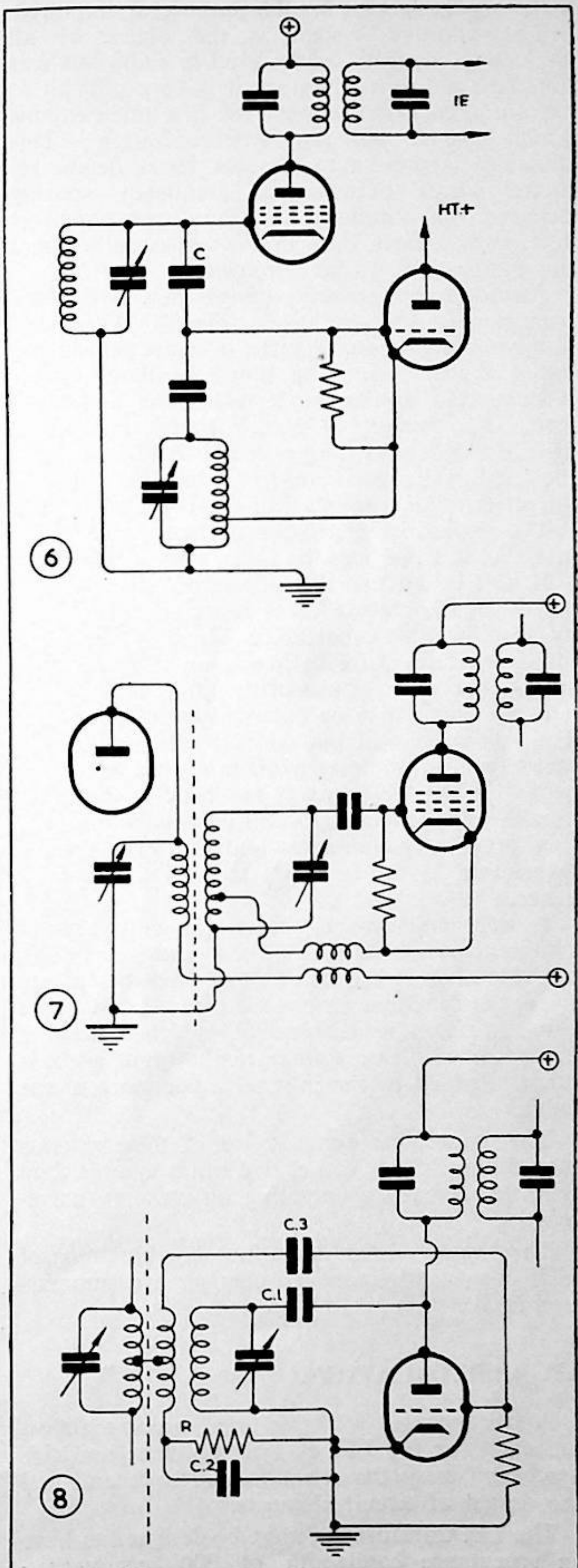


Fig. 5 (a). The traditional " Cascode " amplifier. Typical values being R1 150 Ω, R2 500k Ω, C1 2,200 pf. The heater/cathode potential on the second triode necessitates a specially designed valve.

(b). An alternative form of " Cascode " using a normal double triode. L is a neutralising coil which is not always required.

Fig. 6. Additive frequency changer with separate oscillator. C should have a capacitance of 1 to 3 pf.

Fig. 7. Additive frequency changer in which the signal is injected via the oscillator cathode.

Fig. 8. Single-triode frequency changer (Philips), which gives a high conversion conductance with minimum noise.

tor is recommended for the purpose of stability.

The additive system is the oldest of all frequency changer circuits used in radio. It was long ago discarded because it is very difficult to prevent intereaction between the two tuned circuits which tend to pull into synchronization. This difficulty is present to a much lesser degree on metre waves because the frequency spacing between the oscillator and the input circuit is 100 times greater than in the old circuits where this system used to be employed.

An additive frequency changer may be formed by means of a simple triode (Fig. 8). The tuned input circuit is connected to a centre tap on the untuned grid coil. The tuned oscillator circuit is connected to the anode which has a parallel feed. The primary of the I.F. transformer serves as a V.H.F. choke, and is tuned to 10.7 Mc/s by the combined capacitance of C1 together with the interelectrode capacitance of the valve.

The impedance of the tuned circuit is very low at 10.7 Mc/s and may be taken to be negligible.

It will be noticed that the grid circuit is connected to the chassis via a resistance R shunted by an adjustable capacitance C2. This combination constitutes with the input capacitance of the valve and the two halves of the grid coil, a bridge network which may be balanced by adjusting C2. The AC voltage at the tapping point is then no more than approximately 50 mV, thus rendering negligible the VHF energy fed back to the input circuit. The tendency to pull into synchronism is thus practically eliminated and the VHF voltage transferred to the aerial is reduced to insignificance.*

In this arrangement, the single valve serves simultaneously both as oscillator and as modulator. However it is generally preferred to separate these two functions by the use of a double triode (Fig. 9). The capacitance C, which serves to apply the oscillator voltage to the input grids, is often provided by the internal capacitance of the valve.

The conversion conductance of these circuits may attain 2.5mA/V, i.e. five times greater than for a triode-hexode operating on ordinary wavelengths.

The characteristics of various combinations of VHF stage and frequency changer are summarised in the table on the opposite page.

I.F. AMPLIFICATION.

A frequency of 10.7 Mc/s has become almost universal for the I.F. of FM receivers, and this agreement eases the selection of components and the design of circuit elements.

The I.F. transformers must be designed to have an acceptance bandwidth of 300 kc/s, with a

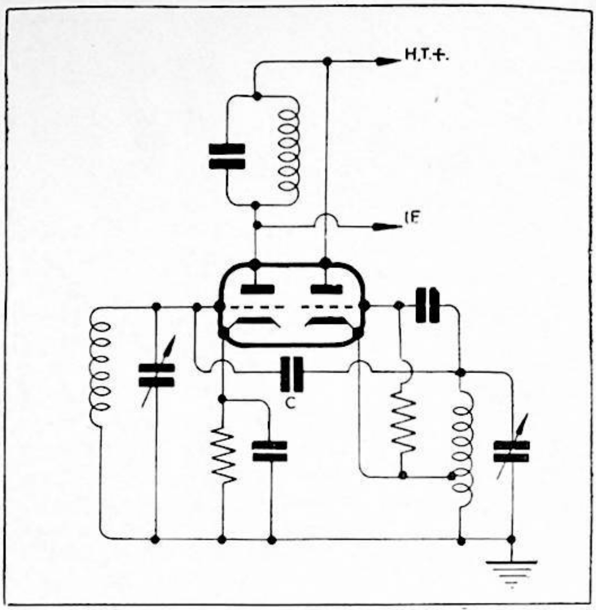


Fig. 9. A double triode being used as oscillator-modulator, this circuit is tending to become standard for F.M. receivers. The capacitance C is often provided by the interelectrode capacitances within the valve.

practically flat-topped response curve. This bandwidth is essential in order to accept, not only the maximum frequency excursions due directly to the modulation, but also an adequate proportion of the sidebands.

Such a response characteristic is achieved partly by overcoupling the circuits and partly by their internal damping. Some makers prefer initially to provide critical coupling and to widen the band by increasing the damping.

Experience has shown that the frequency of 10.7 Mc/s allows the desired response curve to be realised without difficulty, while providing a very satisfactory stage gain.

In addition, this frequency is located in a gap in the short-wave band which at the moment is free from powerful transmissions, thus eliminating the need for an I.F. rejector.

The tuning of the circuits is often effected largely by the internal capacitance of the valves to which must be added the self-capacitance of the coil and its leads. The capacitors proper, connected to the coil terminals, then have very low capacitances (10 to 15 pF). This arrangement allows a favourable L/C ratio to be achieved. It has however one disadvantage: as the capacitive reactance of the valve varies with the temperature of the cathode, exact tuning is obtained only several minutes after switching on the equipment. This is a minor defect which may be disconcerting to the uninitiated.

*Reproduced by courtesy of Messrs. Philips, Eindhoven.

V.H.F. STAGES

A COMPARISON OF THE VARIOUS COMBINATIONS WHICH MAY BE ENCOUNTERED

V.H.F. Amplifier	Frequency Changer Multiplying	Frequency Changer Additive	Overall Gain	Noise Voltage	Radiation
Pentode	Heptode	—	40	4 μV	15 to 30 mV
,,	—	Triode	170	2 μV	10 to 20 mV
,,	—	High-slope pentode	180	3 μV	10 to 20 mV
,,	—	Double triode	170	1.5μV	8 to 16 mV
Grounded-grid triode	—	Triode	150	0.6μV	4 to 6 mV
Double triode (cascode)	—	Double triode	160	1.2μV	2 to 4 mV
None	—	Triode	70	1.3μV	15 to 80 mV
,,	Heptode	—	5 — 10	6 μV	25 to 150 mV
Triode-heptode (heptode section)	—	Triode-heptode (triode section)	100	1.8μV	20 to 40 mV

For the same reason, the use of A.G.C. is not advised in this case. If it is desired to control the I.F. gain in this way, the I.F. transformers must be designed differently, with the tuning capacitors sufficiently large to swamp the external stray capacitances.

DETECTION.

The role of this section of the receiver is to convert the frequency variations into amplitude variations, which are then detected in the usual way.

It is necessary, moreover, for the system to be insensitive to any amplitude variations on the incoming signal.

There are many possible circuits which allow this objective to be achieved, but we shall consider only the three most popular.

(a) Discriminators.

Figure 10 shows the conventional circuit for this unit. Certain variations are available (Fig. 11) which do not greatly alter the performance.

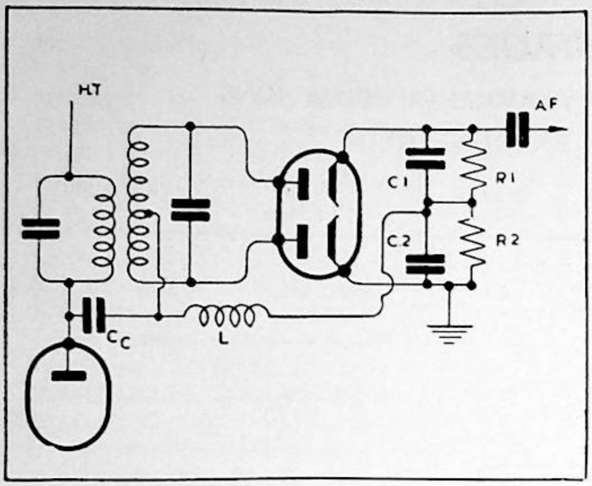


Fig. 10. The classical Foster-Seeley discriminator, yielding minimum distortion.

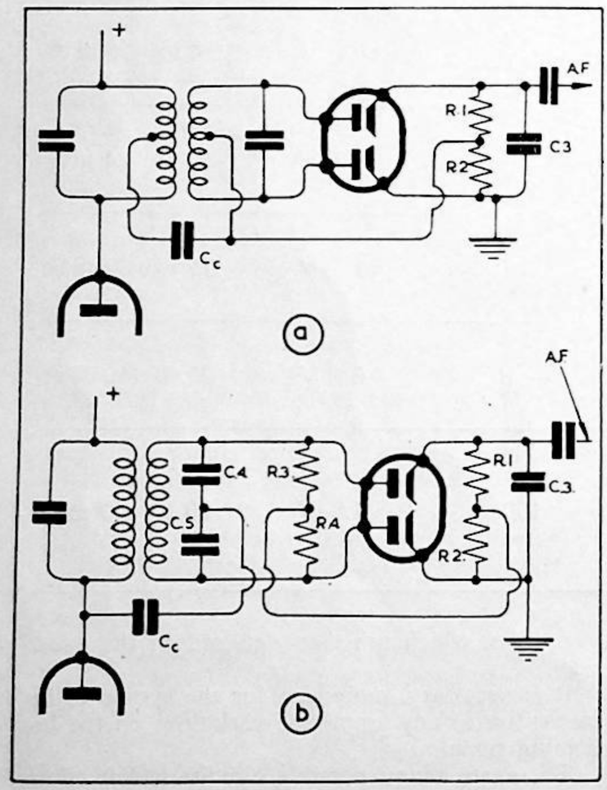


Fig. 11. Two other types of discriminator:—

(a) The V.H.F. choke is eliminated.
(b) In this circuit even the centre tap has been dispensed with.

The discriminator possesses the advantage of being perfectly symmetrical, and is the form of detector which gives least distortion. It is not, however, completely unresponsive to amplitude variation, and must be preceded by a *limiter* about which more will be said later.

The operation may be explained as follows: The I.F. voltage is applied to a pair of diodes by way of a circuit consisting of (i) the secondary of a transformer which provides two voltages which are 180° out of phase, and (ii) a capacitive coupling element (Cc) between the preceding anode and a centre tap on the secondary which thereby assumes a voltage 90° out of phase with the induced voltages in the winding.

The effect of this combination is that, when the frequency rises above or falls below the quiescent frequency (to which the I.F. circuits are tuned), the instantaneous voltage rises on one of the diodes while it falls on the other. In consequence, there is a difference between the rectified voltages from the two diodes, which produces an A.F. component, corresponding to the modulation, at the terminals of the load constituted by R_1 and R_2.

(b) Ratio Detectors.

On examining Figure 12, it will be seen that it differs from Figure 10 by the inversion of one of the diodes. These are now in series and acting in the same direction instead of being in opposition.

On the other hand, the load resistor is shunted by an electrolytic capacitor C_3 having high capacitance, in addition to the 220 pF capacitors (C_1 and C_2).

This capacitor is kept charged by the rectified current, since its discharge time-constant is determined by R_1+R_2 and is very long (approximately half a second).

The bias voltage developed across the capacitor C_3 cuts off the diodes and allows rectification only when the peaks of the input signal exceed this level. This voltage settles down to the mean level of the incoming signal.

So long as the frequency remains constant, the *ratio* between the voltages at the terminals of the capacitors C_1 and C_2 remains equal to unity.

When the frequency changes, the voltage will no longer remain the same at the two diodes, as in the case of the discriminator. The total voltage at the terminals of C_1+C_2 and R_1+R_2 will not change, but the ratio between the voltages at the terminals of C_1 and C_2 will deviate from unity, thus generating a voltage at the point of connection of these two capacitors, which will vary in step with the modulation.

Note that this point is at the same voltage as

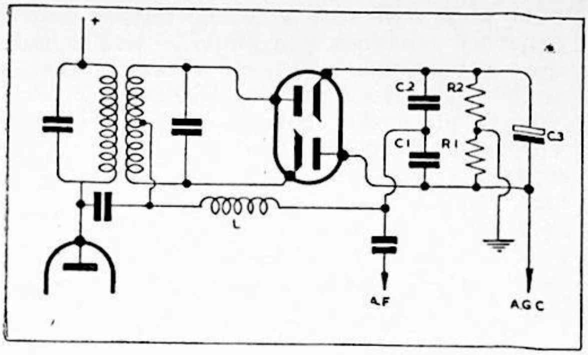


Fig. 12. The first type of Ratio Detector similar to the discriminator shown in Fig. 10.

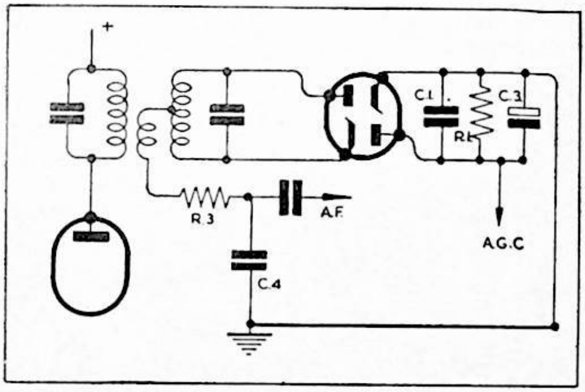


Fig. 13. Modern type Ratio Detector in which the coupling is entirely inductive,

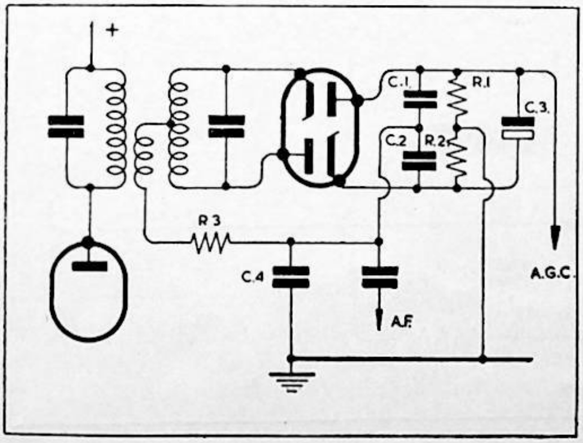


Fig. 14. A Ratio Detector which is balanced with respect to chassis.

the centre tap on the secondary since it is connected to it. But, as the voltage on the centre tap depends upon the ratio between the currents passing through the diodes, this connection may well be eliminated and the capacitors C_1, C_2 may be replaced by a single capacitor. The A.F. output is then taken from the centre tap.

Furthermore, the capacitor C_3 acts as a short circuit for amplitude changes of short duration such as those produced by interference.

Finally, as the voltage on the terminals of C_3 is proportional to the signal level, it may be utilised for A.G.C. The basic circuit of Figure 12 is rarely used. The circuit of Figure 13 is to be preferred, in which the centre point of the secondary is fed by a winding coupled inductively to the primary, instead of via a capacitor.

Another version is that of Figure 14 which possesses the advantage of being symmetrical with respect to the chassis, from the V.H.F. point of view.

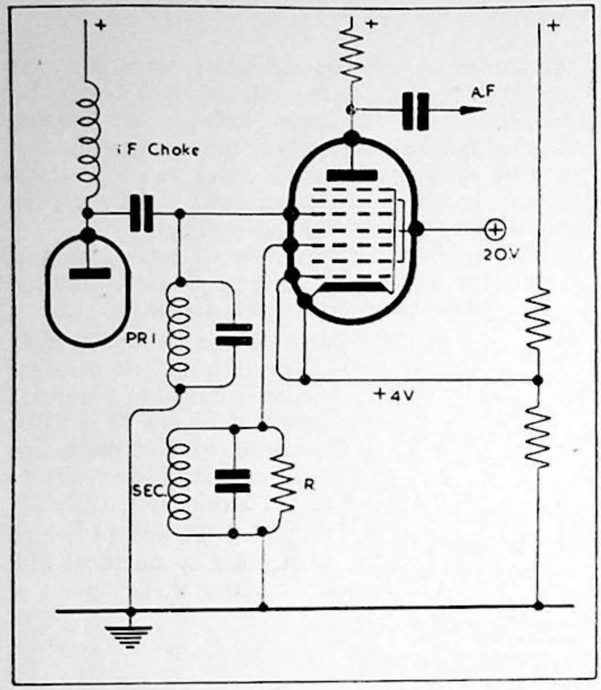
(c) The Phase Discriminator.

This system (Fig. 15) uses a special valve (*nonode*) having seven grids. Two of these are control grids. They act on the anode current in accordance with the phase relationship existing between the signals applied to them, without responding to the signal amplitudes. The first grid is maintained at *zero volts* with respect to the cathode; grids 2, 4 and 6 are the screens to which a voltage of +20v is applied. Grids 3 and 5 are the control electrodes, and the last is a suppressor grid.

A bias voltage of −4v with respect to the cathode is applied to the control grids. One of these is connected to the primary of the I.F. transformer and the other to the secondary. The primary is not situated in the anode circuit of the preceding valve but is shunt fed by means of a choke and capacitor.

When the signal frequency is the same as that to which the two circuits are tuned, the voltages applied to the two grids are out of phase by 90°. For every other frequency this phase shift changes and the anode current changes correspondingly. The secondary is shunted by a resistance which determines the overload factor of this circuit in relation to the Vg_3/Ia characteristic.

Successful operation of this circuit demands a signal voltage of 8 volts effective on the grids, therefore the gain of the preceding stages must be adequate for this purpose.



LIMITER CIRCUITS.

An ideal F.M. receiver would respond only to frequency variations, and would be totally insensitive to amplitude variations. A way of arriving at this state of affairs is to level the signal by clipping all peaks above a certain magnitude. This operation may be accomplished by the detector system itself. The ratio detector is, as we have seen, relatively insensitive towards amplitude modulation. The phase discriminator constitutes an absolute limiter, provided the signal voltage is sufficient.

The discriminator is never insensitive to amplitude changes and must always be preceded by a limiter. There exist many peak-clipping circuits, but in practice only the *saturated pentode* is used in F.M. receivers. This is a straight pentode with very low screen-grid and anode voltages (Fig. 16).

15 (Left). Phase discriminator. R is a damping resistor which is indispensable, and is required for adjusting the secondary overload factor to suit the valve characteristics.

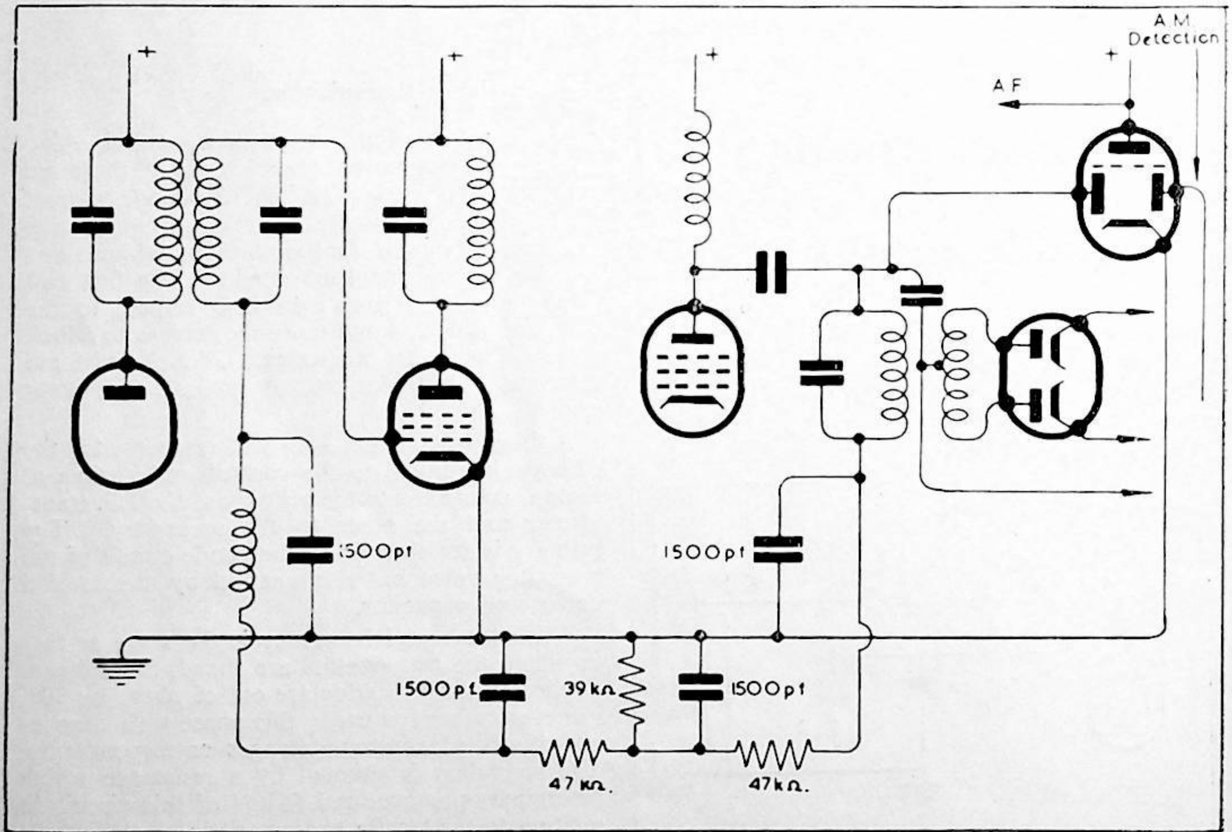


Fig. 17. Use of negative modulation feedback for limiting signal amplitude variation. The feedback is applied to the I.F. amplifier input.

The grid circuit includes a capacitor shunted by a resistor. The signal generates a considerable bias due to grid current, which has the effect of cutting off the anode current almost completely. Frequently two similar stages with resistance-capacitance coupling are used to intensify the effect.

Another method of removing amplitude variation is modulation feedback (Fig. 17) which consists in feeding back to the grid of the first I.F. valve the A.F. signal derived by detection of these variations. The phase of the feedback is adjusted to be in opposition to that of the amplitude variations on the incoming signal.

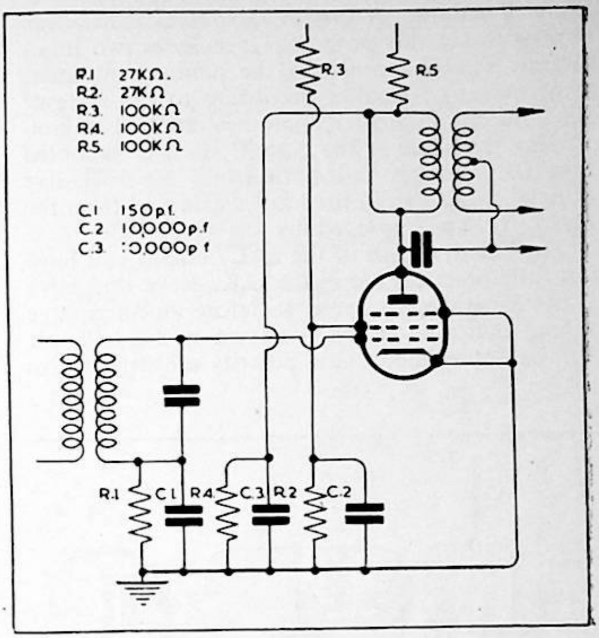
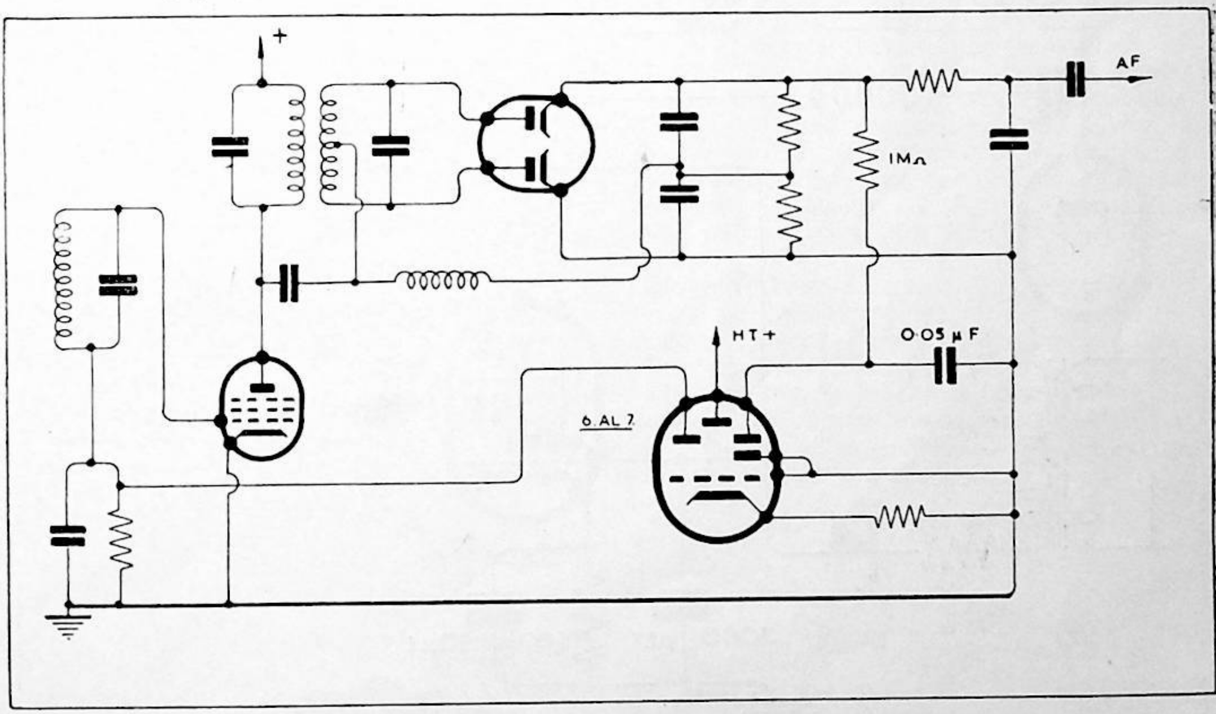


Fig. 16 (Right). Clipper circuit for levelling amplitude variation by means of an under-run pentode.

Fig. 18. How to connect an Indicator type 6AL7 in the discriminator circuit.



TUNING INDICATORS.

The tuning of an F.M. receiver must be reasonably exact in order to avoid distortion; and so the use of a cathode-ray tuning indicator, commonly referred to as a " Magic Eye " is recommended.

The ratio detector provides an A.G.C. voltage; hence it is a simple matter to use an existing type of indicator valve. It is not so easy for the discriminator. Strictly speaking, the negative voltage appearing on the grid of the limiter might be used, but the indications obtained in this way would be rather indefinite. A special valve (6AL7) has been developed for this purpose. It includes two luminescent screens on which the luminescent areas grow larger or smaller according to the state of the control. Figure 18 shows the method of connecting the valve in the circuit. It is to be noted that the valve is fed both from the negative voltage coming from the limiter grid and from the steady voltage provided by the detector.

The circuit details of the 6AL7 circuit will have but little practical use in the U.K., since this valve is not generally available, therefore an alternative tuning indicator circuit is shown in Fig. 19. It will be appreciated that a polarity sensitive device is necessary to indicate the D.C. output from the discriminator. In the circuit an EM34 in parallel with two selenium rectifiers is shown, the D.C. from the discriminator is applied to the grid of the valve. The rectifiers act as switches at 50c/s so that for half the time the voltage does not appear on the grid. Two patterns appear on the screen, one indicating zero input and one the D.C. output from the discriminator. When both are equal, that is, zero, the two patterns overlap with sharp edges and the receiver is in tune. Circuits originally arranged by the designer to use indicator type 6AL7 have been modified in this edition to use this alternative system.

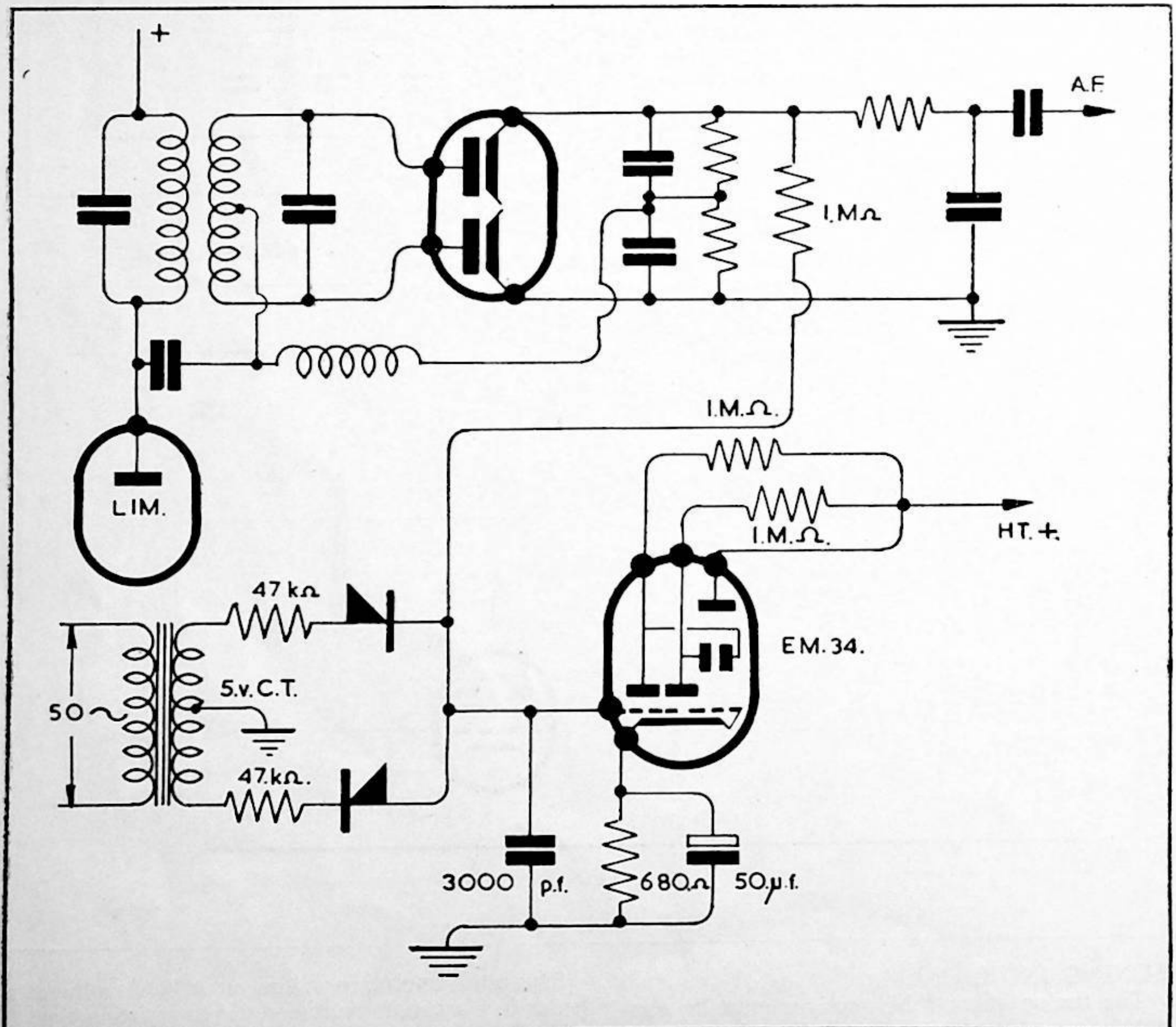


Fig. 19. The EM34 Tuning Indicator used in conjunction with a discriminator.

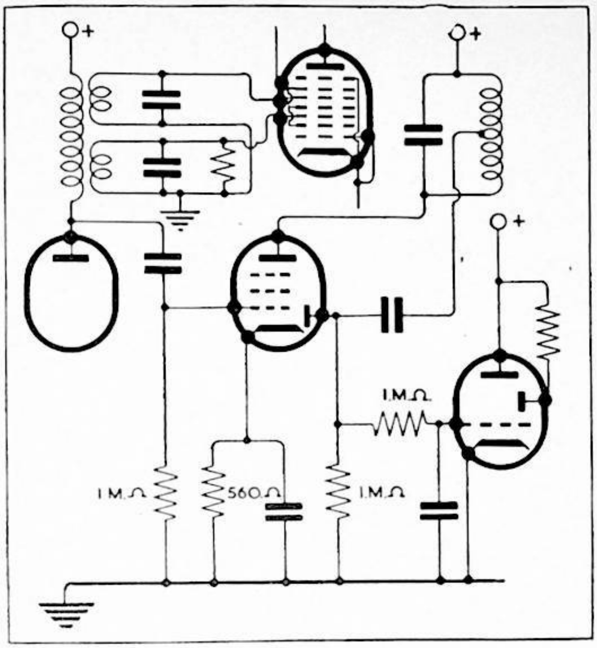


Fig. 20. **The phase discriminator provides no negative voltage. To obtain a definite tuning indication it is necessary to include a separate detector and an additional high—Q tuned circuit.**

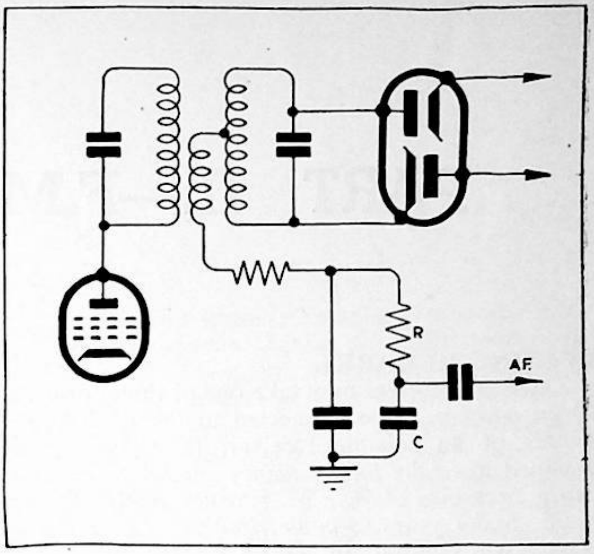


Fig. 21. **The de-emphasis circuit. A low-pass filter which compensates for the pre-emphasis of high frequencies.**

The phase discriminator imposes an entirely different problem, because there is no variable negative voltage available. A separate diode must then be used, and may be connected as shown in Figure 20.

A.F. AMPLIFIER DESIGN.

This presents no special difficulty apart from the fact that it must be free from distortion, if full advantage is to be taken of the high quality offered by frequency modulation. A fixed correcting network is necessary at the detector output in order to compensate for the pre-emphasis at the higher frequencies. It is realised very simply by means of a low-pass filter (Fig. 21) consisting of a resistor R and a capacitor C and having a time constant of 50 microseconds. This result may be achieved by any one of many possible combinations of values for R and C. Let us choose preferred values, for example 33000 ohms and 1500pF.

The conventional tone control system is superfluous: it is sufficient to make provision for reducing the overall response in the centre of the audio range in order to adjust the response curve to suit the listening conditions (that is to say to suit the general sound level), and to adjust it in such a manner as to compensate for changes in the frequency response of the ear.

PART II.—F.M. TECHNIQUE

OPENING REMARKS.

The F.M. receiver may take one of three forms: (i) an *adaptor* to be connected to the input terminals of an existing receiver, (ii) a receiver *designed specially for frequency modulation*, and (iii) a *combined A.M./F.M. receiver*.

For many years to come, traditional radio receivers will continue in service, and their owners will feel no inclination to buy a special AM/FM receiver just for the facility of being able to receive frequency-modulated transmissions.

For these, the adaptor is an economic solution. This apparatus may be constructed in various ways: it is possible, for reasons of simplicity, to take the supply voltages from the receiver, but this solution requires modifications to the receiver and, moreover, it is not certain that the mains transformer will be able to supply the extra watts demanded. An adaptor having high-slope valves takes between 25 and 40mA of H.T. current according to the number of valves, and from one to two amperes for the heaters. This constitutes an appreciable drain on the power unit.

It is much better to construct an adaptor with self-contained power supplies, requiring to be connected only to the input terminals of the receiver. By providing the adaptor with an input socket and a change-over switch, it may be left permanently in circuit.

The simple super-regenerative detector has often been recommended as an adaptor. This apparatus is indeed capable of receiving frequency-modulated transmissions provided it is tuned on the skirt of the response curve. This solution must be rejected. Not only does it strip the F.M. of its principal attributes, but it constitutes a source of interference which, by virtue of its innumerable harmonics, will wipe out reception in the entire locality. Furthermore it is justly prohibited in several countries.

The receiver designed exclusively for F.M. is reserved for the specialist. Free from switching complications and having a single specialised end in view, i.e. a reproduction of the highest quality possible, he does not have to accept a compromise solution. The A.F. section will clearly have to support the aim in view, and will demand the utilization of one or more high-fidelity loudspeakers.

We thus arrive at the third class of receiver: namely the receiver designed for the reception of two kinds of transmission. This is the design of the future which will gradually constitute a larger and larger proportion of industrial production.

Large numbers of mixed receiver circuits have seen the light of day, and remarkable devices have been thought out to reduce the number of valves. From all this a circuit has been evolved which may be regarded as the basic AM/FM receiver circuit around which certain variations may be woven.

In the following pages, we shall give examples of each class of equipment, but only of proved designs which have been simplified as far as possible without detracting from their performance. They can all be constructed from commercially available components. We have however provided at the end of the book information which will allow the constructor to wind his own coils if he so desires.

In regard to the actual construction, it is important to avoid making the assumption that certain connections may be made physically long because, for clarity, they are shown long on the circuit diagrams. In reality, it is essential that all the connections included in the "hot" parts of the circuits be **as short and direct as possible,** without regard to the appearance or symmetry of the finished article. It is important not to lose sight of the fact that the self-inductance of a conductor only an inch or two long is sufficient to produce undesirable effects when 100 Mc. frequencies are involved.

It should be noted also that all the circuits are given without any guarantee as to their eventual protection by patents covering the various components which are built into them. The reader wishing to produce them on a commercial scale should first of all consult a patent agent in regard to this aspect. But if it is only a question of a circuit constructed for personal use, no question of royalty will arise.

CIRCUIT No. 1.

Simple 5 Valve Adaptor

This design is derived from a circuit which is conventional in the U.S.A. and which possesses good sensitivity having regard to the number of stages.

The input is taken to a tap on the tuned circuit and thus is not symmetrical with respect to earth.

In order to reduce the damping of the circuit, the input grid is also tapped down on the coil.

A similar arrangement is used in the second tuned circuit which is shunt fed from the anode of the V.H.F. valve by a choke CH1 and a 50 pF capacitor. The tuning is effected by means of a 3-gang capacitor (3 × 15 pF).

It is possible to simplify the construction by varying only the tuning capacitance of the oscillator circuit. The aerial circuit and the anode circuit of the V.H.F. valve will, in this case, be tuned to the middle of the band by means of fixed capacitances. These will be formed principally by the internal valve capacitances in such a way as to maintain as high an L/C ratio as possible. The damping of the coils may be made high enough for the pass band to cover the entire waveband.

It is feasible even to completely dispense with a variable capacitor, tuning the oscillator by the movement of a magnetic core inside the coil. This system is used in certain commercial apparatus.

The frequency changer is a conventional circuit with cathode feedback. Observe that one side of the heater is connected to the cathode and the other to a V.H.F. choke. This arrangement is indispensable and is used to counteract the effect of cathode-heater capacitance.

Note, the screen of the frequency changer is carefully decoupled by means of a paper capacitor backed by a mica capacitor.

It will seen that the two I.F. valves have their cathodes connected to the chassis and are biassed by grid current. In this way a certain degree of automatic control is obtained. In order to avoid running into cut-off it is preferable to use variable-mu valves.

The ratio detector is of a very simple design which does not provide any A.G.C. voltage.

The power supplies are provided by a mains transformer designed to give a rectified output of about a hundred volts and using either a selenium or a copper oxide rectifier.

COMPONENTS LIST
CIRCUIT No. 1

COILS & CHOKES.

QTY.	REF.	PURPOSE	QTY.	REF.	PURPOSE
1	L1	Aerial Coil	1	CH1	R.F. Choke
1	L2	R.F. Coupling	2	CH2	Heater Chokes
1	L3	Oscillator Coil	2	CH3	Mains Filter Chokes

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
I.F.T.1.	1st I.F. Transformer	10.7 Mc/s	IFT.601
I.F.T.2.	2nd I.F. Transformer	10.7 Mc/s	IFT.603
D.T.1.	Ratio Detector Transformer	10.7 Mc/s	DT.101
T.1.	Mains Transformer		MT.1222
	Primary	230v	
	Secondaries	130v 50mA	
		6.3v 1.5A	

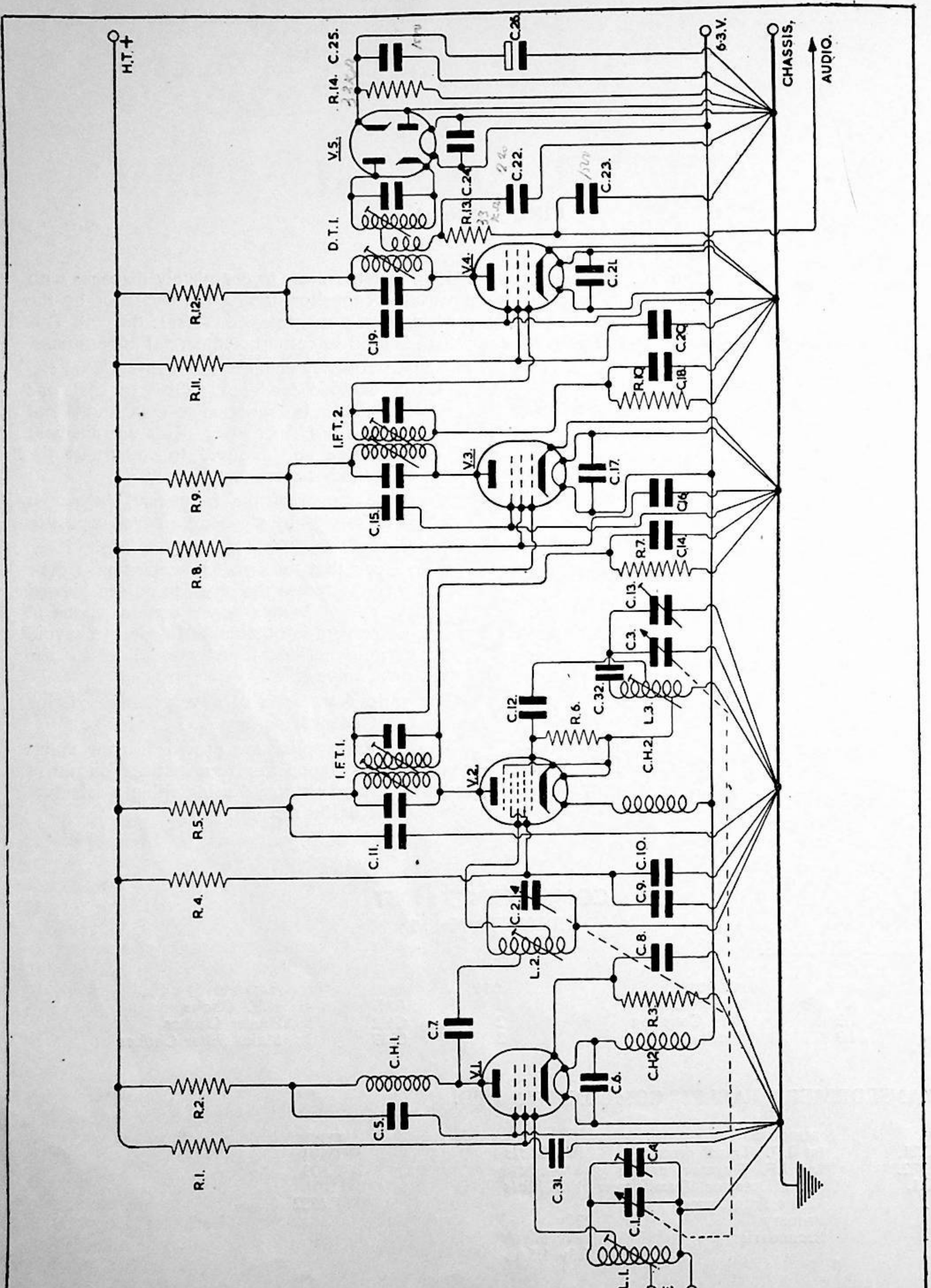


Fig. 22. Circuit No. 1. Simple 5 valve adaptor.

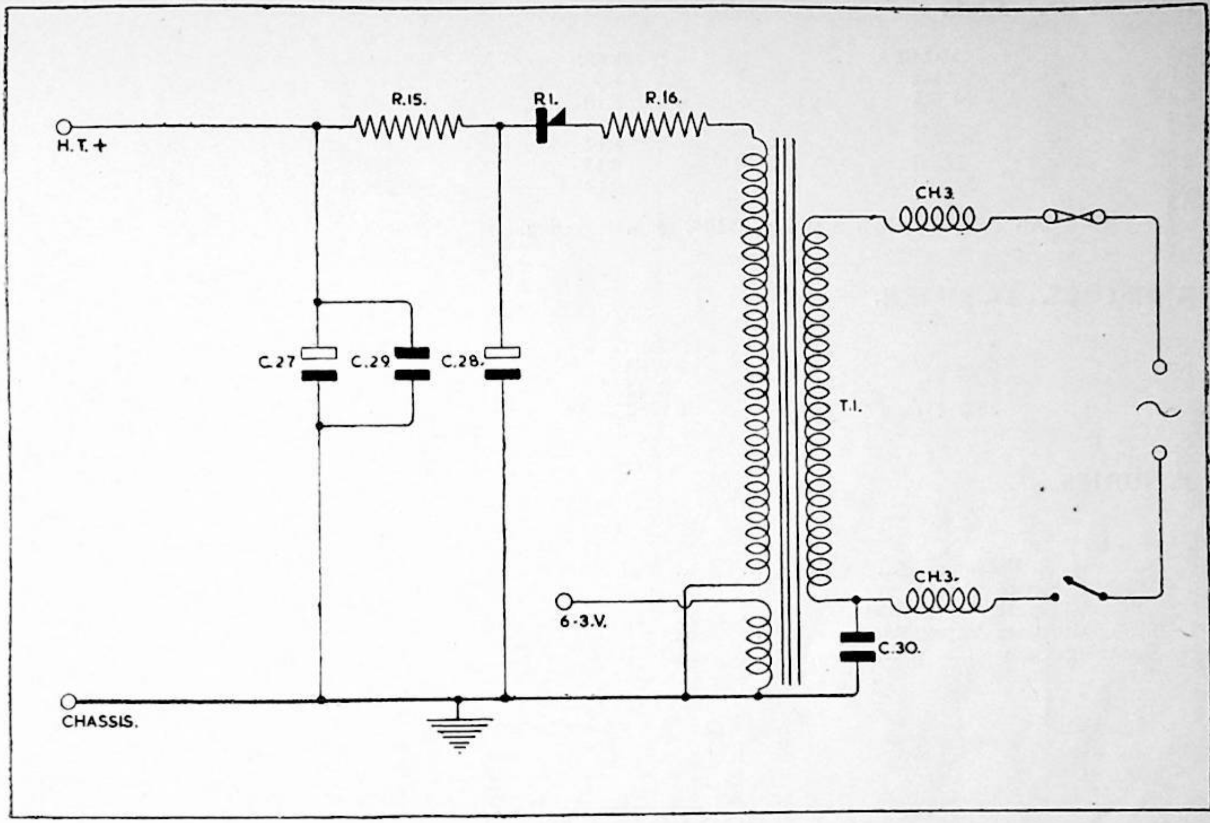


Fig. 23. Circuit No. 1 (continued).

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE	FORM	TYPE
C5	1500pF	Ceramic	CC 150	C20	1500pF	Ceramic	CC 150
C6	0.01μF	"	CTH 422	C21	0.01μF	"	CTH 422
C7	47pF	"	SCT 12	C22	220pF	"	SCT 14
C8	1500pF	"	CC 150	C23	1500pF	"	CC 150
C9	0.01μF	"	CTH 422	C24	0.01μF	"	CTH 422
C10	1500pF	"	CC 150	C25	1500pF	"	CC 150
C11	0.01μF	"	CTH 422	C26	10μF	Electrolytic	25vw CE 75C
C12	47pF	"	SCT 12	C27	50μF	"	350vw CE 171LE
C14	1500pF	"	CC 150	C28	50μF	"	350vw CE 171LE
C15	1500pF	"	CC 150	C29	0.05μF	Paper	350vw CP 35N
C16	1500pF	"	CC 150	C30	5000pF	"	1000vw CP 45W
C17	0.01μF	"	CTH 422	C31	1500pF	Ceramic	CC 150
C18	1500pF	"	CC 150	C32	100pF	"	SCT 13
C19	0.01μF	"	CTH 422				

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM	TYPE
C1, C2, C3	3 x 15pF	Variable	U103
C4	2 to 30pF	Air spaced trimmer	C804
C13	2 to 30pF	Air spaced trimmer	C804

VALVES & RECTIFIER.

REF.	TYPE		REF.	TYPE	
V1	EF93	MULLARD	V4	EF93	MULLARD
V2	EK90	"	V5	EB91	MULLARD
V3	EF93	"	R1	11H8X	G.E.C.

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE
R1	1kΩ	R9	470Ω
R2	470Ω	R10	100kΩ
R4	1kΩ	R11	1kΩ
R5	470Ω	R12	470Ω
R6	22kΩ	R13	33kΩ
R7	270kΩ	R14	33kΩ
R8	1kΩ		

All resistors High Stability ±10% ½ watt rating.

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R3	68Ω ½W	BWF2
R15	1kΩ 5W	A1/1
R16	22Ω ½W	BWF2

SUNDRIES.

		TYPE	MANUFACTURER
1	Chassis		
1	2A. Fuse & Holder	L356	BELLING-LEE
1	ON/OFF Switch	S259	A. F. BULGIN & CO., LTD.
2	B.7.G. Miniature Valveholders	XM7/UC-1	McMURDO INSTRUMENT CO., LTD.
3	B.7.G. Miniature Valveholders	XM7/U	McMURDO INSTRUMENT CO., LTD.
2.	Screening Cans	45	McMURDO INSTRUMENT CO., LTD.

CIRCUIT No. 2

5 Valve Adaptor with Tuning Indicator

This design is similar to the preceding one, but differs from it by the use of germanium diodes for the detector and by the inclusion of a cathode-ray tuning indicator.

An A.G.C. voltage is applied to the first I.F. valve.

Automatic control is, moreover, indispensable when germanium diodes are used because these diodes are able to withstand only a certain limited voltage. Without A.G.C. it would be possible to damage them by tuning to a nearby transmitter.

It will be noted that the detector stage is connected to the chassis at a point centrally located on the load resistor, and this has the effect of ensuring improved symmetry of the two sides of the secondary with respect to this point.

The time constant of the noise limiter has been determined by means of the 1500 ohm resistor in series with the 10μF electrolytic capacitor.

COMPONENTS LIST
CIRCUIT No. 2

COILS & CHOKES.

QTY.	REF.	PURPOSE	QTY.	REF.	PURPOSE	QTY.	REF.	PURPOSE
1	L1	Aerial Coil	1	L3	Oscillator Coil	2	CH2	Heater Chokes
1	L2	R.F. Coupling	1	CH1	R.F. Choke	2	CH3	Mains Filter Chokes

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
I.F.T.1.	1st I. F. Transformer	10.7 Mc/s	IFT603
I.F.T.2.	2nd I.F. Transformer	10.7 Mc/s	IFT603
D.T.1.	Ratio Detector Transformer	10.7 Mc/s	DT101
T.1.	Mains Transformer		MT1222
	Primary	230v	
	Secondaries	130v 50mA	
		6.3v 1.5A	

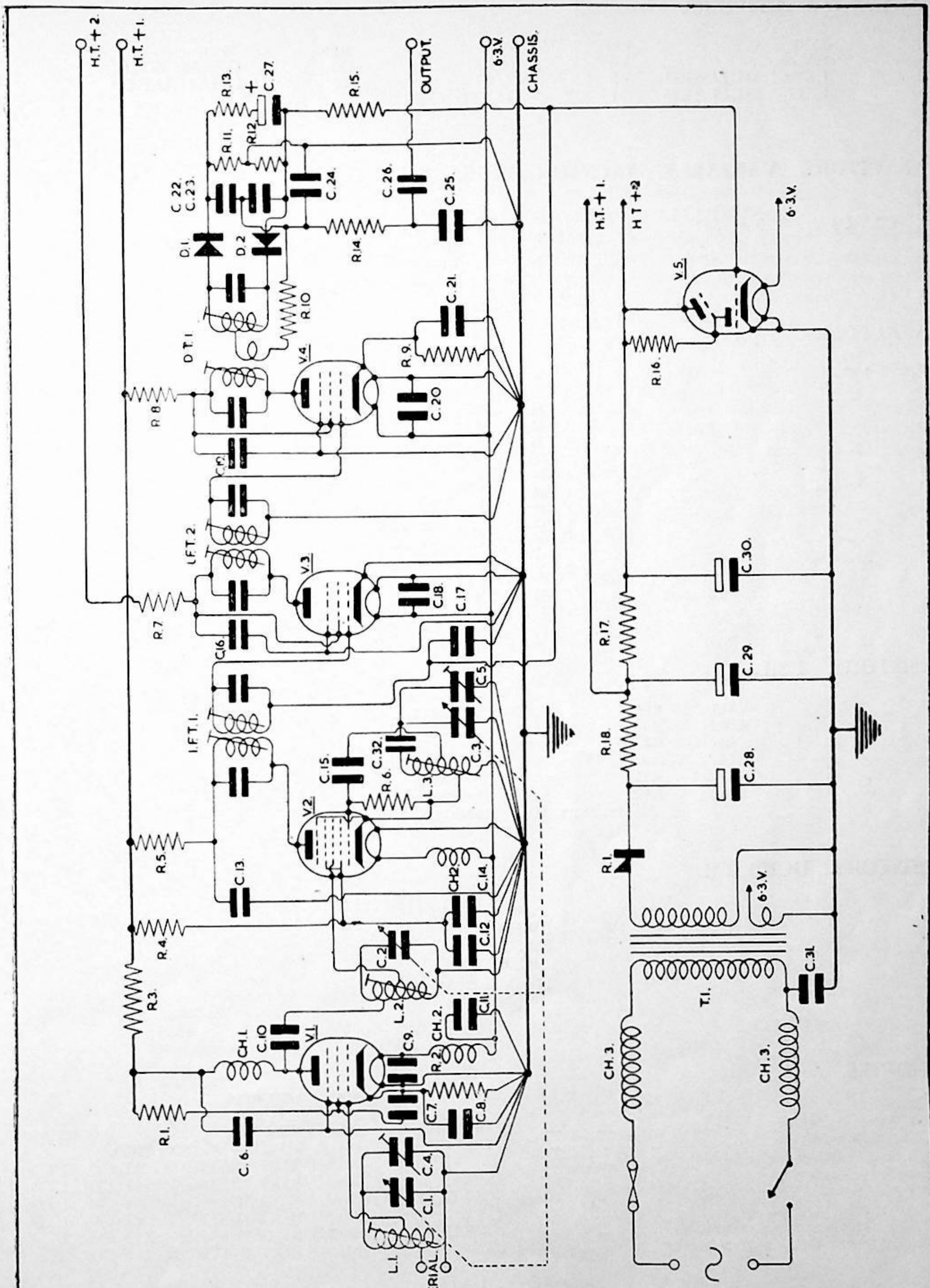


Fig. 24. Circuit No. 2. 5 valve adaptor with Tuning Indicator.

VALVES & RECTIFIERS.

REF.	TYPE		REF.	TYPE		REF.	TYPE	
V1	6AU6		V4	6AU6		D2	GEX34	G.E.C.
V2	EK90	MULLARD	V5	6U5G		R1	11H8X	G.E.C.
V3	EF93	MULLARD	D1	GEX34	G.E.C.			

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM	TYPE
C1, C2, C3	3 x 15pF	Variable	U103
C4	2 to 30pF	Air spaced trimmer	C804
C5	2 to 30pF	Air spaced trimmer	C804

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE	FORM		TYPE
C6	2200pF	Ceramic	CTH 310	C20	0.01μF	Paper		CP 112H
C7	2200pF	,,	CTH 310	C21	2200pF	Ceramic		CTH 310
C8	2200pF	,,	CTH 310	C22	220pF	,,		SCT 14
C9	2200pF	,,	CTH 310	C23	220pF	,,		SCT 14
C10	22pF	,,	SCT 11	C24	470pF	,,		SPG 1
C11	2200pF	,,	CTH 310	C25	4700pF	,,		CTH 315
C12	2200pF	,,	CTH 310	C26	0.05μF	Paper		CP 34H
C13	0.01μF	,,	CTH 422	C27	10μF	Electrolytic	25vw	CE 75C
C14	0.01μF	,,	CTH 422	C28	50μF	,,	350vw	CE 171LE
C15	47pF	,,	SCT 12	C29	50μF	,,	350vw	CE 171LE
C16	2200pF	,,	CTH 310	C30	50μF	,,	350vw	CE 171LE
C17	0.05μF	Paper	CP 34H	C31	5000pF	Paper	1000vw	CP 45W
C18	2200pF	Ceramic	CTH 310	C32	100pF	Ceramic		SCT 13
C19	2200pF	,,	CTH 310					

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE	REF.	VALUE
R1	4.7kΩ	R7	2.2kΩ	R13	1.5kΩ
R3	1kΩ	R8	1kΩ	R14	15kΩ
R4	1kΩ	R9	100Ω	R15	1MΩ
R5	470Ω	R11	68kΩ	R16	1MΩ
R6	22kΩ	R12	68kΩ		

All resistors High Stability ±10% ½ watt rating.

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R2	68Ω ½W	BWF2
R10	47Ω ½W	BWF2
R17	470Ω 5W	A1/1
R18	470Ω 5W	A1/1

SUNDRIES.

		TYPE	MANUFACTURER
1	Chassis		
1	2A Fuse & Holder	L365	BELLING-LEE
1	ON/OFF Switch	S259	A. F. BULGIN & CO., LTD.
1	B.7.G. Miniature Valve holder	XM7/UC-1	McMURDO INSTRUMENT CO., LTD.
	with screening can	45	McMURDO INSTRUMENT CO., LTD.
1	B.9.A. (Noval) Valve holder	XM9/UC-1	McMURDO INSTRUMENT CO., LTD.
	with screening can	75	McMURDO INSTRUMENT CO., LTD.
2	B.7.G. Miniature Valve holders	XM7/U	McMURDO INSTRUMENT CO., LTD.
1	International Octal Valve holder	B8/U	McMURDO INSTRUMENT CO., LTD.

CIRCUIT No. 3

Adaptor with Adjustable A.M. Rejection

This circuit uses a very stable form of Frequency Changer which is in effect a tuned-anode tuned-grid oscillator. This being the case, there is no critical coupling between L2 and L3 which should be spaced $\frac{1}{4}''$ apart. After construction, L2 should be tuned by spacing the turns to give a maximum grid voltage reading on V4. L3 and C2 form the main frequency controlling circuit.

Surprise may be occasioned by the reference to grid voltage on V4. In this circuit V4 functions as a limiter valve, and though the combination of a limiter and ratio detector is somewhat unconventional, greatly improved A.M. rejection results. The grid voltage of V4 should be measured at the junction off C17 and R11 using a 100kΩ isolating resistor between this point and the meter. This precaution is necessary to prevent detuning the I.F. transformer.

The Ratio Detector load circuit is somewhat unusual in that the earth point is adjustable; this has necessitated the use of two electrolytic capacitors C25 and C26, but the basic functioning of the circuit remains unaltered. VR1 is of the pre-set variety and should be adjusted for maximum A.M. rejection. This is best accomplished by injecting an amplitude modulated signal of low level at the grid of V4. Alteration of VR1 very slightly alters the secondary tuning of DT1, which should be re-adjusted after the best setting for VR1 has been found.

Once correctly adjusted, this circuit gives an excellent performance and A.M. rejection closely approaches 100%.

COMPONENTS LIST

CIRCUIT No. 3

COILS & CHOKES.

QTY.	REF.	PURPOSE	QTY.	REF.	PURPOSE
1	L1	Aerial Coil	2	CH3	Filter Chokes
1	L2	R.F. Coupling Coil	1	CH2	Heater Choke
1	L3	Oscillator Coil			

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
I.F.T.1.	1st I.F. Transformer	10.7 Mc/s	IFT601
I.F.T.2.	2nd I.F. Transformer	10.7 Mc/s	IFT603
D.T.1	Ratio Detector Transformer	10.7 Mc/s	DT101
T.1	Mains Transformer		MT1224
	Primary	230v	
	Secondaries	230-0-250v 60mA	
		6.3v 3A	
		5v 2A	

VALVES.

REF.	TYPE		REF.	TYPE	
V1	EF91	MULLARD	V5	EB91	MULLARD
V2	EF91	MULLARD	V6	EM34	MULLARD
V3	EF91	MULLARD	V7	GZ30	MULLARD
V4	EF91	MULLARD			

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM	TYPE
C1, C2	2 x 25pF	Variable	U101

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE	FORM	TYPE
C3	5000pF	Ceramic	CC153	C18	5000pF	Ceramic	CC153
C4	100pF	„	CTH310	C19	10,000pF	„	CTH422
C5	5000pF	„	CC153	C20	300pF	„	SCT15
C6	2000pF	„	CC151	C21	300pF	„	SCT15
C7	2000pF	„	CC151	C22	10,000pF	„	CTH422
C8	47pF	Silver Mica	SMP101	C23	1000pF	„	CTH310
C9	33pF	„	SMP101	C24	0.05μF	Paper	CP34H
C10	33pF	„	SMP101	C25	50μF	25vw Electrolytic	CE88CE
C11	5000pF	Ceramic	CC153	C26	50μF	25vw „	CE88CE
C12	2000pF	„	CC151	C27	300pF	Ceramic	SCT15
C13	5000pF	„	CC153	C28	0.1μF	Paper	CP36H
C14	5000pF	„	CC153	C29	50μF	350vw Electrolytic	CE171LE
C15	5000pF	„	CC153	C30	50μF	350vw „	CE171LE
C16	2000pF	„	CC151	C31	.005μF	1000vw Paper	CP45W
C17	47pF	Silver Mica	SMP101				

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE
R1	100kΩ	R11	47kΩ
R2	4.7kΩ	R12	47kΩ
R3	6.8kΩ	R14	47kΩ
R4	150Ω	R15	6.8kΩ
R5	470kΩ	R16	6.8kΩ
R6	47kΩ	R17	1.2MΩ
R7	4.7kΩ	R18	1.2MΩ
R8	4.7kΩ	R19	1.2MΩ
R9	47kΩ	R21	100Ω
R10	150Ω	R22	100Ω

All resistors High Stability ±10% ½ watt rating.

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R13	47Ω ¼W	DWF2
R20	2.2kΩ 5W	A1/1

POTENTIOMETER.

REF.	VALUE	TYPE
VR1	2.5kΩ Linear Pre-set	CLR 901

SUNDRIES.

		TYPE	MANUFACTURER
1	Chassis		
1	2A Fuse & Holder	L365	BELLING-LEE
1	ON/OFF Switch	S259	A. F. BULGIN & CO., LTD.
5	B7G Miniature valveholders	XM7/UC-1	McMURDO INSTRUMENT CO., LTD.
5	Screening Cans	45	McMURDO INSTRUMENT CO., LTD.
2	International Octal valveholders	B8/U	McMURDO INSTRUMENT CO., LTD.

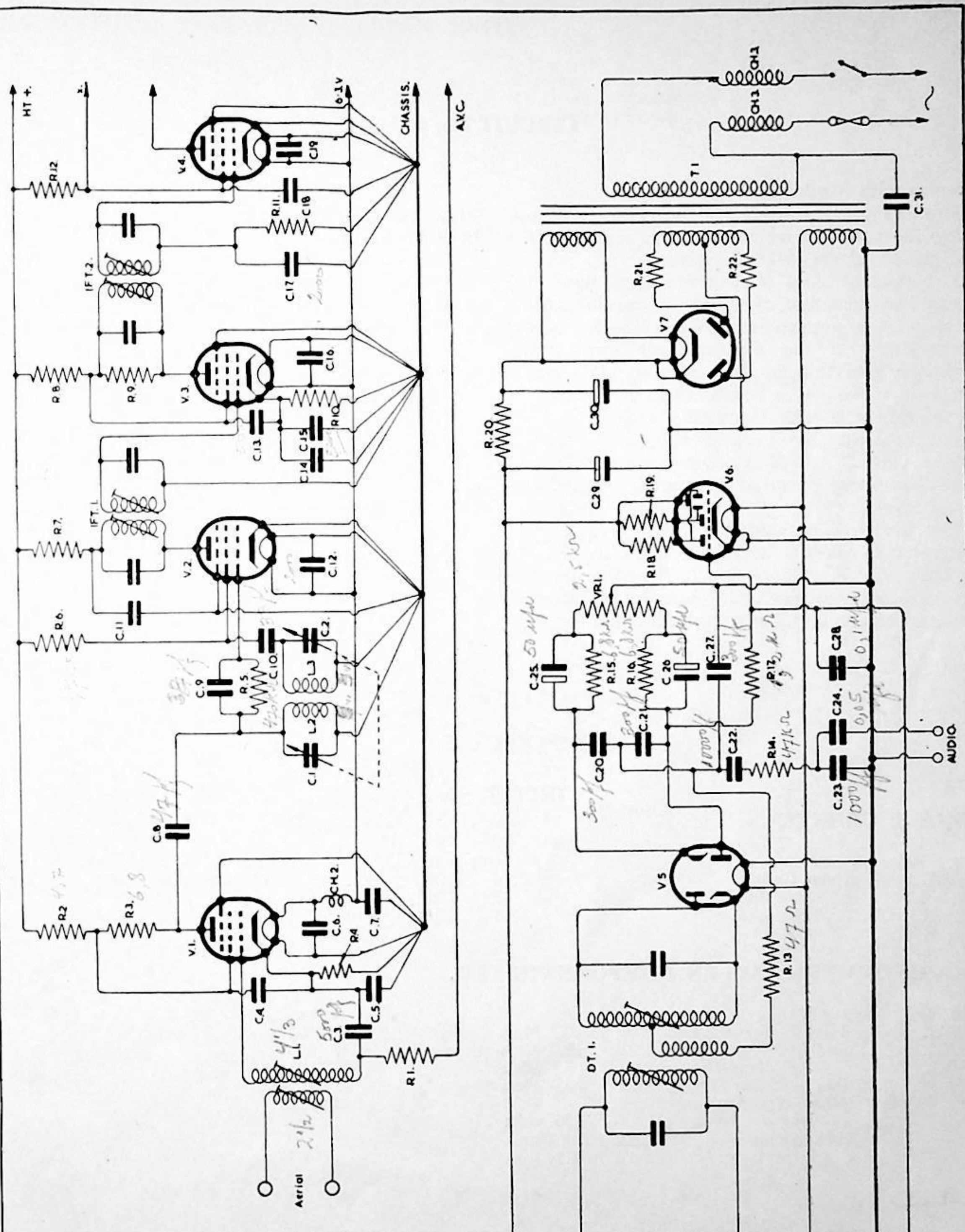


Fig. 25. Circuit No. 3. Adaptor with adjustable A.M. Rejection.

CIRCUIT No. 4.

Adaptor with Modulation Feedback

This example is intended to show how to reduce amplitude variation by negative feedback into the grid circuit of the first I.F. valve.

Two distinct types of detection come into play here. The detection of amplitude modulation is affected by a germanium diode connected across the primary of the discriminator transformer, while the detection of frequency modulation is made by means of a discriminator. Because of the efficiency of the feedback, it has not been found necessary to precede the detector by a limiter valve. On the other hand, three I.F. stages have been required to produce an adequate signal level.

The feedback network must be very carefully decoupled in order to avoid all possibility of feeding back V.H.F. voltage, but at the same time its time constant must not be too long (of the order of 200 microseconds). The required conditions are obtained by means of the network constituted by R15, R27, C28, C37, C36, and CH1.

The lead joining the primary of the discriminator to the secondary of the first I.F. transformer must be screened throughout the whole of its length, and the metallic screening must be connected to the chassis only at the cathode of the first I.F. valve. In order to avoid contact elsewhere, it is advisable to pass a length of insulating sleeving over the metallic braid.

All the I.F. valves have their cathodes connected to the chassis. They are given a bias of −2V which corresponds to the condition of maximum available slope.

Frequency changing is effected in this case by means of a double triode in which one of the elements forms the oscillator while the other forms the modulator. This circuit yields a conversion conductance of more than 2mA/V.

COMPONENTS LIST

CIRCUIT No. 4

COILS & CHOKES.

QTY.	REF.	PURPOSE	QTY.	REF.	PURPOSE
1	L1	Aerial Coil	4	CH1	R.F. Chokes
1	L2	R.F. Coupling	2	CH2	Heater Chokes
1	L3	Oscillator Coil	3	CH3	Filter Chokes

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
I.F.T.1.	1st I.F. Transformer	10.7 Mc/s	IFT602
I.F.T.2.	2nd I.F. Transformer	10.7 Mc/s	IFT603
I.F.T.3.	3rd I.F. Transformer	10.7 Mc/s	IFT603
DT1	Discriminator Transformer	10.7 Mc/s	DT102
T1	Mains Transformer.		MT1226
	Primary	230 volts	
	Secondaries	200-0-200 60mA	
		6.3v 3A	

VALVES.

REF.	TYPE	REF.	TYPE
V1	6AU6	V5	6AU6
V2	ECC91 MULLARD	V6	EB91 MULLARD
V3	6AU6	V7	EZ90 MULLARD
V4	6AU6	D1	GEX34 G.E.C.

6.3v .3A Pilot Light.

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM	TYPE
C1, C2, C3	3 x 15pF	Variable	U103
C4	2 to 30pF	Air spaced trimmer	C804
C5	2 to 30pF	Air spaced trimmer	C804

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE	FORM	TYPE
C6	2200pF	Ceramic	CTH310	C24	4700pF	„	CTH315
C7	2200pF	„	CTH310	C25	0.01μF	Paper	CP112H
C8	2200pF	„	CTH310	C26	220pF	Ceramic	SCT14
C9	32μF	350vw Electrolytic	CE93LE	C27	33pF	„	SCT12
C10	22pF	Ceramic	SCT11	C28	1500pF	„	CC150
C11	2200pF	„	CTH310	C29	150pF	„	SCT13
C12	2200pF	„	CTH310	C30	150pF	„	SCT13
C13	4700pF	„	CTH315	C31	1000pF	„	CC150
C14	2200pF	„	CTH310	C32	0.05μF	Paper	CP34H
C15	33pF	„	SCT12	C33	0.1μF	„	CP36H
C16	47pF	„	SCT12	C34	50μF	350vw Electrolytic	CE-171-LE
C17	1500pF	„	CC150	C35	50μF	350vw „ with insulated mounting	CE-171-LE
C18	4700pF	„	CTH315				
C19	2200pF	„	CTH310	C36	1500pF	Ceramic	CC150
C20	4700pF	„	CTH315	C37	1500pF	„	CC150
C21	4700pF	„	CTH315	C38	100μF	12vw Electrolytic	CE100B
C22	0.01μF	Paper	CP112H	C39	.005μF	1000vw Paper	CP45W
C23	4700pF	Ceramic	CTH315				

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE
R1	1kΩ	R13	100kΩ
R2	120Ω	R14	1kΩ
R3	100Ω	R15	220kΩ
R5	2.2kΩ	R17	100kΩ
R6	1.5kΩ	R18	100kΩ
R7	22kΩ	R19	100kΩ
R8	33kΩ	R21	200kΩ
R10	1kΩ	R26	39kΩ
R11	100kΩ	R27	47kΩ
R12	1kΩ	R28	220kΩ

All resistors High Stability ±10% ½ watt rating.

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R4	10Ω ½W	BWF2
R9	1kΩ 1W	BWF1
R16	3Ω 1W	BWF1
R20	1.5kΩ 5W	A1/1
R22	56Ω 1W	BWF1
R23	120Ω 1W	BWF1
R24	100Ω 1W	BWF1
R25	100Ω 1W	BWF1

SUNDRIES.

		TYPE	MANUFACTURER
1	Chassis		
1	2A Fuse & Holder	L365	BELLING-LEE
1	ON/OFF Switch	S259	A. F. BULGIN & CO., LTD.
1	Pilot Light holder	D370 Red	A. F. BULGIN & CO., LTD.
2	B7G Miniature Valve holders	XM7/UC-1	McMURDO INSTRUMENT CO., LTD.
	with screening cans	45	McMURDO INSTRUMENT CO., LTD
5	B7G Miniature Valve holders	XM7/U	McMURDO INSTRUMENT CO., LTD

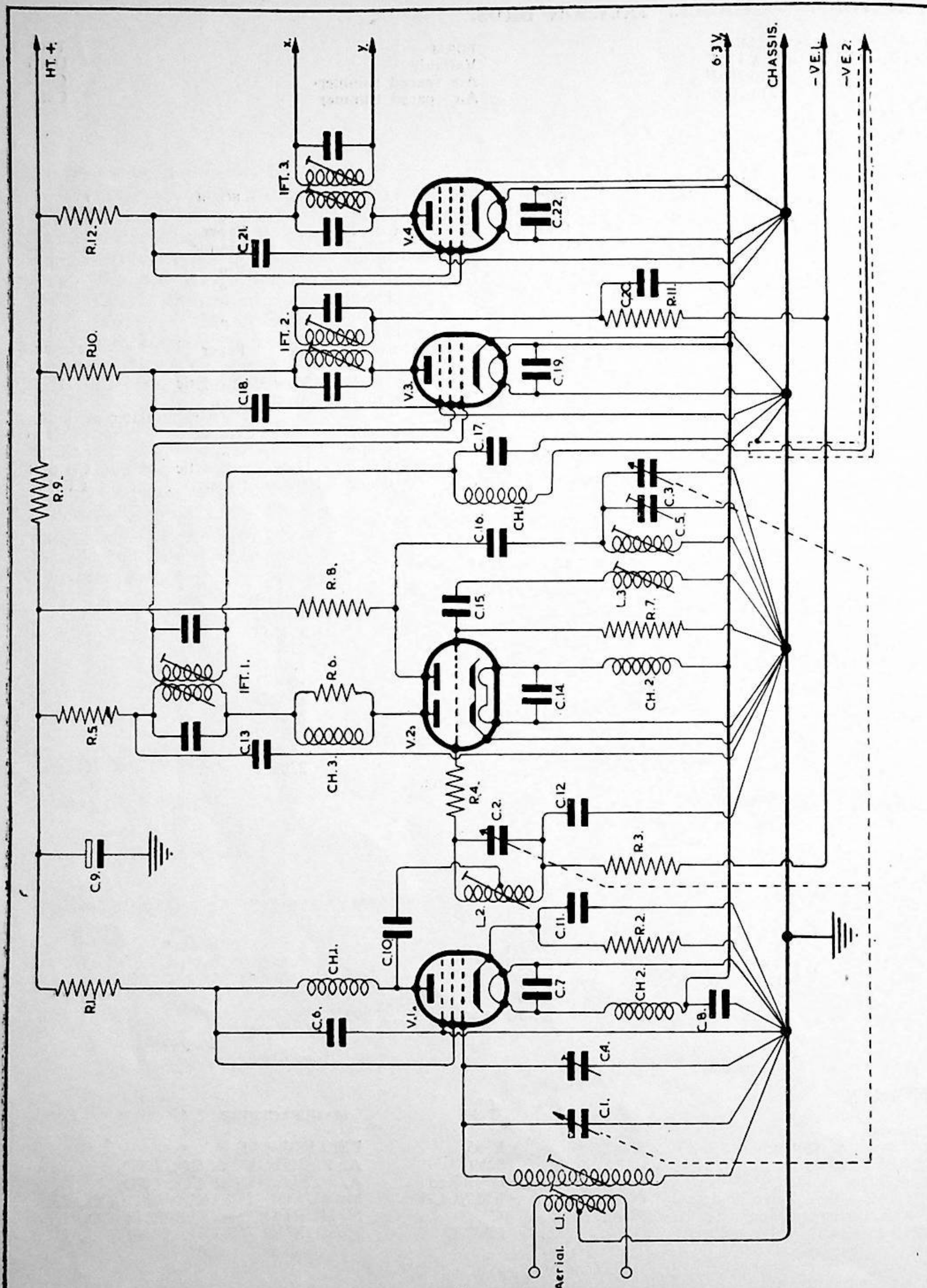


Fig. 26. Circuit No. 4. Adaptor with Modulation Feedback.

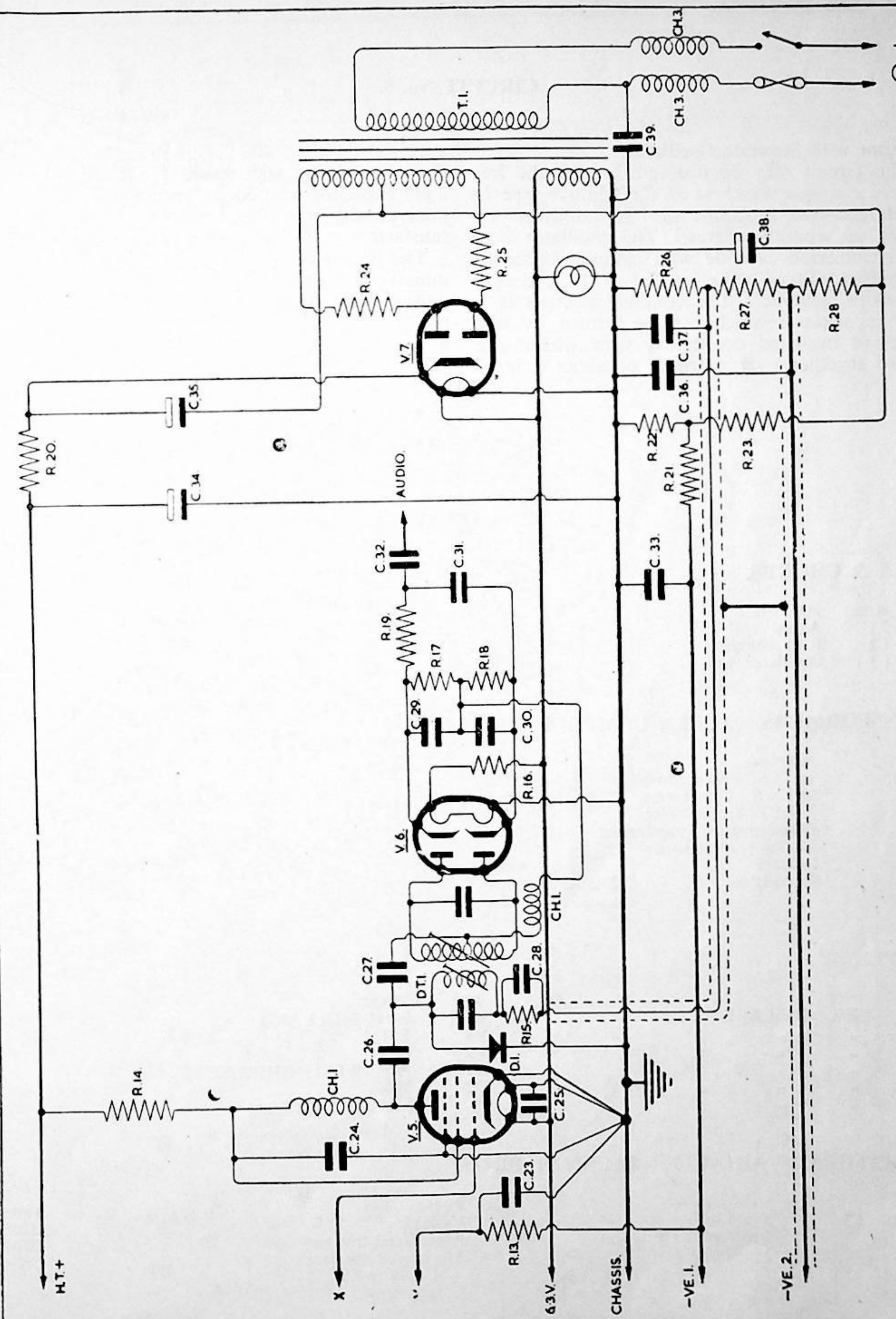


Fig. 27. Circuit No. 4 (continued).

CIRCUIT No. 5.

Adaptor with Separate Oscillator

This circuit may be distinguished by the frequency changer, which is of the additive type in which the two functions are accomplished by means of separate valves. The oscillator is a triode-connected pentode with cathode feedback, the output voltage being applied to the grid of a high-slope pentode. The coupling consists of a 2 pF capacitance which can be formed by two pieces of insulated connecting wire which are twisted together over a length of about ½ inch. Greater stability will result if a close tolerance 2 pF capacitor is used as specified in the components list, but the former method is quite satisfactory.

The circuit is completely conventional and terminates in a discriminator preceded by a limiter.

Also included is a cathode-ray tuning indicator, type EM34. If available, a 6AL7 indicator could be used in the manner shown by Fig 18, which is described in the earlier part of this manual.

COMPONENTS LIST

CIRCUIT No. 5

COILS & CHOKES.

QTY.	REF.	PURPOSE
1	L1	Aerial coil
1	L2	R.F. coupling
1	L3	Oscillator Coil
2	CH1	R.F. Chokes
3	CH2	Heater Chokes
2	CH3	Mains Filter Chokes

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
I.F.T.1.	1st I.F. Transformer	10.7 Mc/s	IFT604
I.F.T.2.	2nd I.F. Transformer	10.7 Mc/s	IFT604
I.F.T.3.	3rd I.F. Transformer	10.7 Mc/s	IFT604
D.T.1.	Discriminator Transformer	10.7 Mc/s	DT102
T.1.	Mains Transformer.		MT1224
	Primary	230 volts	
	Secondaries	250-0-250 60mA	
		6.3v 3A	

VALVES.

REF.	TYPE
V1	EF42 MULLARD
V2	,, ,,
V3	,, ,,
V4	,, ,,
V5	,, ,,
V6	,, ,,
V7	EB41 MULLARD
V8	EM34 ,,
V9	EZ40 ,,
D1	W6 WESTINGHOUSE
D2	W6 ,,
P1	6.3v .3A Pilot Light

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM	TYPE
C1, C2, C3	3 x 15pF	Variable	U103
C4	2 to 30pF	Air spaced trimmer	C804
C5	2 to 30pF	Air spaced trimmer	C804

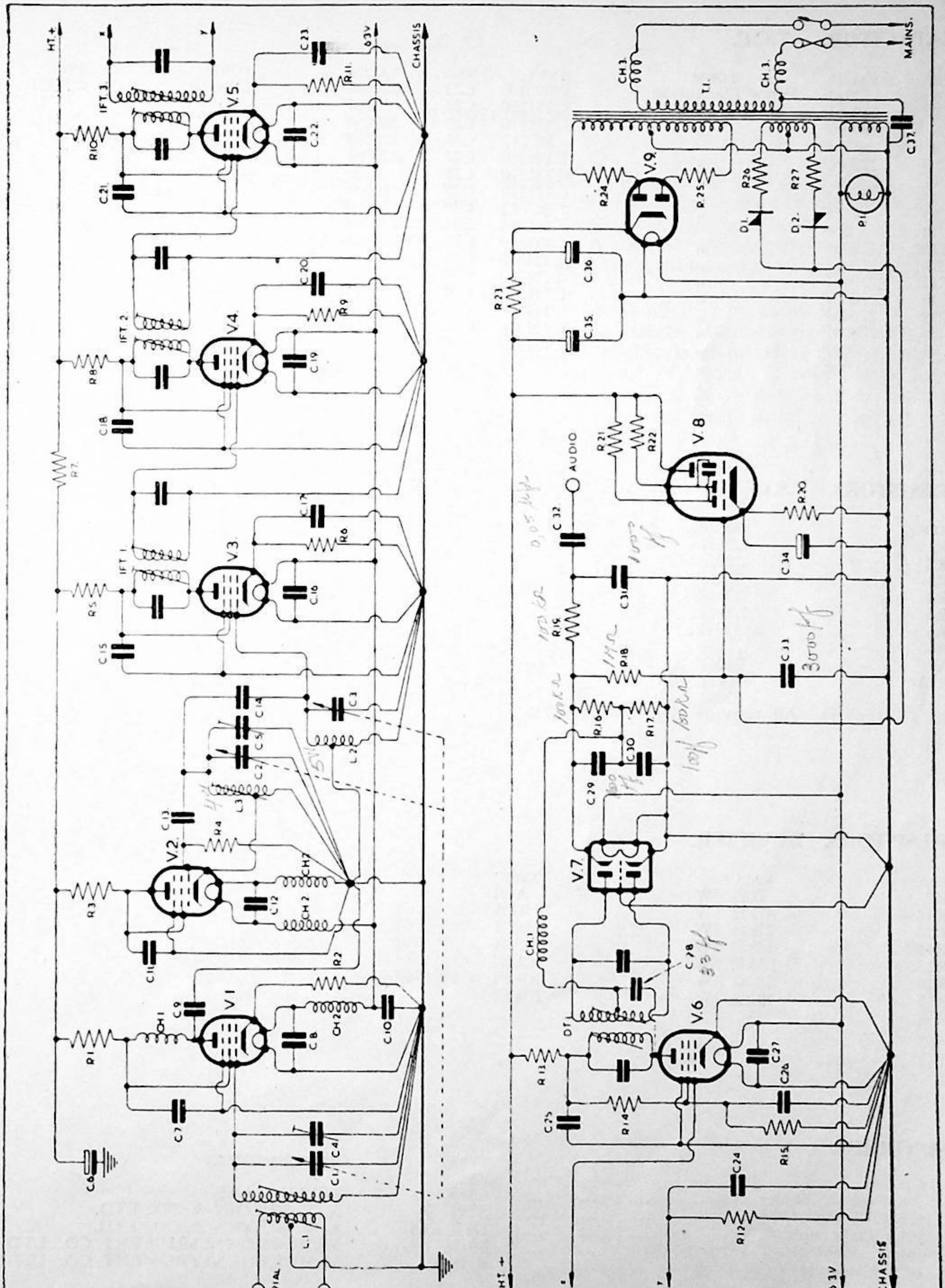


Fig. 28. Circuit No. 5. Adaptor with Separate Oscillator.

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE	FORM	TYPE
C6	32μF	350vw Electrolytic	CE93LE	C23	2200pF	Ceramic	CTH310
C7	2200pF	Ceramic	CTH310	C24	150pF	„	SCT13
C8	2200pF	„	CTH310	C25	2200pF	„	CTH310
C9	33pF		SCT12	C26	2200pF	„	CTH310
C10	2200pF	„	CTH310	C27	2200pF	„	CTH310
C11	2200pF	„	CTH310	C28	33pF	„	SCT12
C12	2200pF	„	CTH310	C29	100pF	„	SCT13
C13	47pF	„	SCT12	C30	100pF	„	SCT13
C14	2pF		CC125S	C31	1000pF	„	CC150
C15	2200pF	„	CTH310	C32	0.05μF	Paper	CP34H
C16	2200pF	„	CTH310	C33	3000pF	Ceramic	CC152
C17	2200pF	„	CTH310	C34	50μF	12vw Electrolytic	CE87B
C18	2200pF	„	CTH310	C35	50μF	350vw „	CE171LE
C19	2200pF	„	CTH310	C36	50μF	350vw „	CE171LE
C20	2200pF	„	CTH310	C37	5000pF	1000vw Paper	CP45W
C21	2200pF	„	CTH310				
C22	2200pF	„	CTH310				

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE
R1	2.2kΩ	R12	33kΩ
R2	220Ω	R16	100kΩ
R3	47kΩ	R17	100kΩ
R4	22kΩ	R18	1MΩ
R5	2.2kΩ	R19	100kΩ
R6	330Ω	R20	680Ω
R8	1kΩ	R21	1MΩ
R9	220Ω	R22	1MΩ
R10	1kΩ	R26	47kΩ
R11	220Ω	R27	47kΩ

All resistors High Stability $\pm 10\%$ $\frac{1}{2}$ watt rating.

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R7	1kΩ 5W	A1/1
R13	47kΩ 1W	BTB
R14	27kΩ 1W	BTB
R15	15kΩ 1W	BTB
R23	1.5kΩ 5W	A1/1
R24	120Ω 1W	BWF1
R25	120Ω 1W	BWF1

SUNDRIES.

		TYPE	MANUFACTURER
1	Chassis		
1	2A Fuse & holder	L365	BELLING-LEE
1	ON/OFF Switch	S259	A. F. BULGIN & CO., LTD.
1	Pilot Light holder	D370 Red	A. F. BULGIN & CO., LTD.
1	International Octal Valve holder	B8/U	McMURDO INSTRUMENT CO., LTD.
8	B8A Miniature Valve holders	BM8/E	McMURDO INSTRUMENT CO., LTD.

CIRCUIT No. 6.

Adaptor with Phase Discriminator

The input stage is a cascode circuit which is constructed around a double triode. The anode of the first triode is coupled to the cathode of the second by a shunt feed circuit comprising a 5k ohm resistor, a 100 pF capacitor, and a choke, type CH4, the characteristics of which are given in the chapter dealing with winding details.

Total stage gain so obtained is only slightly inferior to that produced by a pentode, and the noise level is much lower.

The frequency changer is also constructed around a double triode using a circuit arrangement which has already been described.

All three I.F. stages consist of high-slope pentodes with their cathodes connected to the chassis. A bias of approximately −3V is provided by a resistor inserted in the negative supply lead.

Detection is effected by means of valve type EQ80 in the manner already explained The maximum modulation level produces an A.F. signal of the order of 15V which is adequate to drive the output stage of an existing receiver without need for additional audio amplification.

COMPONENTS LIST

CIRCUIT No. 6

COILS & CHOKES.

QTY.	REF.	PURPOSE
1	L1	Aerial Coil
1	L2	R.F. Coupling
1	L3	Oscillator Coil
2	CH2	Heater Chokes
2	CH3	Mains Filter Chokes
1	CH4	R.F. Choke

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
I.F.T.1.	1st I.F. Transformer	10.7 Mc/s	IFT602
I.F.T.2.	2nd I.F. Transformer	10.7 Mc/s	IFT604
I.F.T.3.	3rd I.F. Transformer	10.7 Mc/s	IFT604
D.T.1.	Phase Detector Transformer	10.7 Mc/s	DT103
T.1.	Mains Transformer.		MT1224
	Primary	230 volts	
	Secondaries	250-0-250v 60mA	
		6.3v 3A	

VALVES.

REF.	TYPE	
V1	ECC81	MULLARD
V2	,,	,,
V3	EF80	,,
V4	,,	,,
V5	EF80	MULLARD
V6	EQ80	,,
V7	EZ80	,,

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM	TYPE
C1, C2	2 x 12pF	Variable	U102
C3	2 to 30pF	Air spaced trimmer	C804
C4	2 to 30pF	Air spaced trimmer	C804
C5	2 to 30pF	Air spaced trimmer	C804
C28	2 to 30pF	Air spaced trimmer	C804
C29	2 to 30pF	Air spaced trimmer	C804

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE		FORM	TYPE
C6	1500pF	Ceramic	CTH310	C23	3300pF		Ceramic	CTH315
C7	1500pF	Ceramic	CTH310	C24	3300pF		Ceramic	CTH315
C8	2200pF	Ceramic	CTH310	C25	3300pF		Ceramic	CTH315
C9	220pF	Ceramic	SCT14	C26	4700pF		Ceramic	CTH315
C10	1500pF	Ceramic	CTH310	C27	4700pF		Ceramic	CTH315
C11	100pF	Ceramic	SCT13	C30	3300pF		Ceramic	CTH315
C12	47pF	Ceramic	SCT12	C31	4700pF		Ceramic	CTH315
C13	3300pF	Ceramic	CTH315	C32	50μF	12vw	Electrolytic	CE77B
C14	2pF	Ceramic	CC125S	C33	50μF	350vw	Electrolytic	CE171LE
C15	2200pF	Ceramic	CTH310	C34	50μF	350vw	Electrolytic with insulated mounting	CE171LE
C16	2200pF	Ceramic	CTH310					
C17	22pF	Ceramic	SCT11	C35	32μF	350vw	Electrolytic	CE93LE
C18	220pF	Ceramic	SCT14	C36	0.05μF	350vw	Paper	CP35N
C19	22pF	Ceramic	SCT11	C37	150pF		Ceramic	SCT13
C20	3300pF	Ceramic	CTH315	C38	1000pF		Ceramic	CC150
C21	3300pF	Ceramic	CTH315	C39	0.1μF	200vw	Paper	CP36H
C22	3300pF	Ceramic	CTH315	C40	.005μF	1000vw	Paper	CP45W

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE	REF.	VALUE	REF.	VALUE
R1	200Ω	R7	4.7kΩ	R14	470kΩ	R21	560Ω
R2	470Ω	R8	470Ω	R15	4.7kΩ	R22	680kΩ
R3	4.7kΩ	R9	10kΩ	R16	470kΩ	R23	100kΩ
R4	4.7kΩ	R10	15kΩ	R17	4.7kΩ	R25	100Ω
R5	200Ω	R11	470kΩ	R18	22kΩ	R26	100Ω
R6	1MΩ	R13	4.7kΩ	R20	3.9kΩ	R28	220kΩ

All resistors High Stability ±10% ½ watt rating.

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R12	2.2kΩ 1W.	BWF1
R19	33kΩ 2W.±5%	R850
R24	2.2kΩ 5W.	A1/1
R27	150Ω 2W.±5%	R850

SUNDRIES.

		TYPE	MANUFACTURER
1	Chassis		
1	2A Fuse & Holder	L365	BELLING-LEE
1	ON/OFF Switch	S259	A. F. BULGIN & CO. LTD.
2	B.9.A. (Noval) Valve Holders	XM9/UC-1	McMURDO INSTRUMENT CO. LTD.
2	Screening Cans	75	McMURDO INSTRUMENT CO. LTD.
5	B.9.A. (Noval) Valve Holders	XM9/U	McMURDO INSTRUMENT CO. LTD.

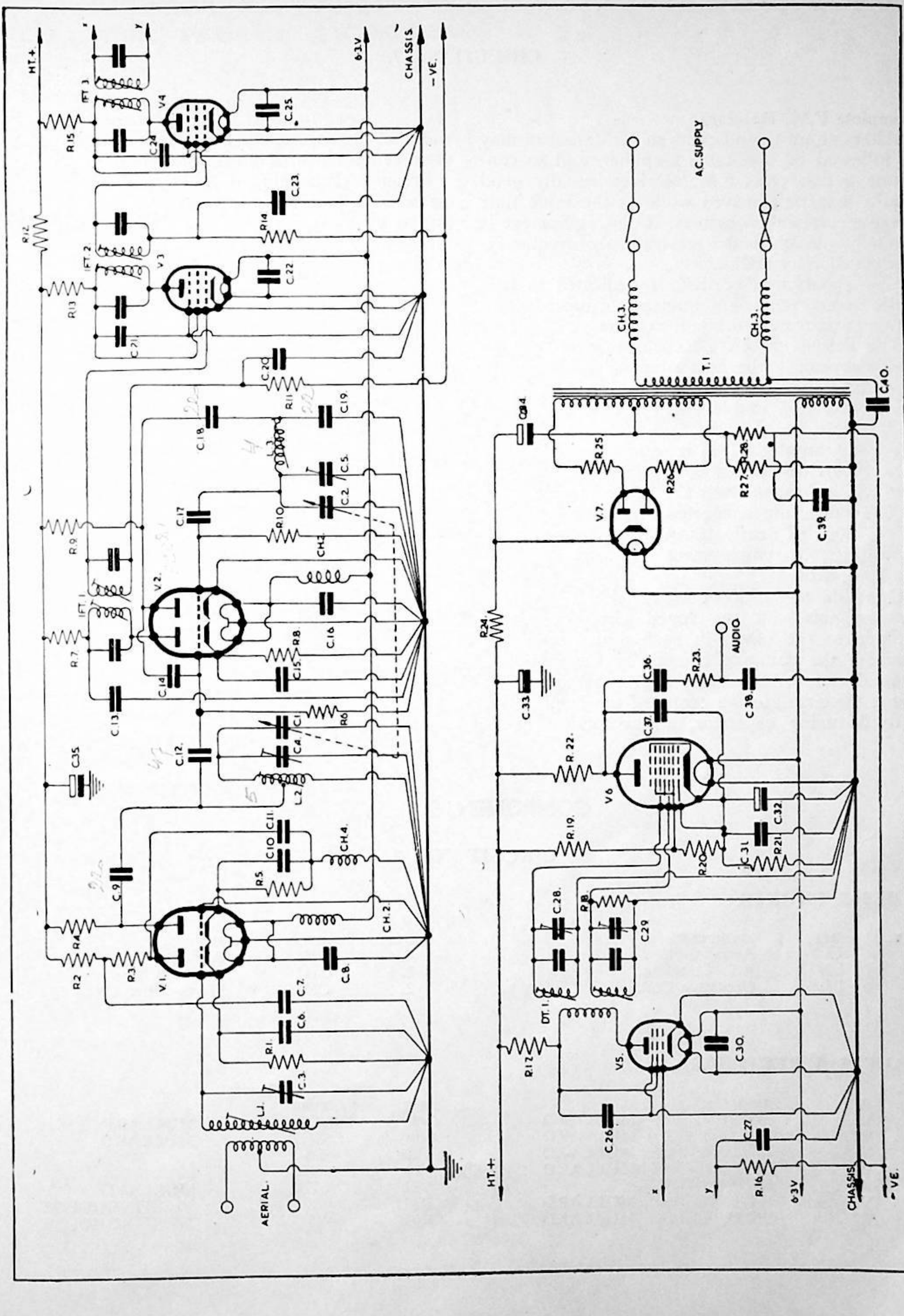


Fig. 29. Circuit No. 6. Adaptor with Phase Discriminator.

CIRCUIT No. 7.

Complete F.M. Receiver

Although all the adaptors so far described may be followed by a suitable amplifier, and so constitute a first class F.M. receiver, equally good results may be achieved while at the same time effecting certain economies, if the equipment is specially designed to receive only frequency-modulated transmissions.

The apparatus described is dedicated to true music lovers who want immaculate reproduction without incurring exorbitant expense.

The design chosen for each stage is the one which appears to be best adapted to the end in view, bearing in mind the desirability of making the construction simple and the components list short.

V.H.F. amplification is effected by means of a grounded-grid triode. It should be noted that this is formed from the two elements of an ECC91 which are connected in parallel. In this way a slope of nearly 10mA/V is obtained, thus permitting the employment of low-impedance coupling networks.

One side of the 300 ohm aerial is taken to a tapping point on the tuned circuit and the cathode to the other, in such a manner as to diminish the damping caused by the very low internal output impedance of the cathode. By tuning the circuit to the centre of the band, using a fixed tuning capacitor, an acceptance band-width of approximately 20 Mc/s is obtained. A variable tuning capacitor is not therefore required.

Frequency changing is again accomplished by means of a double triode in a circuit arrangement similar to that used in circuit No. 6.

A conventional discriminator has been arranged to give minimum distortion, and is preceded by one limiter stage.

The A.F. section includes two stages of pre-amplification separated by a two-channel tone corrector which serves primarily for adjusting the level of the middle-register response in accordance with listening conditions. Following this, we have a phase-splitter with 100% negative feedback and adjustable balancing which feeds the push-pull triode output stage. A negative feedback voltage is taken from the secondary of the output transformer and applied to the cathode of the second pre-amplifier valve.

The use of triode connected 6L6 valves for the final stage, makes it possible to obtain a negligible degree of distortion without recourse to complicated correction networks. Final results depend to a large extent, however, on the quality of the output transformer which must have a core section of at least 1.5 to 2 sq. inches.

VR5 is a pre-set control which enables the two output valves to be accurately balanced sc that they both draw equal anode currents.

COMPONENTS LIST

CIRCUIT No. 7

COILS & CHOKES.

QTY.	REF.	PURPOSE	QTY.	REF.	PURPOSE
1.	L1	Aerial Coil.	1.	CH1	R.F. Choke.
1.	L2	R.F. Coupling.	2.	CH2	Heater Chokes.
1.	L3	Oscillator Coil.	2.	CH3	Mains Filter Chokes.

VALVES & RECTIFIERS.

REF.	TYPE		REF.	TYPE	
V1	ECC91	MULLARD	V8	ECC82	MULLARD
V2	ECC81	MULLARD	V9	6SN7	MULLARD
V3	EF93	MULLARD	V10	6L6	
V4	EF93	MULLARD	V11	6L6	
V5	6AU6		V12	GZ32	MULLARD
V6	EB91	MULLARD	RM1	W6	WESTINGHOUSE
V7	EM34	MULLARD	RM2	W6	WESTINGHOUSE

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM	TYPE
C.1. C.2	2 × 12pF	Variable	U102
C.3	2 to 30pF	Air spaced trimmer.	C804
C.4	2 to 30pF	Air spaced trimmer.	C804

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE	FORM	TYPE
C5	2200pF	Ceramic	CTH310	C32	150pF	Ceramic	SCT13
C6	2200pF	Ceramic	CTH310	C33	1500pF	Ceramic	CC150
C7	2200pF	Ceramic	CTH310	C34	3000pF	Ceramic	CC152
C8	47pF	Ceramic	SCT12	C35	0.05μF	Paper	CP34H
C9	2200pF	Ceramic	CTH310	C36	50μF 12vw	Electrolytic	CE87B
C10	2200pF	Ceramic	CTH310	C37			
C11	2200pF	Ceramic	CTH310		32-32μF 450vw	Electrolytic	CE28PE
C12	2200pF	Ceramic	CTH310	C38			
C13	22pF	Ceramic	SCT11	C39	0.05μF	Paper	CP37S
C14	220pF	Ceramic	SCT14	C40	220pF	Ceramic	SCT14
C15	22pF	Ceramic	SCT11	C41	2200pF	Ceramic	CTH310
C16	2200pF	Ceramic	CTH310	C42	2200pF	Ceramic	CTH310
C17	2200pF	Ceramic	CTH310	C43	0.02μF	Paper	CP33N
C18	2200pF	Ceramic	CTH310	C44	0.05μF	Paper	CP37S
C19	2200pF	Ceramic	CTH310	C45	32μF 450vw	Electrolytic	CE28PE*
C20	4700pF	Ceramic	CTH315	C46	0.1μF	Paper	CP46S
C21	4700pF	Ceramic	CTH315	C47	0.1μF	Paper	CP46S
C22	4700pF	Ceramic	CTH315	C48	0.1μF	Paper	CP46S
C23	4700pF	Ceramic	CTH315	C49	0.1μF	Paper	CP46S
C24	32μF 450vw	Electrolytic	CE28PE*	C50	50μF 50vw	Electrolytic	CE17DE
C25	150pF	Ceramic	SCT13	C51	50μF 50vw	Electrolytic	CE17DE
C26	4700pF	Ceramic	CTH315	C52	32μF 500vw	Electrolytic	512
C27	4700pF	Ceramic	CTH315	C53	32μF 500vw	Electrolytic	512 with insulated mounting.
C28	4700pF	Ceramic	CTH315				
C29	33pF	Ceramic	SCT12	C54	50μF 25vw	Electrolytic	CE88CE
C30	10,000pF	Ceramic	CTH422	C55	.005μF 1000vw	Paper	CP45W
C31	150pF	Ceramic	SCT13				

* ½ of a dual electrolytic capacitor 32-32μF

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
CH.LF	Smoothing Choke 15H	150mA	SC402
I.F.T.1	1st I.F. Transformer	10.7Mc/s	IFT602
I.F.T.2	2nd I.F. Transformer	10.7Mc/s	IFT603
I.F.T.3	3rd I.F. Transformer	10.7Mc/s	IFT603
D.T.1	Discriminator Transformer	10.7Mc/s	DT102
T.1	Output Transformer Ratio	23 : 1	O.P.1345
	Primary	8000Ω a-a	
		40mA each half.	
	Secondary to match 15Ω loudspeaker.		
T.2	Mains Transformer		MT1228
	Primary	230v	
	Secondaries 400-0-400v	150 mA	
	6.3v C.T.	3A	
	6.3v	3A	
	5.0v	3A	

POTENTIOMETERS.

REF.	VALUE		FUNCTION	MANUFACTURER	TYPE
VR1	1.5 MΩ	Log.	Volume control	Dubilier	C
VR2	1.0 MΩ	Log.	Treble control	Dubilier	C
VR3	1.0 MΩ	Log.	Bass control	Dubilier	C
VR4	0.1 MΩ	Linear Pre-set	(Dynamic Balance)	Colvern	CLR 4001
VR5	100Ω 3W	Linear Pre-set	(Static Balance)	Colvern	CLR 901

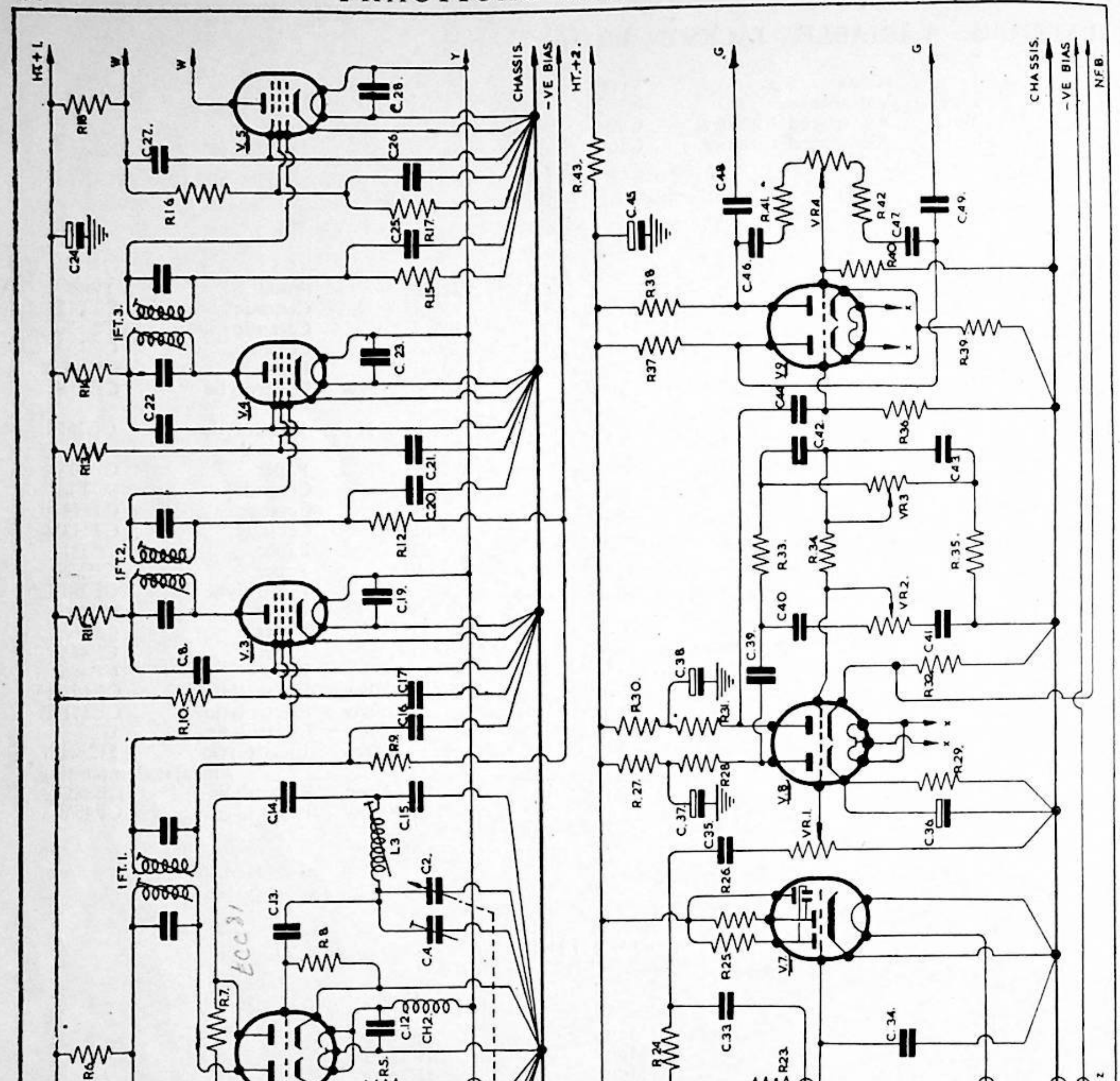


Fig. 30. Circuit No. 7. Complete F.M. Receiver.

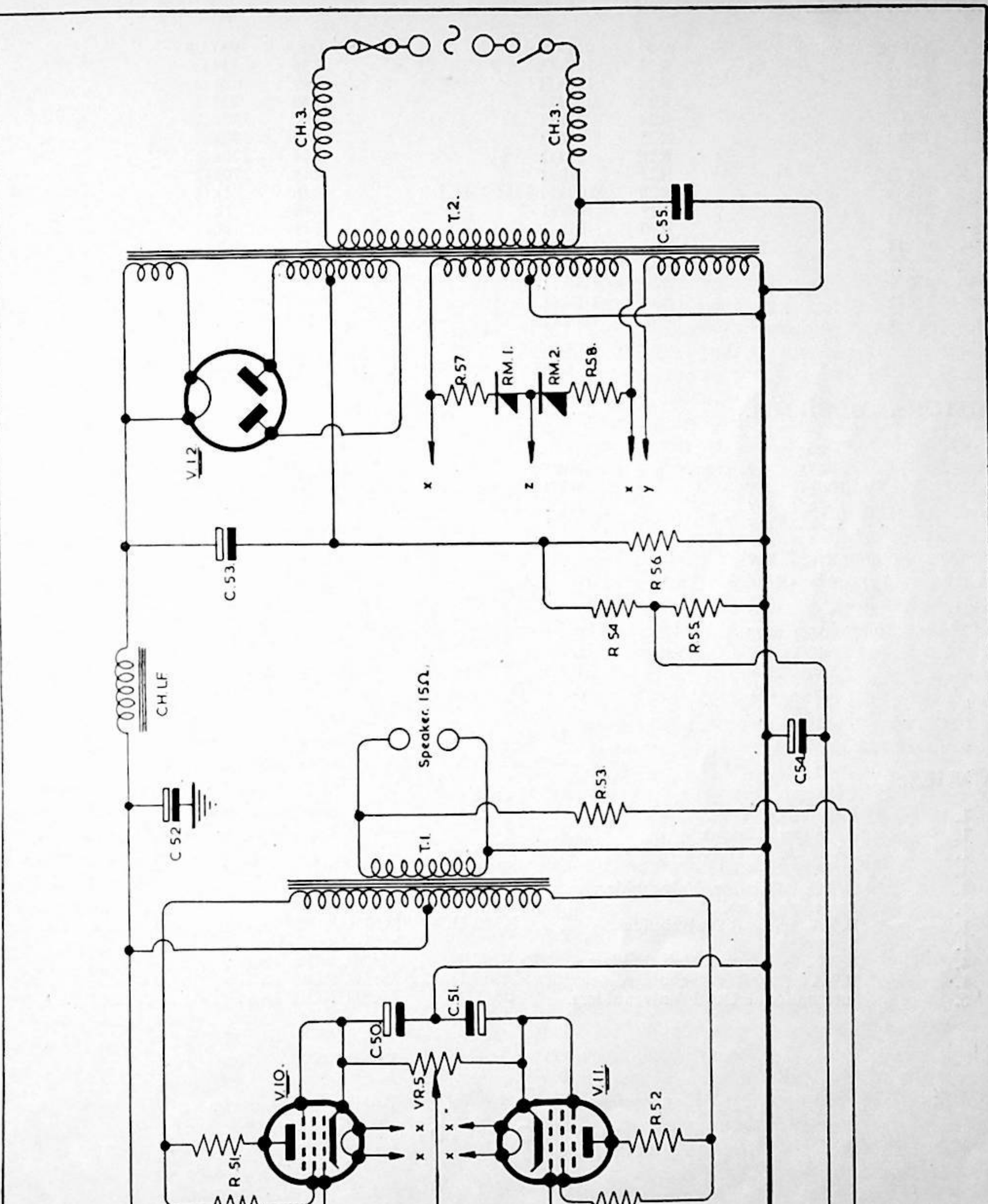


Fig. 31. Circuit No. 7 (continued).

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE	REF.	VALUE
R2	1.5kΩ	R21	100kΩ	R36	1MΩ
R3	22kΩ	R22	100kΩ	R39	1.2kΩ
R4	2.2kΩ	R23	1.2MΩ	R40	2MΩ
R5	470Ω	R24	27kΩ	R41	390kΩ
R6	470Ω	R25	1MΩ	R42	390kΩ
R7	10kΩ	R26	1MΩ	R44	270kΩ
R8	18kΩ	R27	27kΩ	R45	270kΩ
R9	15kΩ	R28	100kΩ	R46	1kΩ
R10	27kΩ	R29	1.8kΩ	R48	1kΩ
R11	470Ω	R30	15kΩ	R49	100Ω
R12	15kΩ	R31	100kΩ	R50	100Ω
R13	27kΩ	R32	1.8kΩ	R53	27kΩ
R14	470Ω	R33	100kΩ	R55	2.2kΩ
R15	27kΩ	R34	100kΩ	R57	47kΩ
R17	27kΩ	R35	100kΩ	R58	47kΩ

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R1	47Ω ½W	BWF2
R16	100kΩ 1W	BTB
R18	100kΩ 1W	BTB
R19	1.5kΩ 1W	BTB
R20	3Ω 1W	BWF1
R37	47kΩ 1W	BTB
R38	47kΩ 1W	BTB
R43	1kΩ 5W	A1/1
R47	350Ω 5W	A1/1
R51	47Ω ½W	BWF2
R52	47Ω ½W	BWF2
R54	56kΩ 1W	BTB
R56	500Ω 5W	A1/1

SUNDRIES.

		TYPE	MANUFACTURER
1.	Receiver Chassis.		
1.	Amplifier Chassis.		
1.	3A Fuse & Holder	L356	BELLING-LEE
1.	ON/OFF Switch.	S259	A. F. BULGIN & CO. LTD.
1.	B.7.G. Miniature Valveholder.	XM7/UC-1	McMURDO INSTRUMENT CO. LTD.
1.	Screening Can.	45	McMURDO INSTRUMENT CO. LTD.
1.	B.9.A (Noval) Valveholder.	XM9/UC-1	McMURDO INSTRUMENT CO. LTD.
1.	Screening Can.	75	McMURDO INSTRUMENT CO. LTD.
4.	B.7.G. Miniature Valveholders.	XM7/U	McMURDO INSTRUMENT CO. LTD.
1.	B.9.A (Noval) Valveholder.	XM9/U	McMURDO INSTRUMENT CO. LTD.
5.	International Octal Valveholders.	B8/U	McMURDO INSTRUMENT CO. LTD.

CIRCUIT No. 8.

Combined A.M./F.M. Receiver

In the near future, the standard commercial requirement for a medium or high quality radio receiver will include the provision of an 87-102 Mc/s F.M. Band.

In order to achieve a simple design, at a price which is not prohibitive, it is essential to assign the maximum possible number of functions to each section, while restricting switching operations to the minimum necessary.

A proposed combined receiver design must take into account the peculiarities of the F.M. waveband: the necessity for a V.H.F. stage, a special frequency changer, a different intermediate frequency, the need for an extra I.F. stage, and a different detector.

The preferred solution, which is not perhaps strictly the most economic, but which has the advantage of the least complicated switching, consists in using two separate valves for the V.H.F. and the F.M. frequency changer, and using the hexode (or heptode) section of the A.M. frequencv changer as the first I.F. amplifier.

It has been verified elsewhere that there are no drawbacks in connecting the two types of I.F. transformers in series or even in mounting them in the same screening can. The switching in this section of the receiver is thereby greatly simplified: it suffices to short circuit the primary of the second 10.7 Mc/s transformer.

It is not necessary to switch any of the transformers feeding the detectors, since these are completely separate. The only switch left is that selecting which of the two detector outputs is fed into the A.F. amplifier.

In a design devised in this way, all the valves are used in the F.M. setting, while, for the A.M. setting of the switch, the receiver becomes a conventional 4 valve receiver.

Circuit No. 8 shows a receiver which includes a V.H.F. valve of the high-slope pentode type and a double-triode frequency changer. This is followed by a 10.7 Mc/s I.F. transformer, in the secondary circuit of which the first switch is found: it permits the selection of the F.M. channel, or of a normal aerial circuit for ordinary broadcast reception.

V3, the third valve is a triode-heptode which operates in the usual way on A.M. On F.M., the H.T. voltage is removed from the triode anode, and the grid of the heptode section becomes connected to the first 10.7 Mc/s I.F. transformer. In the anode circuit of this valve two I.F. transformers are to be found, connected in series, one tuned to 470 kc/s, the other to 10.7 Mc/s. The primary of the latter is located on the "cold" side of the combination. Relative positions of the secondaries are inverted, the one tuned to 470 kc/s being on the chassis side. For A.M. reception, the F.M. primary is short-circuited, and this has the effect of reducing the secondary impedance to a low level. So far as the transmission of the signal is concerned, it is practically the same as if the second transformer were not there. On the other hand, the presence of the A.M. transformer when receiving F.M. is unimportant, because the tuning capacitances are equivalent to a short circuit at the frequency of 10.7 Mc/s.

After the I.F. valve there are still two more I.F. transformers with their primaries connected in series. Both secondaries, however, are connected to completely separate circuits.

In the F.M. section there is an asymmetric ratio detector generating a negative A.G.C. voltage which controls the indicator valve and the V.H.F. valve. A.M. detection is conventional and does not require comment. It feeds an A.G.C. voltage to the triode-heptode and to the I.F. pentode. While operating on F.M. these valves receive a fixed bias.

The last switch is that which connects the volume control to one or other of the A.F. outputs, or to the gramophone pick-up terminals.

It should be appreciated that the operation of switching from A.M. to F.M. has been reduced to the minimum number of contacts, two only are located in parts of the circuit where precautions are required from the point of view of length of connections.

Finally the set terminates in a current output pentode having considerable negative feedback, in which a combination Bass and Treble balance control has been incorporated.

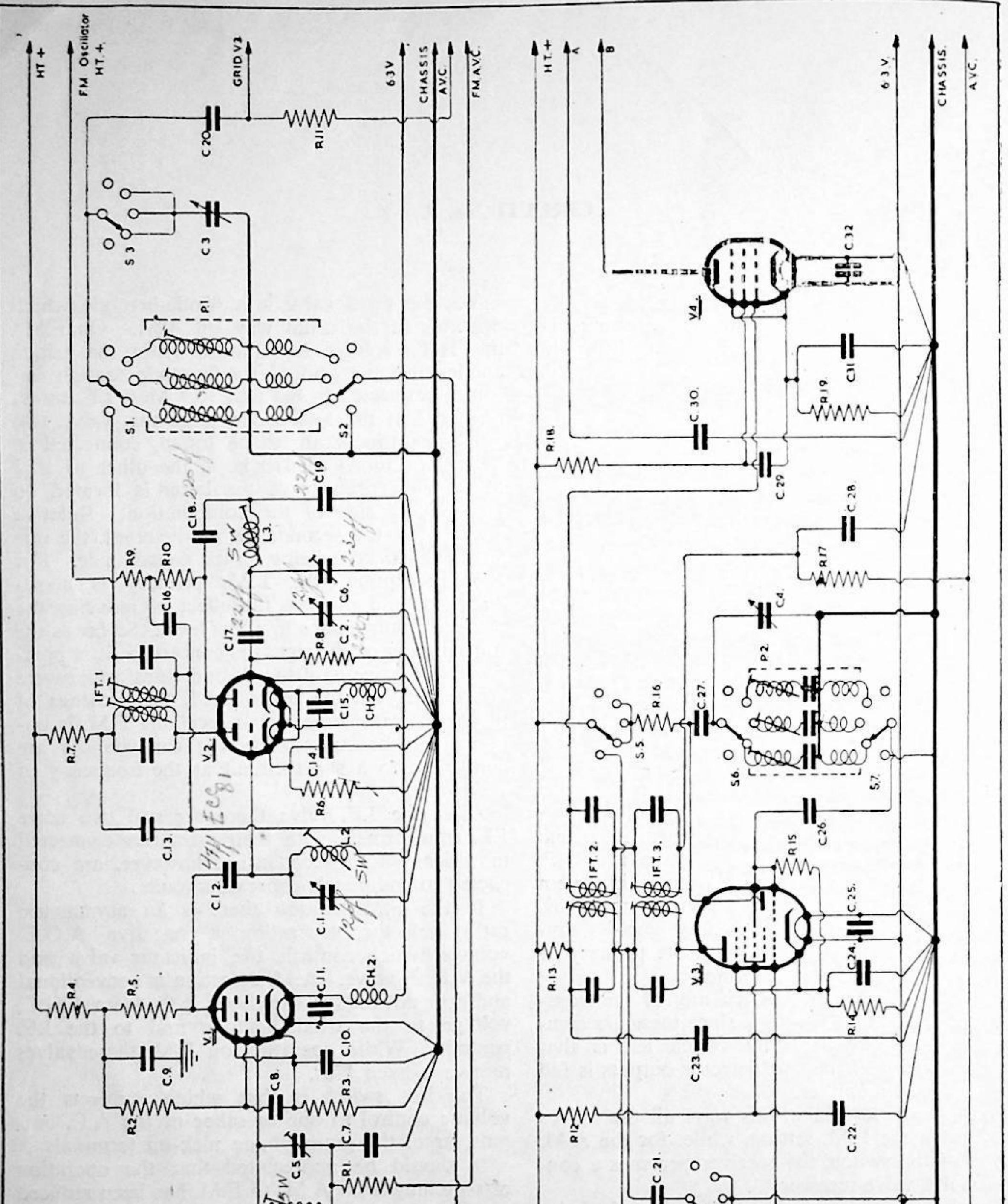


Fig. 32. Circuit No. 8. Combined A.M./F.M. Receiver.

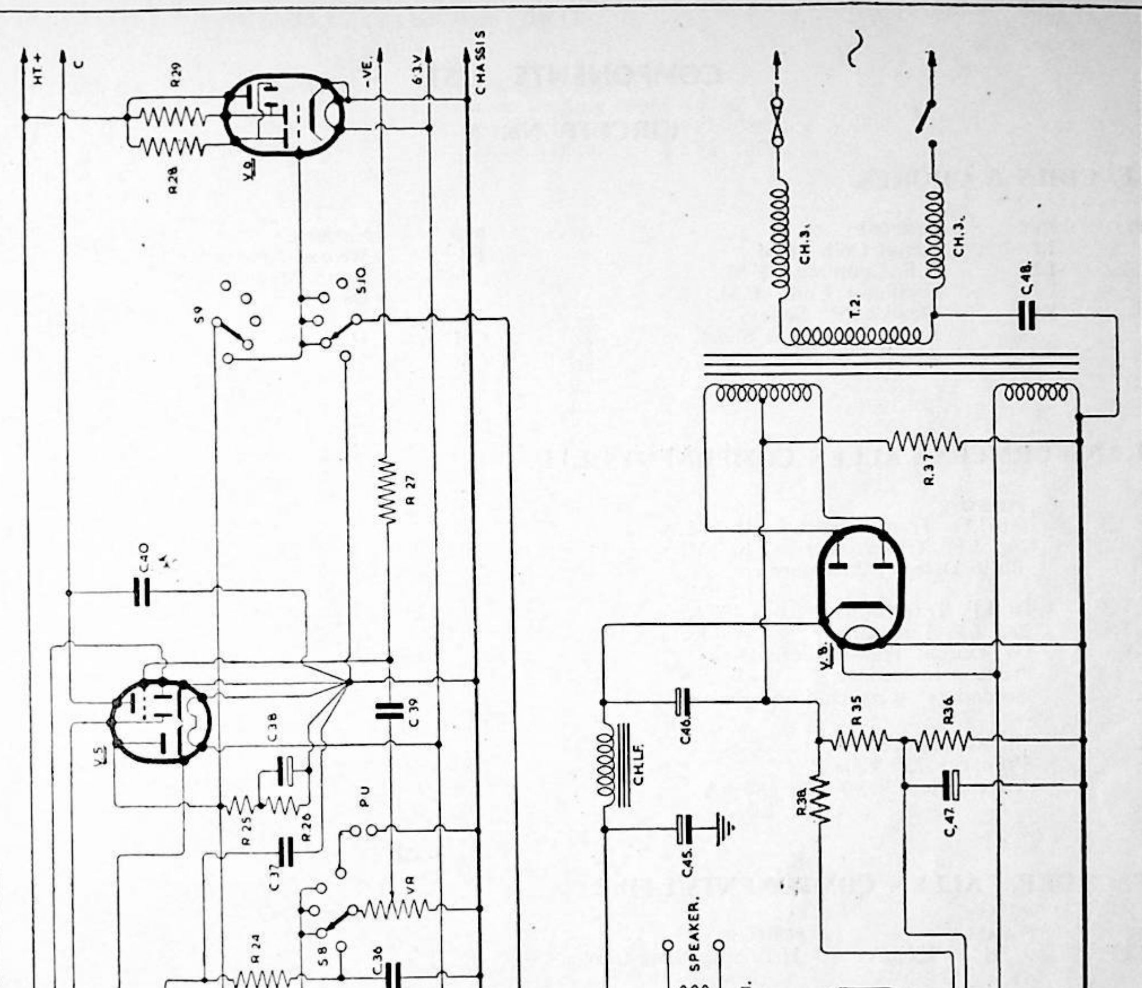


Fig. 33. Circuit No. 8 (continued).

COMPONENTS LIST

CIRCUIT No. 8

R.F. COILS & CHOKES.

QTY.	REF.	PURPOSE
1.	L1	Aerial Coil. F.M.
1.	L2	R.F. Coupling. F.M.
1.	L3	Oscillator Coil. F.M.
1.	P1	Wearite "P" Series Long, Medium & Short Aerial Coupling.
1.	P2	Wearite "P" Series Long, Medium & Short Oscillator Coils complete with fixed "padders"
2.	CH2	Heater Chokes
2.	CH3	Mains Filter Chokes

TRANSFORMERS. ALLEN COMPONENTS LTD.

REF.	PURPOSE		TYPE
I.F.T.1	1st I.F. Transformer	10.7 Mc/s	IFT602
I.F.T.2	2nd I.F. Transformer	10.7 Mc/s	IFT603
D.T.1	Ratio Detector Transformer	10.7 Mc/s	DT101
I.F.T.3	1st I.F. Transformer	470 Kc/s	158/1
I.F.T.4	2nd I.F. Transformer	470 Kc/s	158/2
T.1	5W. Output Transformer Primary Impedance Secondary to match Loudspeaker	5kΩ	O.P.1347
T.2	Mains Transformer. Primary: 230 volts. Secondaries: 300-0-300v 80 mA 6.3v 2.5A		M.T.1230

L.F. CHOKE. ALLEN COMPONENTS LTD.

REF.	VALUE	PURPOSE	TYPE
CH.LF	5H 100mA	H.T. Smoothing Choke.	SC400

CAPACITORS. T.C.C.

REF.	VALUE	FORM	TYPE	REF.	VALUE	FORM	TYPE
C7	2200pF	Ceramic	CTH310	C29	0.05μF	Paper	CP35N
C8	2200pF	Ceramic	CTH310	C30	0.05μF	Paper	CP35N
C9	2200pF	Ceramic	CTH310	C31	0.05μF	Paper	CP34H
C10	2200pF	Ceramic	CTH310	C32	4700pF	Ceramic	CTH315
C11	2200pF	Ceramic	CTH310	C33	0.05μF	Paper	CP34H
C12	47pF	Ceramic	SCT12	C34	100pF	Ceramic	SCT13
C13	2200pF	Ceramic	CTH310	C35	220pF	Ceramic	SCT14
C14	2200pF	Ceramic	CTH310	C36	1500pF	Ceramic	CTH310
C15	2200pF	Ceramic	CTH310	C37	220pF	Ceramic	SCT14
C16	2200pF	Ceramic	CTH310	C38	50μF 12vw	Electrolytic	CE87B
C17	22pF	Ceramic	SCT11	C39	0.05μF	Paper	CP34H
C18	220pF	Ceramic	SCT14	C40	220pF	Ceramic	SCT14
C19	22pF	Ceramic	SCT11	C41•	32μF 450vw	Electrolytic	CE28PE
C20	100pF	Ceramic	SCT13	C42	0.05μF	Paper	CP35N
C21	10,000pF	Ceramic	CTH422	C43	470pF	Ceramic	SPG1
C22	0.05μF	Paper	CP35N	C44	0.1μF	Paper	CP36H
C23	0.05μF	Paper	CP35N	C45•	32μF 450vw	Electrolytic	CE28PE
C24	0.05μF	Paper	CP34H	C46	32μF 500vw	Electrolytic	512 with insulated mounting
C25	2200pF	Ceramic	CTH310				
C26	47pF	Ceramic	SCT12	C47	50μF 12vw	Electrolytic	CE87B
C27	220pF	Ceramic	SCT14	C48	0.005μF 1000vw	Paper	CP45W
C28	0.05μF	Paper	CP34H	C49	50μF 25vw	Electrolytic	CE88CE

• ½ of a dual electrolytic capacitor 32-32μF

CAPACITORS. VARIABLE. JACKSON BROS.

REF.	VALUE	FORM
C1. C2. C3. C4.	12-12-490-490pF	Band Spread Variable Condenser 2 gang 490pF+12pF
C5	2 to 30pF	Air spaced trimmer TYPE C804.
C6	2 to 30pF	Air spaced trimmer TYPE C804.

RESISTORS. T.S.L.

REF.	VALUE	REF.	VALUE	REF.	VALUE	REF.	VALUE
R1	22kΩ	R10	10kΩ	R19	150Ω	R29	1MΩ
R2	56kΩ	R11	1MΩ	R20	2.2kΩ	R31	220kΩ
R3	150Ω	R12	39kΩ	R22	470kΩ	R32	1MΩ
R4	470Ω	R13	2.2kΩ	R23	47kΩ	R33	47kΩ
R5	10kΩ	R14	220Ω	R24	27kΩ	R34	1kΩ
R6	470Ω	R15	47kΩ	R25	1KΩ	R35	22kΩ
R7	470Ω	R16	33kΩ	R26	27kΩ	R36	4.7kΩ
R8	22kΩ	R17	220kΩ	R27	1MΩ	R38	100kΩ
R9	4.7kΩ	R18	56kΩ	R28	1MΩ		

All resistors ±10% high stability, ½ watt rating.

RESISTORS. DUBILIER.

REF.	VALUE	TYPE
R21	47Ω ¼ w.	BWF2
R30	1.5kΩ 2W±5%	R850
R37	225Ω 5W.	A1/1
R39	220Ω 1W.	BWF1

POTENTIOMETERS.

REF.	VALUE		FUNCTION	TYPE	MANUFACTURER
VR1	0.25 MΩ	Log.	Volume control	C	Dubilier
VR2	0.5 MΩ	Log.	Treble Boost/Cut	C	Dubilier

VALVES.

REF	TYPE		REF.	TYPE	
V1	EF85	MULLARD	V5	EABC80	MULLARD
V2	ECC81	,,	V6	EM34	,,
V3	ECH81	,,	V7	EL90	,,
V4	EF85	,,	V8	EZ80	,,

SUNDRIES.

		TYPE	MANUFACTURER
1	Chassis		
1	2A Fuse & Holder	L356	BELLING-LEE
1	ON/OFF Switch	S259	A. F. BULGIN & CO. LTD.
2	B9A (Noval) Valveholders	XM9/UC1	McMURDO INSTRUMENT CO. LTD.
2	Screening Cans	75	McMURDO INSTRUMENT CO. LTD.
4	B9A (Noval) Valveholder	XM9/U	McMURDO INSTRUMENT CO. LTD.
1	B7G Miniature Valveholder	XM7/U	McMURDO INSTRUMENT CO. LTD.
1	International Octal Valveholder	B8/U	McMURDO INSTRUMENT CO. LTD.
1	10 pole 5 way 7 bank W/C Switch (S1, S2————S9, S10)	14,222/B.7	A.B. METAL PRODUCTS LTD.

ALIGNMENT OF F.M. RECEIVERS

It is no more difficult to align an F.M. receiver than an A.M. receiver, and this may be accomplished by means of a simple oscillator with amplitude modulation, and a valve voltmeter or a high-resistance voltmeter (5000 ohm/volt at least). The employment of a special frequency-modulated signal generator and oscilloscope would allow this operation to be carried out much more rapidly, but most constructors will not have these instruments at their disposal.

The procedure varies a little according to the detection system in the receiver. We shall start by considering the case of the ratio detector, because this is by far the most common.

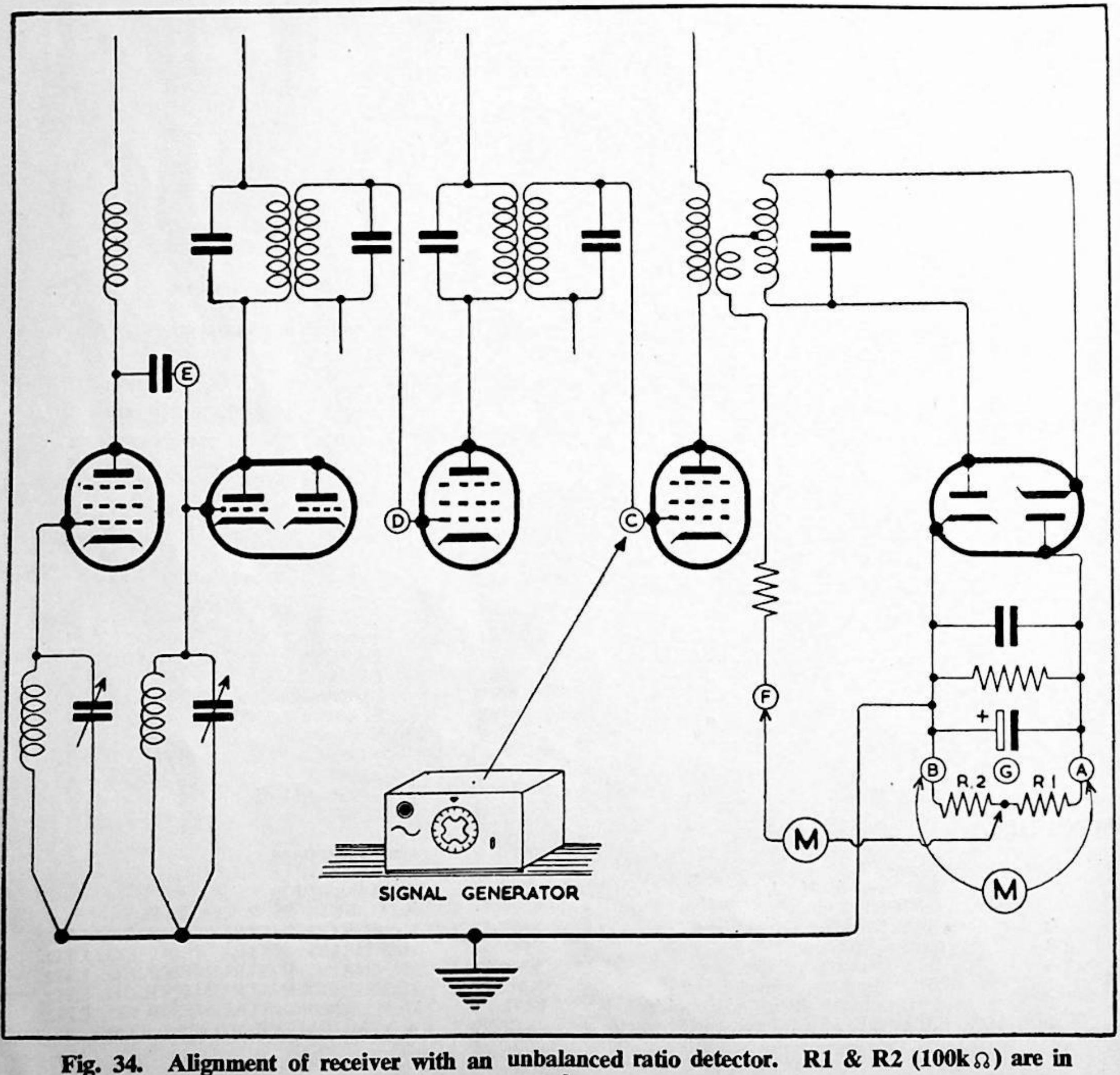


Fig. 34. Alignment of receiver with an unbalanced ratio detector. R1 & R2 (100k Ω) are in circuit for measurement purposes only.

(A) ADJUSTMENT OF I.F. STAGES

1. Connect the measuring instrument (10 volt range) between the points A and B (fig. 34) and inject a 10.7 Mc/s sine-wave signal of approximately 50mV at the point C. Adjust the primary for maximum reading, using the lowest voltage which will give a clear indication, so as to avoid saturation of the I.F. valve.

2. Apply the signal (reduced in magnitude to give the same deflection) to the point D. Adjust the I.F. transformer circuits for maximum reading. In order to obtain a clear maximum, it may be necessary to damp the primary while tuning the secondary and vice-versa. This is done by connecting in shunt a resistance of 4700 ohms.

3. Repeat the same operation on the earlier I.F. transformers, reducing the input signal as progress is made towards the receiver input.

4. Adjust the secondary of the detection transformer with the voltmeter connected between points F and G. In the case of an asymmetric detector, G is located at the junction of two 100k Ω resistors temporarily connected across A and B thereby forming an effective centre point of the output impedance.

The secondary is adjusted to give a minimum reading (equal to zero for a properly adjusted detector).

5. Repeat operation **1.** and readjust the primary if required.

(B) ALIGNMENT OF V.H.F. STAGE

Make use of a harmonic of the oscillator or, alternatively, the signal from a transmitter. Adjust the V.H.F. circuits to give a maximum reading on a voltmeter connected across A and B. Make this adjustment, as far as possible, at the centre (95 Mc/s), and at the two ends of the waveband (87 Mc/s and 102 Mc/s). The trimmers and dust cores should be utilised for this adjustment in the same way as for an ordinary A.M. receiver.

(C) A.M. REJECTION TEST

Connect the oscillator to the point E and inject an *amplitude-modulated* signal. Connect headphones or an amplifier to the A.F. output. On varying the frequency adjustment of the oscillator, a sound will be heard so long as the frequency is not exactly 10.7 Mc/s, but on this latter frequency there should be complete extinction.

(D) ACCEPTANCE BANDWIDTH TEST

With the oscillator connected to E and the indicating instrument across F and G, the frequency is slowly traversed from 10.5 Mc/s to 10.9 Mc/s. There should be a voltage maximum at 10.6 Mc/s, a zero voltage at 10.7 Mc/s, and another maximum *of inverse polarity* at 10.8 Mc/s. *The two maxima should have the same magnitude.*

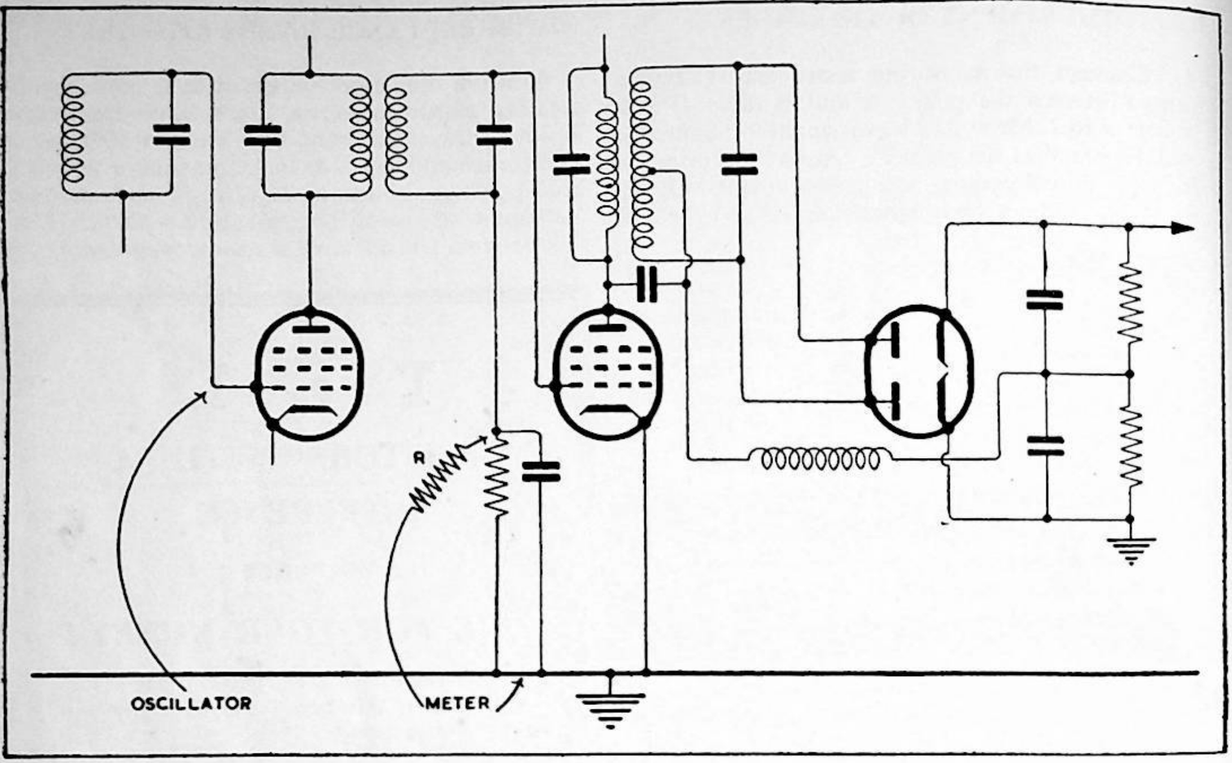


Fig. 35. In the case of a discriminator, the voltage is measured at the terminals of the limiter grid resistor.

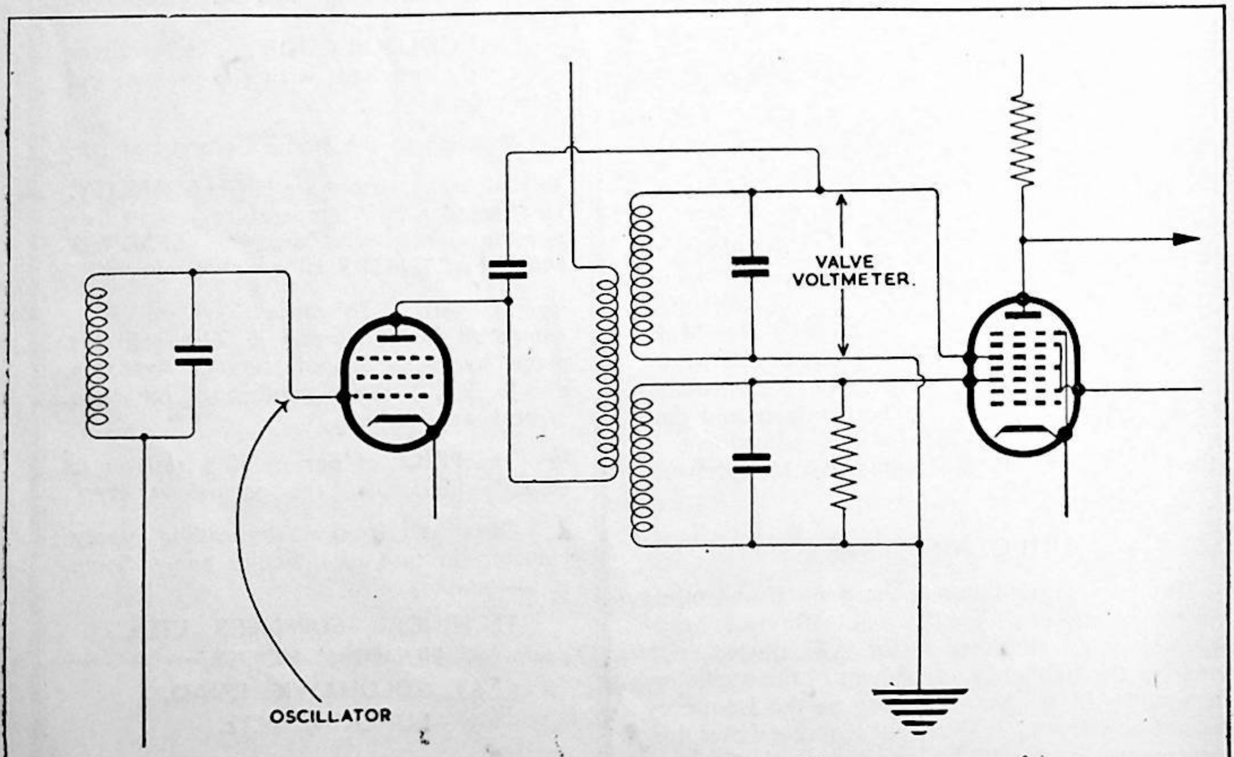


Fig. 36. Alignment of the Phase Discriminator. A valve voltmeter is essential.

In the case of a discriminator, the I.F. alignment is made in the same way, but the indicating instrument should be connected across the grid resistor associated with the limiter valve (fig. 35). The resistor R of 0.1 megohm is inserted to avoid detuning the circuit.

The adjustment of the detector is effected as follows: Connect an output meter, or alternatively a sensitive voltmeter, to the A.F. output. Apply an *amplitude-modulated* signal of 10.7 Mc/s to the grid of the I.F. valve preceding the limiter; detune the secondary of the detector transformer and tune the primary to give maximum A.F. voltage. Next, adjust the secondary for extinction of the response (reading zero on the output meter). Ensure that the adjustment is definite.

For the phase discriminator, after aligning the I.F. as before, a 4700 ohm resistor is connected across the secondary of the detector transformer and a valve voltmeter (1 megohm/volt) across the primary (fig. 36). A signal of 10.7 Mc/s (100mV) is applied to the grid of the I.F. valve preceding the detector. The primary is then adjusted to give maximum voltage as read on the instrument. The 4700 ohm resistor is removed and the secondary is adjusted for minimum voltage. To complete the operation the resistor is replaced across the secondary and the valve voltmeter is transferred also to the secondary. The primary is then readjusted for maximum voltage.

CONSTRUCTION OF COILS

The coils required for the construction of the circuits which have been described, may all be obtained from commercial sources. However, as some readers will prefer to make them themselves, the necessary details are given. Making these coils will not offer any special difficulty, and since the turns are few, they can be wound by hand without trouble.

The V.H.F. coils could take the form of self-supporting solenoids of 18 SWG wire, opening or closing the pitch to adjust the inductance—Circuit No. 3 uses this method.

The adjustment is rendered easier and more exact by using magnetic dust cores. The majority of the coils described are therefore wound on cylindrical insulating formers, which are threaded internally. The adjustment is effected by displacement of the dust core, which is threaded to fit the former.

NOTE :

Formers of the metric dimensions given, whilst standard on the Continent, are difficult to obtain in this country.

For this reason it is recommended that the inductances be wound on formers of British dimensions which are slightly smaller in diameter than their metric counterparts.

The small discrepancy in inductance will be catered for during the alignment process, since all he formers are fitted with dust cores which permit a variation in value of nearly 15%.

In the unlikely event of the core adjustment being insufficient, the former should be wrapped with polythene tape to increase the diameter by the required amount.

Suitable formers are obtainable from the Publishers, or direct from :—

ALLEN COMPONENTS LTD.,
Crown Works,
197, Lower Richmond Road,
Richmond, Surrey.

WINDING DETAILS FOR I.F. TRANSFORMERS

Preceding Valve	Type of Coil	Number of Turns	Type of Winding	Coupling	Type of Wire	Size of Wire	Fixed Tuning Capacitance	Damping	Comments
Pentode or Heptode	Fig. 37	Primary: 24 Secondary: 24	Closewound	13/32in.	Enam. Copper	40 SWG	10 pF 10 pF	Natural	Highimpedance. High gain. Critically coupled.
Triode	Fig. 37	Primary: 12 Secondary: 20	Closewound	5/16in.	Enam. Copper	42 SWG	100 pF 30 pF	Natural	—
Universal	Fig. 37	Primary: 10 Secondary: 10	Closewound	5/16in.	Enam. Copper	42 SWG	100 pF 100 pF	Natural	Low gain. High stability. Overcoupled.
High-slope Pentode	Fig. 38	Primary: 45 Secondary: 45	Closewound	5/8in.	Enam. Copper	36 SWG	30 pF 30 pF	Primary shunted by 3,900 ohms	Critically coupled. Heavily damped

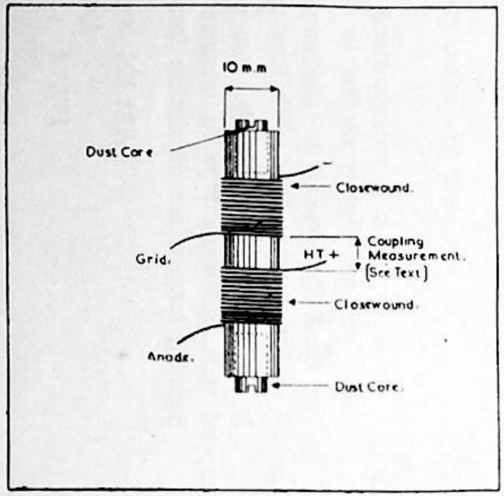


Fig. 37

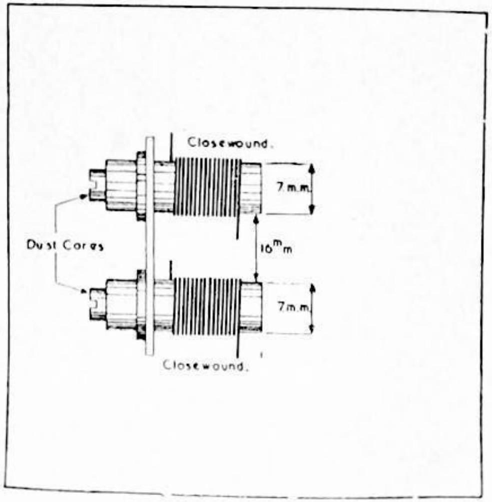


Fig. 38

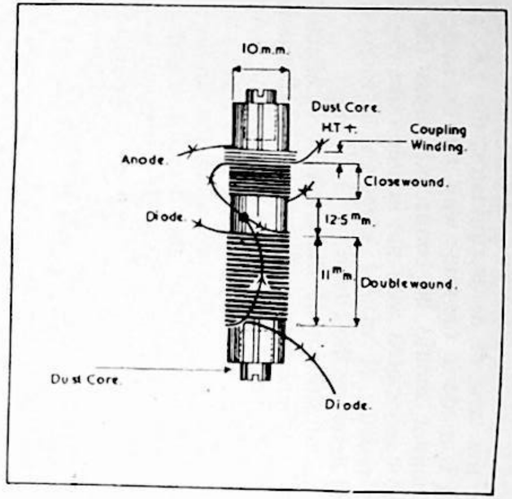


Fig. 39

WINDING DETAILS FOR DETECTOR TRANSFORMERS

Type of Detector	Diameter of Former	Number of Turns	Type of Winding	Coupling	Type of Wire	Size of Wire	Fixed Tuning Capacitance	Comments
Ratio Detector (fig. 39)	0.5 in.	Primary: 24 Coupling 4½ Secondary: 18	Closewound Closewound Doublewound	½in.	Enam. Copper	40 SWG 40 SWG 30 SWG	10 pF — 39 pF	High impedance High gain Length of secondary = 7/16in.
Ratio Detector (fig. 40)	0.3 in.	Primary: 20 Coupling: 7 Secondary: 28	Closewound Closewound Doublewound	7/16in.	Enam. Copper	30 SWG 30 SWG 25 SWG	33 pF — 33 pF	Length of secondary = 15/16in.
Discriminator (fig. 41)	0.5 in.	Primary: 18 Secondary: 20	Closewound Doublewound	13/32in.	Enam. Copper	30 SWG 23 SWG	68 pF 33 pF	Length of secondary = 1in.
Phase Discriminator (fig. 42)	0.5 in.	Coupling: 20 Primary: 20 Secondary: 20	Closewound Closewound Closewound	11/32in.	Enam. Copper	30 SWG 24 SWG 24 SWG	— 33 pF 47 pF	Secondary damped by resistance of 22,000 ohms.

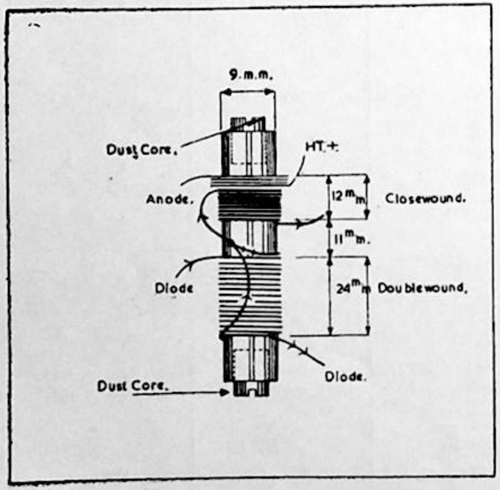


Fig. 40

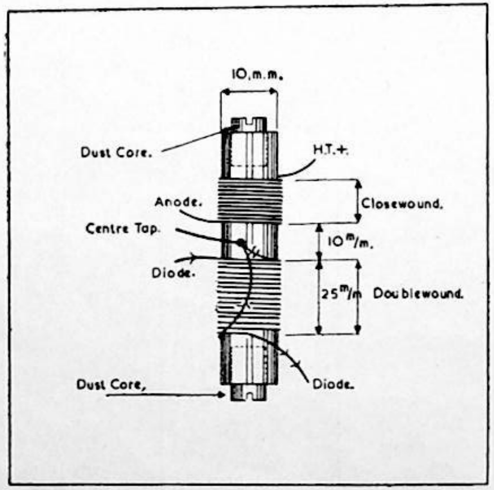


Fig. 41

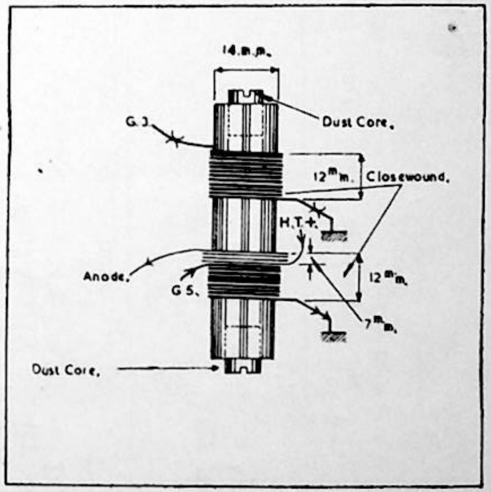


Fig. 42

R.F. COILS

Circuit No.	Coil No.	Function	Dia.	Turns	Winding Length	Wire Type	S.W.G. No.	Taps. Turns from earth end	Remarks
1 (fig. 22)	L1	Aerial Coil	$\frac{9}{32}''$	$4\frac{1}{2}$	$\frac{11}{32}''$	Bare	28	Aerial $2\frac{1}{2}$ Grid $3\frac{1}{2}$	
	L2	R.F. Coupling	$\frac{9}{32}''$	5	$\frac{13}{32}''$	Bare	28	Anode 4 Grid 3	
	L3	Osc. Coil	$\frac{9}{32}''$	4	$\frac{11}{32}''$	Bare	28	Cath. $1\frac{1}{2}$ Grid $3\frac{1}{2}$	
2 (fig. 24)	L1	Aerial Coil	$\frac{9}{32}''$	$4\frac{1}{2}$	$\frac{11}{32}''$	Bare	28	Aerial $2\frac{1}{2}$ Grid $3\frac{1}{2}$	
	L2	R.F. Coupling	$\frac{9}{32}''$	5	$\frac{13}{32}''$	Bare	28	Anode 4 Grid 3	
	L3	Osc. Coil	$\frac{9}{32}''$	4	$\frac{11}{32}''$	Bare	28	Cath. $1\frac{1}{2}$ Grid $3\frac{1}{2}$	
3 (fig. 25)	L1	Aerial Coil	—	Pri. $2\frac{1}{2}$ Sec. $4\frac{1}{2}$	—	D.S.C. D.S.C.	24 24	Pri. & Sec. interwound in grooves of Aladdin dust core type PP5839.	Cut off excess core.
	L2	R.F. Coupling	$\frac{5}{16}''$	4	$\frac{21}{64}''$	Tinned Copper	16	——	Self Supporting.
	L3	Osc. Coil	$\frac{5}{16}''$	5	$\frac{13}{32}''$	Tinned Copper	16	Cathode 1	Self Supporting.
4 (fig. 26)	L1	Aerial Coil	$\frac{9}{32}''$	Pri. $2\frac{1}{2}$ Sec. $4\frac{1}{2}$	— $\frac{11}{32}''$	Enam. Enam.	28 28	Centre ——	Pri. & Sec. Interwound.
	L2	R.F. Coupling	$\frac{9}{32}''$	5	$\frac{13}{32}''$	Enam.	28	4	
	L3	Osc. Coil	$\frac{9}{32}''$	Anode 5 Grid 3	$\frac{13}{32}''$	Enam. D.S.C.	25 36	—— ——	Grid and Anode Winding interwound.
5 (fig. 28)	L1	Aerial Coil	$\frac{9}{32}''$	Pri. $2\frac{1}{2}$ Sec. $4\frac{1}{2}$	— $\frac{11}{32}''$	Enam. Enam.	28 28	Centre ——	Pri. & Sec. Interwound.
	L2	R.F. Coupling	$\frac{9}{32}''$	5	$\frac{13}{32}''$	Enam.	28	$2\frac{1}{2}$	
	L3	Osc. Coil	$\frac{9}{32}''$	4	$\frac{11}{32}''$	Enam.	25	$1\frac{1}{2}$	
6 (fig. 29)	L1	Aerial Coil	$\frac{13}{32}''$	Pri. $2\frac{1}{2}$ Sec. 5	— $\frac{5}{16}''$	Enam. Enam.	26 26	—— ——	Pri. & Sec. Interwound.
	L2	R.F. Coupling	$\frac{13}{32}''$	5	$\frac{5}{16}''$	Enam.	28	3	
	L3	Osc. Coil	$\frac{13}{32}''$	4	$\frac{1}{4}''$	Enam.	25	——	
7 (fig. 30)	L1	Aerial Coil	$\frac{9}{32}''$	5	$\frac{13}{32}''$	Enam.	25	Aerial 2 Cathode 3	
	L2	R.F. Coupling	$\frac{9}{32}''$	5	$\frac{13}{32}''$	Enam.	25	——	
	L3	Osc. Coil	$\frac{9}{32}''$ 7,144	5	$\frac{13}{32}''$	Enam.	21	——	
8 (fig. 32)	L1	Aerial Coil	$\frac{9}{32}''$	Pri. $2\frac{1}{2}$ Sec. 5	— $\frac{9}{32}''$	Enam. Enam.	25 25	Centre ——	Pri. & Sec. Interwound
	L2	R.F. Coupling	$\frac{9}{32}''$	5	$\frac{9}{32}''$	Enam.	25 0,5	——	
	L3	Osc. Coil	$\frac{9}{32}''$	5	$\frac{13}{32}''$ 10,319	Enam.	21 0,8	——	

0,85

CHOKE COILS

Type	Former	Number of Turns	Type of Wire	Size of Wire	Type of Winding	Comments
CH1	0.1 megohm resistor, 1 watt, diameter 5/32in.	50	Enam. Copper	36 SWG	Close-wound	V.H.F. choke
CH2	68,000 ohm resistor, ½ watt, 5/32in. dia.	25	Enam. Copper	28 SWG	Close-wound	Heater choke
CH3	1,500 ohm resistor, 1 watt, diameter 3/16in.	15	Silk-covered Copper	24 SWG	Spaced	Load coil
CH4	15,000 ohm resistor, 1 watt, diameter 5/32in.	60	Enam. Copper	36 SWG	Close-wound	Cathode coupling choke

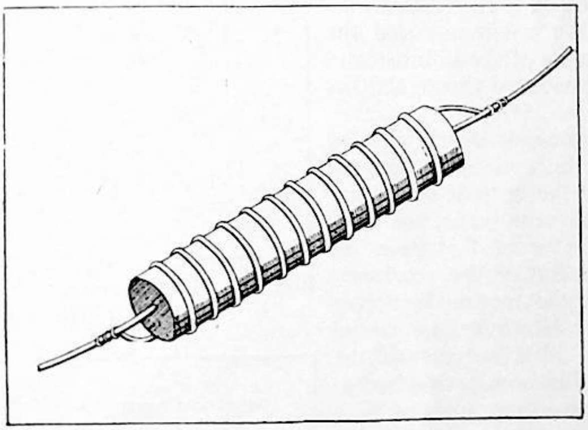


Fig. 43. A resistor being used as the former for a V.H.F. choke.

THE AERIAL PROBLEM

Unless there is a powerful transmitter in the immediate neighbourhood it is no use hoping to receive metre waves by means of an odd length of wire trailing on the ground or arbitrarily twisted around the gas bracket. Indeed, F.M. receivers are much more susceptible to the influence of the receiving aerial than those which are designed for the ordinary broadcast wavebands.

Usually, aerials for reception of V.H.F. waves are derived from the traditional dipole, the basic theory of which will now be reviewed.

A straight conductor, isolated in space, possesses a resonant frequency which corresponds to a wavelength equal to twice its own length. If this conductor is excited by an alternating electromagnetic field of the required frequency, it behaves like the parallel resonant circuit which it resembles. The self-inductance is that distributed throughout the length of the conductor and the capacitance is the effective sum of the infinitesimal elementary capacitances distributed throughout its length (fig. 44).

At resonance, the instantaneous distribution of current and voltage along the conductor appears as shown in figure 45. Since the current maximum occurs at the centre of the conductor, we may conveniently cut the conductor at this point in order to insert the input circuit of the receiver.

In this way we arrive at the method which is actually used in practice. However, an aerial is never isolated in space: it is subject to the influence of the earth and of all conducting bodies in its environment. In consequence there is a slight reduction in its resonant frequency, which should be taken into account, and which may be compensated by reducing its length to 5% below the theoretical value.

Maximum current is induced in a dipole when it is located:

1. In the plane of polarisation of the transmitted signal, which is horizontal in the case of F.M. transmissions.
2. Perpendicular to the direction of the transmitter.

It follows that the dipole, like the frame aerial, is directive. Figure 46 shows the polar diagram of a dipole, showing in graphical form the relative response to the signal as a function of the angle of inclination to the direction of the transmitter. It should be noted that the response is the same in the backward as in the forward direction.

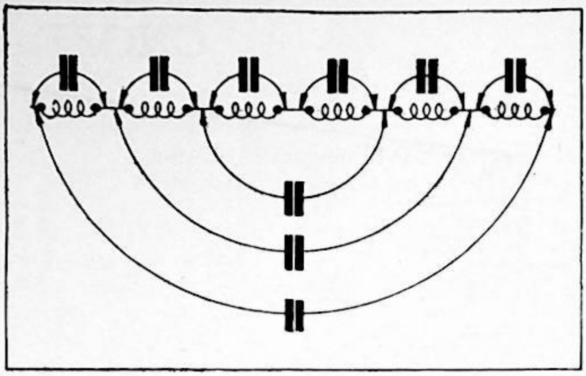


Fig. 44. A straight conductor isolated in space may be regarded as a resonant circuit.

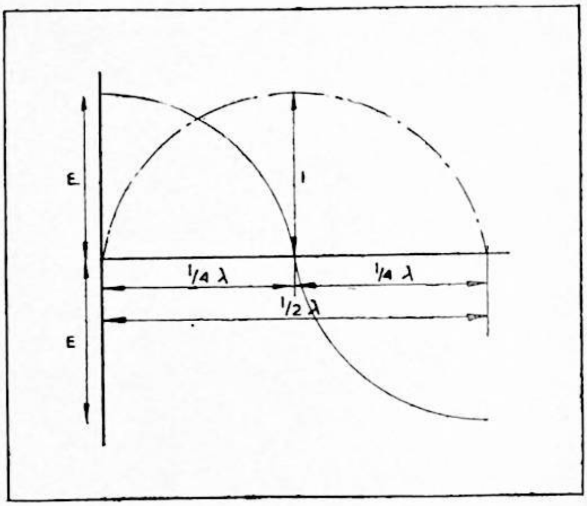


Fig. 45. Distribution of voltage and current along a straight conductor.

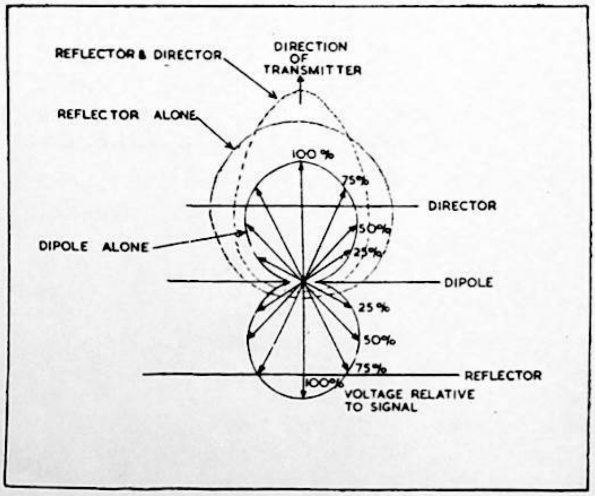


Fig. 46. Polar diagram of a dipole aerial, showing the influence of a reflector and of a director.

A simple dipole presents, at its centre, a resistive impedance of approximately 72 ohms, and the coupling network to the receiver should have a corresponding characteristic impedance.

The traditional dipole is not often used, because its acceptance band is too narrow and it lacks mechanical rigidity. **Folded dipoles** are usually preferred (fig. 47). This may be envisaged as two dipoles in parallel. If they are in sufficiently close proximity, the voltages induced in them are in phase and they may therefore be connected together at their ends. When this is done the impedance rises to 300 ohms, and the bandwidth is substantially increased. The assembly is mechanically much more rigid than a simple dipole and stands less chance of being dislodged by the wind.

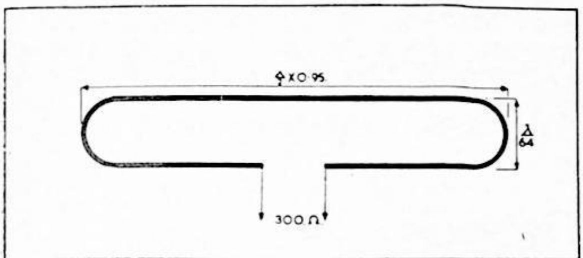


Fig. 47. Dimensions of a Folded Dipole in relation to the wavelength.

Overall gain of a dipole may be increased by mounting behind it a second element termed a **reflector.** Response will then become greater in the forward than in the backward direction. Unless they are unusually powerful, it is now possible to receive transmissions only from the front.

Figure 46 also shows the polar diagram of the folded dipole-reflector combination. The acceptance bandwith is a little lower than that of a plain folded dipole.

A still more pronounced directive effect, as well as a significant increase in gain, may be obtained by placing a further dipole, termed a **director** in front of the folded dipole. Note that the distances required between the elements are given in fig. 48. A reflector should be approximately 5% longer than the folded dipole and the director approximately 4% shorter.

Generally, a three element assembly constitutes the best system for long distance reception.

The presence of either a reflector or director appreciably lowers the characteristic impedence of the radiating element, and a simple dipole used in conjunction with two parasitic elements may present an impedance as low as 20 ohms instead of 72 ohms.

Due to the difficulty of correctly matching such a low impedance, the 3-element array usually uses a folded dipole. By suitable choice of spacing

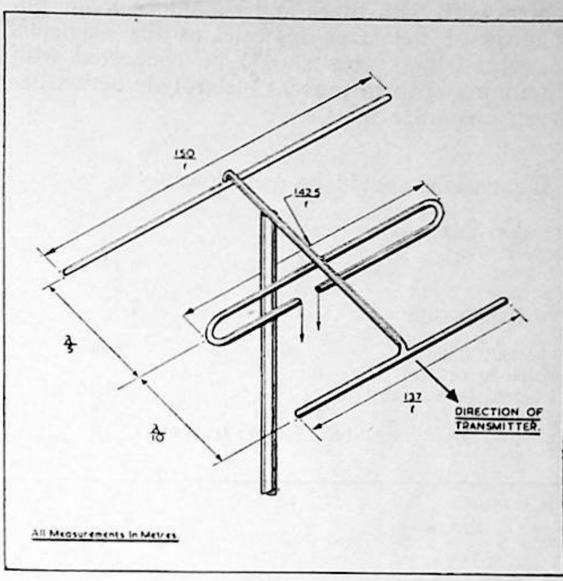


Fig. 48 Arrangement of the 3-element aerial.

and tube diameter, the aerial can be designed to match an 80 ohms co-axial feeder. This is quite easy to obtain since it is the normal type used for television installations in this country.

Fig. 49 shows the arrangement of a 3-element array which is tuned to the centre of the F.M. band, and which accurately matches an 80 ohms feeder. Since the aerial is a balanced device and the feeder is of unbalanced type a $\frac{1}{4}\ \lambda$ matching section is incorporated where the feeder joins the aerial. This matching section is formed out of a short length of feeder cable, and as can be seen in the diagram only the outer braiding is used. The inner conductor can be removed, or clipped off short as the constructor thinks fit.

Thin walled aluminium or copper tube construction is recommended; the elements being formed from continuous lengths which are not broken at the support points. The actual method of support need not necessarily be the "Plumber's Delight" as shown. An alternative method is to fashion a wooden framework, mounting the elements on stand-off insulators.

Outside diameter should be $\frac{1}{2}$ inch for all elements except the lower part of the radiator, which should be made out of $1\frac{1}{2}''$ diameter tubing.

The lower part of the radiator should be cut at the centre, and a tight fitting insulated spacer forced into the open ends. If the constructor has access to a lathe, the spacer could be fashioned with a flange so as to reduce the possibility of electrical leakage across the surface in wet weather. The straps which support the ends of the large tube should make intimate electrical contact with both tubes and should be made out of strips of the same material as the elements, i.e., aluminium tubes should be connected with aluminium strip to prevent electrolytic action between dissimilar metals.

Dimensions should be as follows:—

ELEMENT LENGTHS	feet	inches
Reflector	5	2.64
Director	4	8.52
Radiator	4	11.75
Matching Section	2	7.42

ELEMENT SPACING (centre to centre)	feet	inches
Reflector to Radiator	2	1.15
Radiator to Director	2	7.42
Radiator Small/Large tube (centre to centre)		3.25

Another way of increasing the gain while retaining the property of receiving from both front and back, is to make use of two folded dipoles located one above the other (fig. 50). The acceptance bandwidth is greater than for the preceding combination.

In order to be able to receive transmissions from all quarters, it is possible to use two folded dipoles mounted at right angles (fig. 51), or one elbow-shaped folded dipole (panoramic aerial) (fig. 52). An indoor aerial may be found to give sufficient signal strength within a small radius of the transmitter, which sometimes takes the form of a V-shaped dipole of reduced dimensions (fig. 53). This component is readily obtainable from commercial sources. Certain types are adapted for fixture to a balcony or a window.

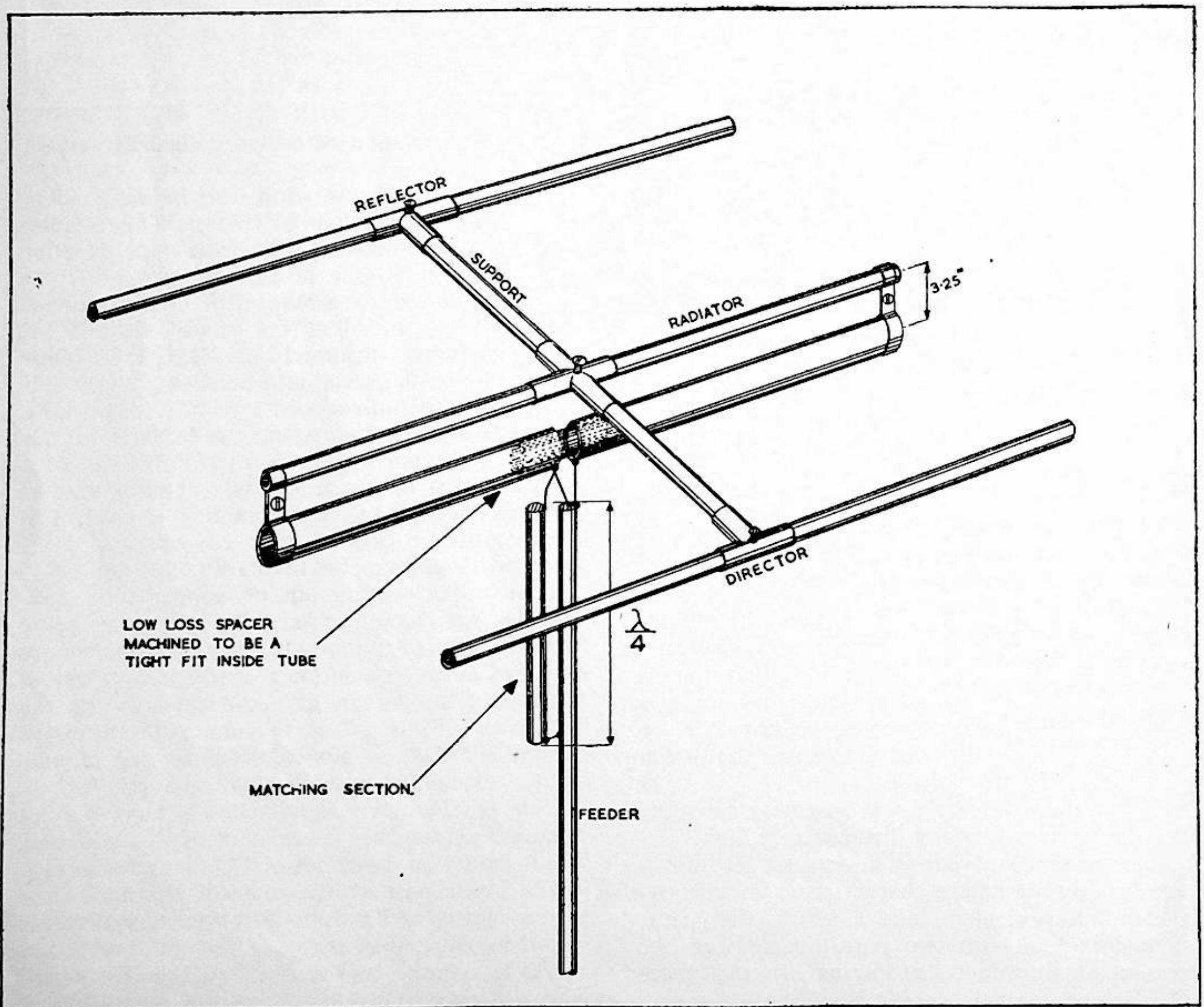
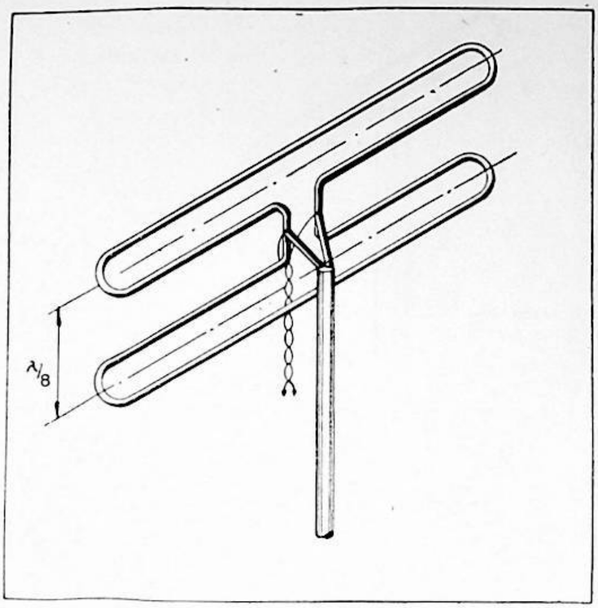


Fig. 49. A 3-element array designed to match an 80 ohm co-axial feeder.



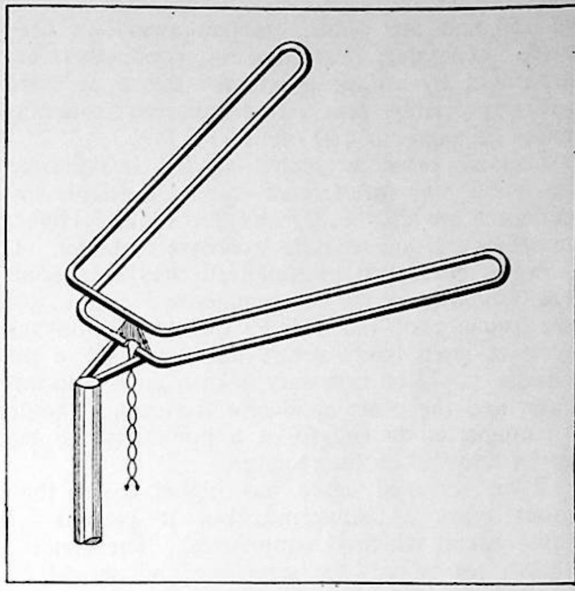
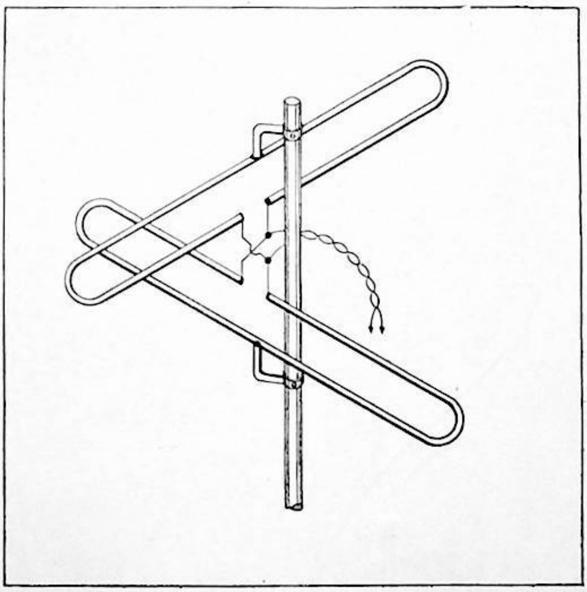


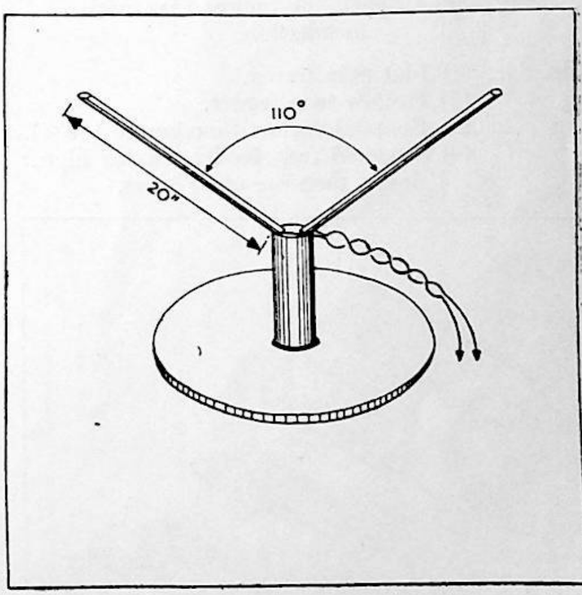
Fig. 50. **Two folded dipoles mounted one above the other give the same gain as a dipole and reflector, but permit reception from two directions.**

Fig. 51. **Two crossed folded dipoles permit reception from all directions, but have the same gain as a simple folded dipole.**

Fig. 52. **The panoramic folded dipole allows reception from all directions, but at the cost of a slight reduction in gain.**

Fig. 53. **Indoor dipole of reduced dimensions.**





Four different types of **aerial downlead** are available, comprising:—(1) Flat Twin, consisting of two conductors embedded in a polythene ribbon which holds them strictly parallel; (2.) Hollow twin, which uses a polythene tube with two conductors moulded into its walls; (3.) Coaxal cable with central conductor, polythene insulation, conducting sheath, and protective P.V.C. outer covering; and lastly, (4.) Screened twin-conductor cable (fig. 54).

Flat twin is popular, and relatively inexpensive. It may be obtained in characteristic impedances of 150 and 300 ohms. Hollow twin is a little more expensive, but as the conductors are separated by an air space, the losses per yard are appreciably less. Impedance is generally either 75 ohms or 150 ohms.

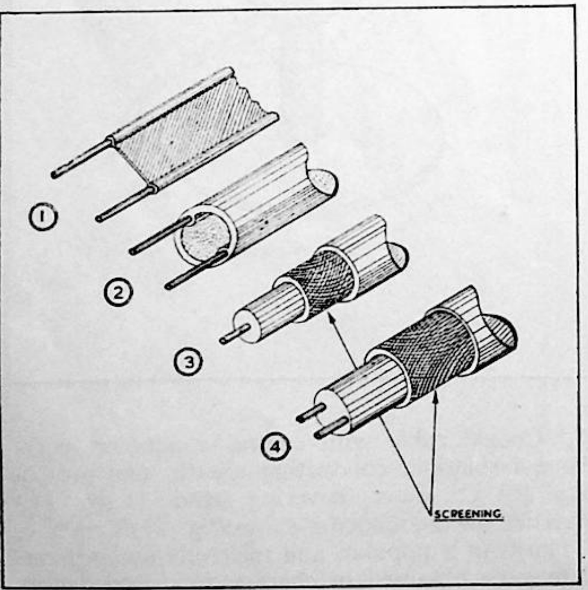
Coaxial cable is preferable for installations having a high interference level. Available impedances are 25, 50, 75 and 150 ohms. Higher impedance would require excessive diameter. It is to be noted that coaxial lead does not permit the employment of a symmetrical input. If the primary of the V.H.F. transformer on the receiver input has a centre tap connected to the chassis, it will be necessary to disconnect it in this case; and the outer conductor (screening) should be connected to chassis at a point near to the aerial terminal on the receiver.

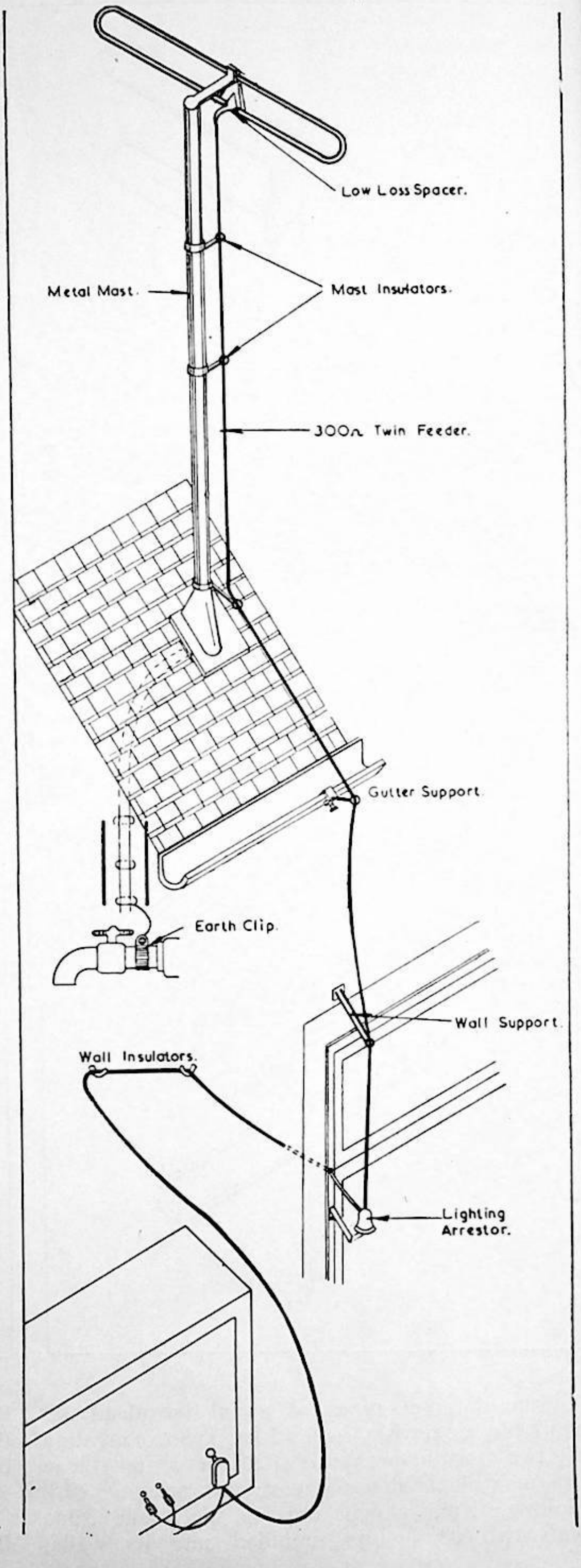
Twin screened cable has higher losses than other types of downlead, but it permits an input circuit which is symmetrical. The metallic sheath serves only for screening and should be connected to the chassis. This type of downlead is satisfactory only when the distance between the aerial and the receiver is not too great. Fig. 55 shows how to erect an aerial installation to obtain best results.

It will be noted that the folded dipole serves simultaneously for F.M. and ordinary reception. In the latter case, the two conductors of the downlead act in parallel.

Fig. (55) (Right). A metre wave aerial installation.

Fig. 54. (1) Flat twin feeder.
(2) Hollow twin feeder.
(3) Co-axial feeder (maximum 150 Ω).
(4) Screened twin feeder, having higher losses than the other types.





PRINCIPAL CHARACTERISTICS OF V.H.F. AERIALS

Type	Polar Diagram	Pass Band	Impedance ohms.	Recommended Down Lead	Relative Voltage	db	Comments
Folded dipole	Bidirectional	Wide	300	Flat twin	1	0	For General use
Folded dipole and reflector	Unidirectional	Fairly Wide	250	Flat twin	2	3	For general use on distant transmissions.
Folded dipole with reflector and director	Highly unidirectional	Narrow	75	Coaxial	2.5 to 4	4 to 6	For reception of a specified transmitter at great distant
2 folded dipoles in parallel	Bidirectional	Wide	150	Flat twin	2.5	4	For reception of distant transmitters in several directions
2 crossed folded dipoles	Omnidirectional	Wide	150	Flat twin	1	0	For reception of transmissions from all directions
Panoramic folded dipole	Omnidirectional	Wide	300	Flat twin	0.7	-1	For reception of short distance transmissions in all directions
Indoor dipole	Bidirectional	Wide	100	Flat twin	0.1 to 0.2	-6	Serves only for the reception of a local transmitter

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ILLUSTRATED FOLDER PROVIDED ON REQUEST.