The Practical
SUPERHETERODYNE MANUAL

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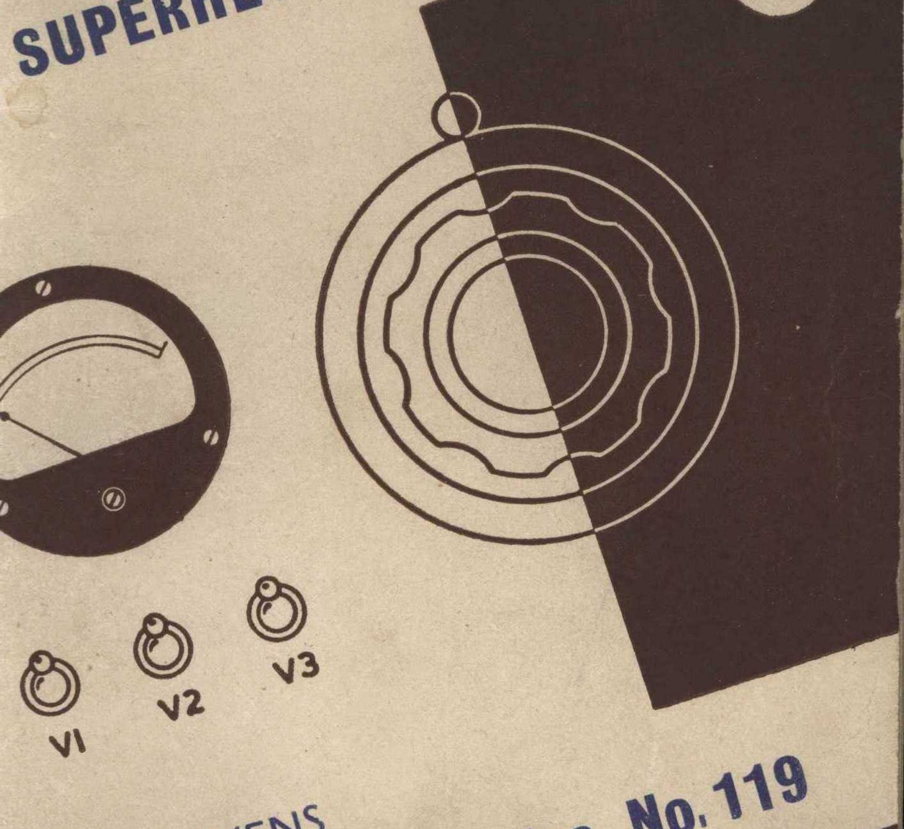

by N. STEVENS

Bernards Radio Series, No. 119

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BERNARDS RADIO SERIES, No. 119

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CONTENTS

CHAPTER ONE

AN INTRODUCTION TO THE SUPERHET.

Almost without exception, commercial radio sets (including those designed specially for the short-wave bands) are of the superheterodyne class. Yet it is certainly true that the majority of home-built receivers use TRF circuits.

A small TRF receiver is certainly easier, and less expensive, to build than an elaborate superheterodyne receiver. Many enthusiasts start their radio construction activities along these lines. A well-designed TRF circuit can prove an effective piece of apparatus even on the short waves. The writer has, in the past, experimented a great deal with various TRF receivers, paying great attention to such things as smooth and constant regeneration action, a separate stage for the beat-frequency oscillator, and other aids to ease of operation and performance—including AVC systems.

For serious listening, however, the superheterodyne is superior in every way. In view of this, readers may wonder why so many constructors fail to take advantage of the better performance offered by this system.

One reason is that many enthusiasts are of the opinion that a superheterodyne is an expensive item to build. True, a receiver in the " communications " class is costly, but it is not so widely realised that a good receiver using four or five valves can be constructed as cheaply as an elaborate TRF receiver—and, moreover, giving far better results.

Two further reasons are largely interwoven. The majority of beginners (and a number of more experienced constructors) have a dread that the superhet is so complicated that it is beyond their constructional abilities. A stage is reached where something more fitting to modern requirements than a TRF is needed, but where a superheterodyne is rejected as being too complex.

The difficulties of superheterodyne construction and alignment have, in the past, been over-emphasised, and difficulties which can easily be overcome have been built up to seem like insuperable problems as far as the ordinary amateur constructor is concerned.

In many respects they are *easier* to get working satisfactorily than a TRF. The main stumbling block (if it can really be called that) is in initial alignment. Even this can be carried out with very simple equipment; if no signal generator is available it may be carried out with units made up in a short time from the "spares box." (See Chapter Six.)

The superheterodyne scores over simple regenerative receivers on veral counts, mainly selectivity, sensitivity, stability, and ease of operation.

One of the greatest drawbacks to the TRF receiver is its poor selectivity. On medium waves the separation between any two adjacent stations is 9 kc/s; on short waves, especially on amateur bands, even more crowded conditions prevail. Although regeneration helps, no TRF is capable of providing the selectivity required and in any case selectivity will vary from one end of each band to the other as the tuning capacitor is varied.

To obtain any reasonable discrimination between adjacent stations, one stage of tuned RF amplification is essential, but even this is scarcely sufficient where signals are strong. The need for good RF amplification is also shown when we consider that a detector is comparatively inefficient at low-drive voltages. With TRF circuits it is generally necessary to use a triode or pentode detector which amplifies as well as rectifies, a practice which often leads to instability and distortion. By incorporating three or more stages of tuned RF amplification, selectivity can be greatly improved, but there are numerous practical difficulties.

As each stage must be tuned in order to eliminate unwanted singals, at least four tuned circuits (including the detector stage) would be required. The whole project would be costly, bulky and extremely difficult to handle.

For instance, each stage of RF amplification would be prone to feed back energy to its predecessor not only through the valve capacitances but through the inter-stage couplings. Instability would be a major problem especially on short waves where very small capacitances (such as stray couplings between wires) might easily give rise to undesirable effects.

With TRF receivers the signal is usually amplified at carrier frequency. As the frequency rises so do the difficulties in obtaining satisfactory amplification and high stage gain. Another inherent shortcoming of the TRF receiver is that the pre-detector stages have to handle signals of all frequencies. Although a compromise is reached in practice by judicious selection of the component values, it is obvious that amplification cannot be uniform throughout any useful range of frequencies because each stage is operating at a widely different degree of efficiency from one end of the band to the other.

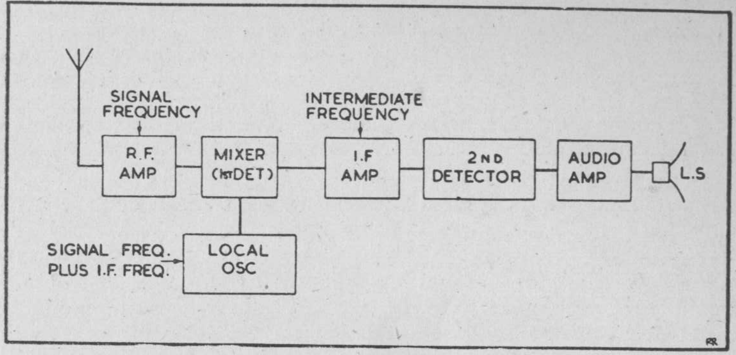

Fig. 1. Black outline of a basic superheterodyne.

The superheterodyne largely overcomes the deficiencies of the TRF circuit. Basically the operation of the superheterodyne is simple to understand and a block outline of a typical circuit is shown in Fig. 1.

The *RF amplifier*, or pre-selector, follows conventional lines. It amplifies the signal at its carrier frequency and ensures a degree of selectivity, thus preventing unwanted signals from passing into the receiver. The amplified signal is then fed to the *mixer* stage. Also injected into the mixer stage is an unmodulated RF signal developed by a *local oscillator*.

When the two signals are mixed together a third signal is produced, this being called a *beat* or *heterodyne* signal. The frequency will be the difference between the two contributory frequencies and is called the intermediate frequency. Thus if two signals of 1,000 kc/s and 900 kc/s were "mixed" a beat frequency of 100 kc/s would result. (N.B. Other frequencies will also be present in the mixer—see Chapter 2.)

An important point to note is that this new signal, although different in frequency, will retain all the modulation characteristics of the original signal amplified by the RF stage.

This conversion of the received signal to the new IF signal is the basic function of the receiver which holds the cumbersome and ponderous official title of "supersonic-heterodyne" receiver. The "heterodyne" part is already explained; "supersonic" simply refers to the fact that the beat frequency is above the audible range.

The act of producing the new signal is called *frequency conversion* and this part of the circuit is referred to as the *frequency changer*. In early types, the applied signals were also detected and this gives rise to the term *first detector* which is synonymous with frequency changer.

The received signal, now converted to a lower frequency but retaining all the original intelligence, is fed to the *IF amplifier*. The benefits of the superheterodyne now begin to be obvious. Although it is easy to amplify a weak signal of low frequency it is a different matter with high frequencies. That is one reason why many TRF receivers lack " punch " on short waves and tend towards parasitic oscillation and general instability.

In the IF signal we have only a low-frequency signal to contend with. And, no matter what station is tuned in by the pre-selector, the IF amplifier has only to deal with one specific frequency. In practice, the local oscillator frequency is varied in step with the received signals so that no matter what signal is applied to the mixer grid the IF will remain constant.

It thus becomes possible to design an amplifier for maximum selectivity and adequate stage gain. After one or more stages of IF amplification the signal is fed to the *second detector* where the signal is rectified in normal way. The remaining audio signal is further amplified at audio frequency and fed to the loudspeaker as in TRF receiver practice.

CHAPTER TWO

THE FREQUENCY CHANGER

The older system of frequency conversion, now used only for very high frequency work, is called the *additive* system. Fig. 2 shows the process step by step. An RF signal, picked up on the aerial, is shown at (a) ; local oscillations, unmodulated and higher in frequency, are at (b). The result of mixing these two signals produces a result shown at (b). The result of mixing these two signals produces a result shown at (c). The two signals added together produce a 1,500 kc/s wave as at (c). The two signals added together produce a 1,500 kc/s wave varying at a frequency of 500 kc/s. The disadvantage is that, in effect, *no* 500 *kc/s signal* exists, because each positive peak is neutralised by a negative peak and the average result becomes zero.

This is overcome by rectifying the waveform in the frequency changer which gives an averaged result of a 500 kc/s signal. (d) The signal, after amplification, is passed through the second detector, leaving only the audio component (f).

Most modern receivers use *multiplicative* frequency changing, except for very high frequency work. In the multiplicative system the

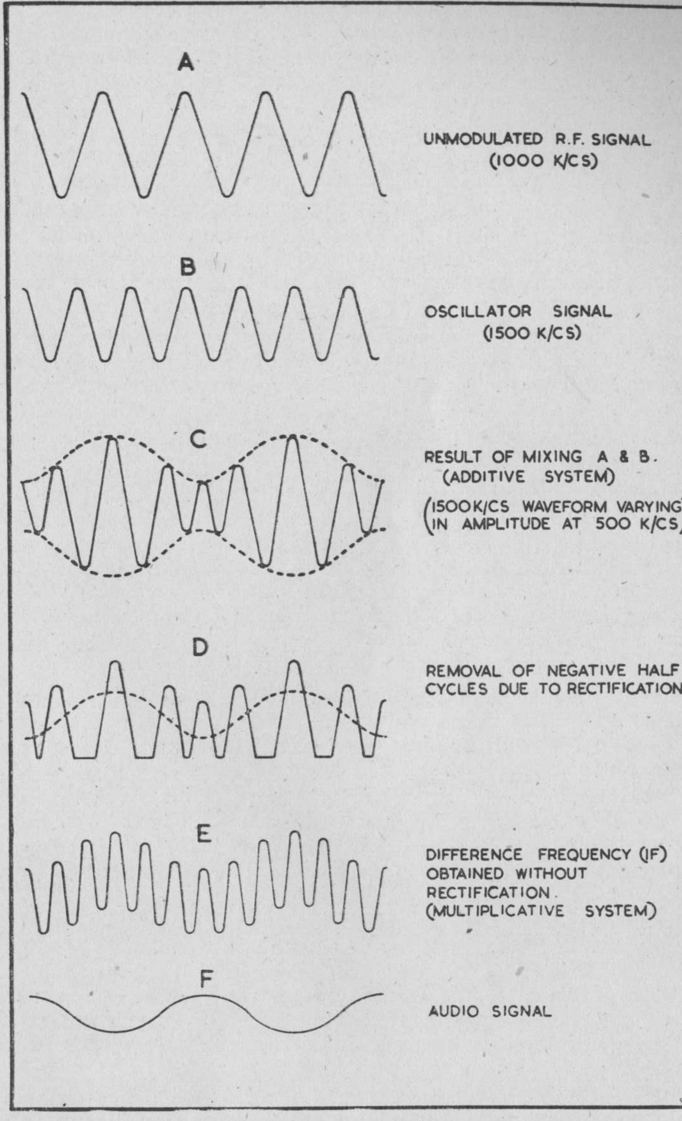

Fig. 2. Waveforms encountered in frequency conversion.

intermediate frequency is obtained by multiplying the two constituent signals instead of adding them. In this way the IF is obtained directly and rectification within the frequency changer is unnecessary (curve e).

The signals are multiplied in this way: the valve's output voltage is approximately equal to the input voltage gmR (gm = mutual conductance and R = dynamic resistance of the output circuit). If gm is proportional to the voltage of the local oscillator, the output voltage of the valve will be proportional to the sum voltages of the input and oscillator signals. (The dynamic resistance, being an IF transformer, is constant.) In referring to the various waveforms, especially (e), it should be noted that multiplying two negative peaks results in a positive peak.

The Fig. 2 waveforms show an unmodulated RF signal of constant amplitude. It should be understood that any modulation of the carrier will be retained after detection and in the IF signal. This has been omitted from the diagram for clarity.

Before discussing the various types of frequency changers it will be convenient to explain how the superheterodyne achieves the degree of selectivity which is an inherent advantage of this circuit.

Adjacent channel selectivity, to give the full name, is the ability of a receiver to reject unwanted signals closely bordering those which it is desired to receive. When an RF signal is mixed with a local oscillator signal, various oscillations will appear in the mixer valve. The most important are (a) the RF signal; (b) a beat frequency equal to the difference between the RF signal and local oscillator signal, and (c) another beat frequency—equal to the sum of the RF and oscillator signals. The most prominent are the two beat frequencies.

From this it is evident that a choice of IF is available. Assuming an RF signal of 10,000 kc/s and a local oscillator signal of 9,500 kc/s, two beat notes will be present—500 kc/s (10,000 − 9,500) and 19,500 kc/s (10,000 + 9,500). The lower IF frequency is chosen for obvious reasons.

If there is another RF signal—a station on 10,010 kc/s—being picked up on the aerial, this also will beat with the oscillator frequency and produce an IF of 510 kc/s (10,010 − 9,500). Now compare these figures.

The frequencies of the two RF signals (10,000 and 10,010 kc/s) differ by only 0·1%, but the two resultant beat frequencies (500 and 510 kc/s) differ by 2%. Thus, if the IF amplifier is made capable of selectivity of this order, the unwanted signals will not be passed to the detector and audio stages. With two stages of sharply tuned IF amplification, stations on adjacent channels can be virtually eliminated—however powerful they may be.

Through the years, an incredible number of frequency changing circuits have been devised and it would serve no useful purpose to describe very many of them. Basically there are three methods which can be adopted and they differ only in the type of valves used and the method of injecting the local oscillator voltage into the mixer stage.

The earliest frequency changers used two valves—one for mixing and anode-bend rectification and the other for providing the local oscillator voltage. These are now obsolete but the circuit of a typical arrangement will be of academic interest (Fig. 3a). The RF signal is fed to V1 in the normal manner for rectification and amplification. V2 is oscillating continuously due to the tight coupling and feedback; the oscillator voltage is fed back to the mixer via the regeneration coil. The electron stream through the pentode is, therefore, modulated by the RF signal and by the injected voltage from V2, resulting in the waveform "d" of Fig. 2.

Later types, using only a pentode or tetrode, employed the cathode injection mixer system. This is similar in action except that the oscillator voltage is produced in the same valve (Fig. 3b). Most of these early frequency changers had serious drawbacks. Interaction (or "pulling") between the oscillator and pre-selector circuits, radiation from the oscillator, and low IF output for a given RF input were the main troubles. In addition, considerable variation of sensitivity over the tuning range resulted from the difficulty in designing a stable oscillator.

Tetrodes or pentodes were also used with separate triode oscillators, but these early versions need only a passing reference. It was usual to use common grid injection whereby the RF signal and oscillator voltage were fed to the mixer control grid. This resulted in all the disadvantages of serious radiation, pulling, non-linearity of oscillator voltage over tuning range and so forth. Better results were obtained by injecting into the mixer cathode which, though theoretically nearly identical to grid injection, provided a more stable injection point. Even so, oscillator radiation and interaction were intolerable by modern standards. Some designs made use of the screen or suppressor grid for injection, but a greater injection voltage had to be provided and this led to a substantial generation of harmonics by the oscillator.

Some early receivers used a triode mixer with a separate triode oscillator, the mixer acting as a leaky-grid detector and injection made at the mixer grid. This system is not used to-day except at very high frequencies where standard types of mixing are inefficient. A typical circuit is shown in Fig. 3c; here, valve capacitances and the common cathode coupling is relied on for injection.

The pentagrid (or heptode) converter (Fig. 3d) is a widely used frequency-changer valve, combining the functions of oscillator and mixer in the one envelope—coupling between sections being through the electron stream. The pentagrid has five grids, G1 and G2 form the oscillator grid and "anode" respectively. These, with the

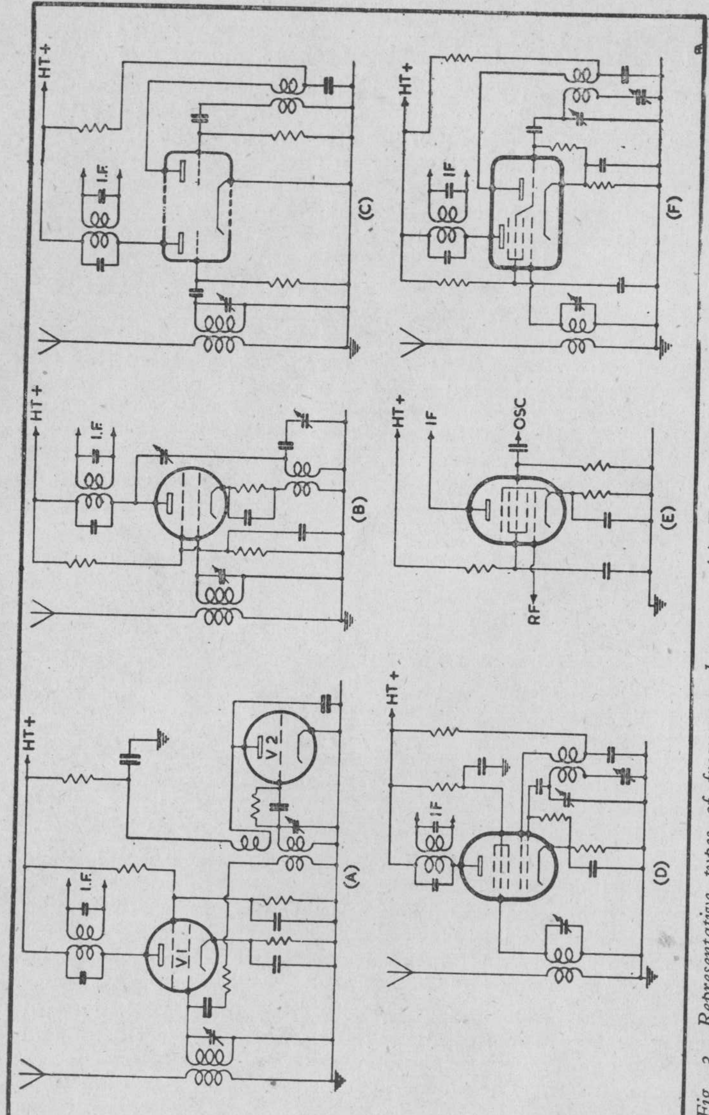

Fig. 3. Representative types of frequency changers: (a) Early, obsolete, two-valve grid-injection circuit; (b) Pentode cathode-injection system, now obsolete; (c) two-triode circuit, very effective on high frequencies; (d) The Pentagrid (heptode) Converter; (e) The Mixing Heptode; (f) The Triode-Hexode.

cathode, are virtually a composite cathode which emits an electron stream which varies according to the oscillator frequency set by the tuned circuit. G3 accelerates the electron stream towards G4 which is the signal grid of the mixer section. Thus G4 and G5 form the grid and screen-grid of a tetrode. The object of G3, apart from acceleration of the electron stream, is to prevent electrostatic coupling between G2 and G4. It is maintained at a positive potential and is internally connected to G5 which serves to screen the anode from the signal grid. Due to electron bombardment of G3, the two grids forming the shield actually emit secondary electrons directed towards the oscillator " anode " G2. The oscillator " anode current " is largely reliant on secondary emission from G3/G5.

The signal grid, G4, being negatively biased, repels electrons and thus a space charge builds up between G3 and G4, this cloud of electrons forming an effective cathode. This grid, therefore, controls the main electron stream and those derived from the space charge, so that the current arriving at the anode carries components of both frequencies (with, of course, the sum and difference frequencies).

The octode is similar to the pentagrid but has an additional grid, G6, between G5 and anode, acting as a suppressor to prevent secondary emission. The octode and the pentagrid are satisfactory for medium-wave operation but have limitations for short-wave operation due to space-charge coupling which causes interaction. The usable frequency range can be extended by introducing a neutralising capacitor between the " hot " end of the oscillator coil and the signal grid, but results are not entirely satisfactory.

It is better to use a self-oscillating pentagrid with a separate triode oscillator since interaction is then reduced and the oscillator voltage necessary for efficiency on high frequencies is easier to obtain. With this method, G1 is used as the oscillator injection grid, G4 as mixer signal grid and G2 is connected directly to G3 and G5.

A different arrangement is possible with the " mixing heptode " (Fig. 3e) which is a valve of the screened-tetrode type suitable for high-frequency operation. G1 is used as the signal grid, G3 as oscillator injection grid and G2/G4 (connected internally) is a screened grid. This is a hexode ; if an extra screened grid is added it is called a heptode. A separate oscillator valve is necessary but any oscillator voltage reaching the signal grid will be small and so interaction is not usually serious.

The most widely used frequency changers are the triode-pentode and triode-hexode, the latter being probably the most efficient converter for short-wave work except at very high frequencies (Fig. 3f). The triode-pentode is not entirely suitable for short waves.

The advantages of the triode-hexode are numerous. It is more efficient at high frequencies than the heptode or octode. It comprises

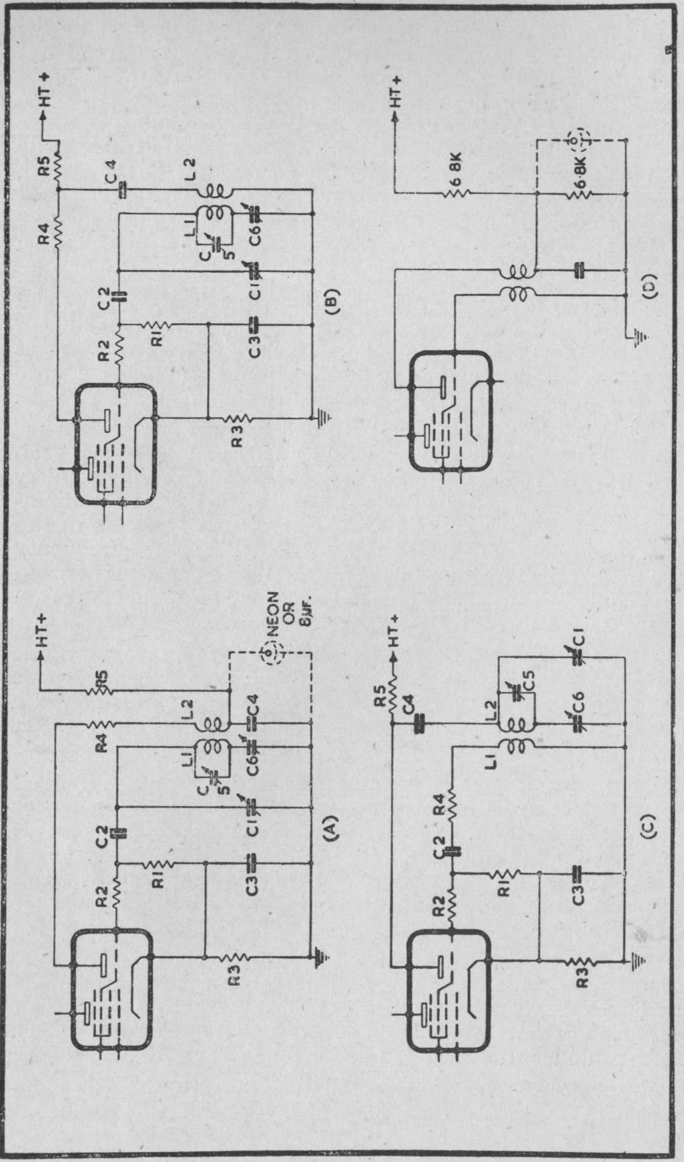

Fig. 4. Methods of arranging the oscillator-feed circuit: (a) Grid-tuned, series-fed; (b) Grid-tuned, shunt (parallel)-fed; (c) anode-tuned, shunt-fed; (d) Series-fed with bleeder network. Component values (inter changeable between examples) are: R1—47 k, R2—33, R3—330, R4—see text, R5—33 k (see text), C1—main oscillator-tuning capacitor, C2—100 pF, C3—0·1 µF, C4—0·1 µF for series-fed circuits and 100 pF for shunt-fed circuits, C5—oscillator trimmer, C6—oscillator padder.

a triode oscillator and a mixing hexode and, as both sections have their own electron stream (reducing the capacitance between sections) and are also shielded by the screen grids, interaction is minimised.

The oscillator voltage is usually injected into the mixer section at the grid nearest to the mixer anode, thus minimising space-charge coupling (a form of interaction). Due to the low interaction, the oscillator grid circuit can be tuned. It is so constructed that a high signal/noise ratio and high conversion gain (owing to small amount of damping on input circuit) can be obtained easily—even on high frequencies.

Local oscillators are usually straightforward arrangements in the form of a leaky-grid detector, except that the reaction coupling is made so tight that the valve is continuously in a state of oscillation. The most popular systems are the series-fed oscillator with the grid circuit tuned, or the parallel-fed oscillator in which either the anode or grid circuit is tuned. (Fig. 4.)

The parallel-fed tuned-anode system is used to provide maximum isolation between the injection grid and oscillator tuned circuit. L1 is the oscillator primary winding which, with C1, tunes to a frequency different to the signal frequency by an amount equal to the chosen intermediate frequency (usually 465-478 kc/s). L2 is the secondary, or feedback winding, tightly coupled to L1 to maintain continuous oscillation.

C2 is the grid blocking capacitor, R1 the grid leak, whilst R3 provides standing bias for the mixer section by-passed in the usual manner by C3. R2 is included to prevent parasitics. R5, decoupled by C4, forms a voltage dropper for the triode anode, in Fig. 4b and c, it is used as the anode-load resistor. The series resistor, R4, is a voltage limiter which may be necessary and is explained later in this chapter.

A small parallel trimmer (C5) is used for alignment at the high-frequency end of the waveband and C6, a series trimmer of padder, is used at the low-frequency end. C1 is, in practice, one section of a ganged capacitor. One other section at least is required—for the mixer-grid circuit—and two if a stage of tuned RF amplification is provided. In this way the oscillator frequency can be kept automatically in step with variations in signal frequency.

Although multiple valves, such as the triode-hexode, are used extensively; sometimes a separate oscillator is used for high-frequency operation. This is to avoid frequency drift, which is serious at high frequencies. Early television receivers, with low-frequency IF stages for the sound channel, often suffered from this fault and it was not unusual to have to re-tune the sound several times during the course of a programme.

Drift may be due to one or more of several causes—small temperature changes, poor mechanical construction, lack of adequate ventilation, varying operating voltages due to a badly regulated HT supply, smoothing capacitors or coils which change characteristics as temperature rises.

It can be minimised by several methods. Referring to Fig. 4a, C4 can be shunted with a larger valve capacitor (say 8 μF) or, even better, by a voltage regulator such as the VR105-30.

An alternative is to use a bleeder network in conjunction with a series-fed oscillator circuit. This (Fig. 4d) enables a smaller series resistor to be used which is an advantage. With a high-value resistor any slight change of anode current introduces a substantial change in anode voltage—hence, frequency drift. This cannot be used with the parallel- or shunt-fed circuit since a high-value anode-load resistor is required for efficient operation.

Frequency drift is, unfortunately, only one of the troubles possible in the local oscillator. Others include : harmonic radiation, parasitics, peaks and dips. These produce effects such as deadspots in the tuning range, miscellaneous whistles, "squegging," feedback and general instability.

It is quite possible for at least one of these faults to occur in a receiver even though it has been constructed to a tested and tried design. This is because the local oscillator stage can be affected by a number of factors : variations in coils, valve characteristics and efficiency, radical changes in layout, altered component tolerances—any of these can cause trouble in a circuit theoretically sound.

This need not cause undue worry, because such matters are usually easily remedied provided that the layout is reasonably good, components are of known efficiency, screening is provided where necessary and is effective, and that the complete stage is constructed rigidly.

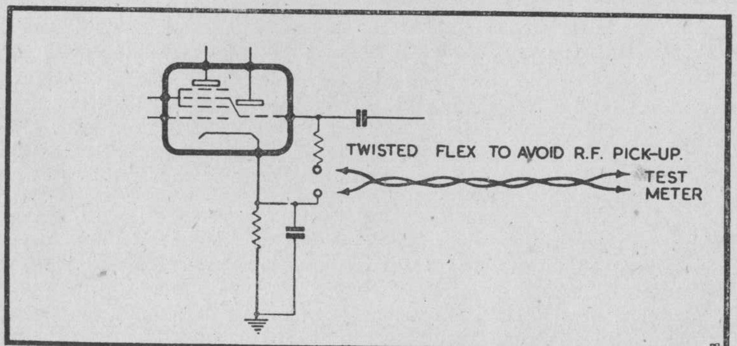

Fig. 5. Using a meter to read grid current.

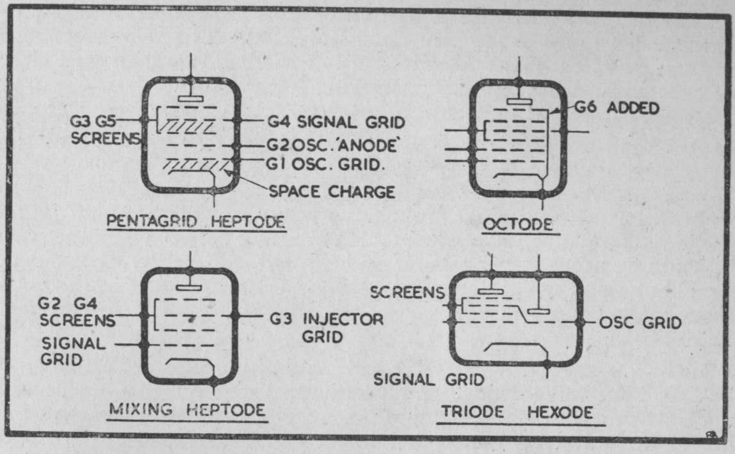

Fig. 6. Frequency changers and their electrode classifications.

Commercial radio receivers usually have anti-parasitic and amplitude-limiting resistors (R2 and R4, Fig. 4) incorporated, so that slight variations in wiring and component tolerances may be counteracted to some degree. The home constructor can ensure good oscillator behaviour with a series of tests, for which only a multi-meter is necessary.

The ideal oscillator would provide a constant amplitude output voltage over the full tuning range to be covered, but this is extremely difficult to obtain in practice due to the reasons already mentioned and to the degree of coupling between coils, wiring, and stray capacitances. The main thing is to ensure that there are no peaks or dips in output voltage when tuning through the waverange and, as these can be caused by parasitics, it is always advisable to fit a stopper-resistor (R2) at the anode or grid pin of the oscillator. To be effective the resistor must be wired direct to the valve pin and its wire ends clipped off close to the body. Peaks and dips can be due to adjacent coils in multi-waveband tuning systems absorbing the oscillator voltage, so that, if possible, the switching should be arranged to short out the coils not in use. It is preferable to use iron-cored coils because the magnetic field is more "concentrated," thereby reducing the risk of interaction.

To check the local oscillator in a newly built receiver, insert a meter in series with the grid-leak, at the earthy end, and switch to the 1 mA range. It is important that, in so doing, the wiring is not unduly disturbed and this is best ensured by using a short length of twisted flex to make the connections (Fig. 5). The self-capacitance of the flex will prevent RF pick-up but it should be kept well clear of coils and other components carrying RF voltages.

The current through the grid-leak may then be read. With valves of the 6K8 or ECH35 class it should be about 200 μA, and the heterodyne voltage will be approximately 10 volts (Ohm's Law—I × R = V). The peak voltage will, of course, vary according to frequency, but on tuning through the waverange there should be no sharp peaks or dips. A gradual falling or rising between extreme ends of a tuning range is permissible and, indeed, can hardly be avoided. Providing that the peak voltage is within the limits of about 5-15 volts throughout the entire coverage of the receiver, efficient mixing will be obtained.

If the current is obviously excessive, a limiting resistor (R4) should be fitted, the value depending on individual requirements. This will not only prevent defects, such as " squegging," but will lengthen the life of the valve. On the other hand, insufficient grid current will cause instability and poor mixing. It can be increased by tightening the coupling between the coils (if home made), increasing the HT on the oscillator anode or by increasing the value of the grid-blocking capacitor (C2) to about 500 pF.

" Squegging " in the oscillator can be caused not only by excessive anode voltage but by too high a grid resistance. On high-frequency bands it may be necessary to reduce the value to secure freedom from this trouble, but it is not advisable to go below about 27 KΩ. Incidentally, all limiter and anti-parasitic resistors must be of carbon construction.

Greater isolation between the injection grid and tuned circuit is obtained by tuned-anode shunt arrangement (Fig. 4c). It will be seen that the voltage-dropping resistor (R5) is also the anode-load resistor and care must be taken when deciding its value. If too high, the anode voltage will be too low for stable operation, but if the resistor is too low in value, damping of the tuned circuit may result. Quite often these defects can be remedied by inserting an RF choke in series with R5 but it must not resonate within the waverange to be covered.

Fig. 6 shows the electrode structure of the various types of frequency changer currently available.

CHAPTER THREE

I.F. AMPLIFIERS

The IF amplifier presents few problems to the constructor, but, none the less, it is an important stage of the receiver because it is here that practically all the voltage amplification is obtained and selectivity derived.

An IF amplifier is simply a high-gain RF amplifier designed to function on one fixed frequency. It scores in performance over a signal-frequency amplifier for several reasons. Simplicity: after initial alignment, no further adjustments to the tuned circuits are necessary. Efficiency: high gain is obtainable owing to the low working frequency and due to its fixed frequency characteristic (tuned RF stages vary in efficiency from one end of the band to the other). Other advantages include the preclusion of self-oscillation due to the low frequency used and the fact that tuned circuits with a high L/C ratio, leading to greater selectivity, can be employed.

The tuned circuits in an IF amplifier consist of 1 : 1 ratio shielded RF transformers, universally wound and small physically (to reduce magnetic fields). The IF transformer can be air or dust cored, the latter is usually preferred because it is easier to obtain a high Q which results in high selectivity and amplification. Alignment is carried out by varying the position of the iron-dust core. Air-cored types are usually fitted with small mica-dielectric trimmers but for a highly efficient short-wave receiver it is best to use those with air trimmers, since they are more stable and not so prone to capacitance change due to thermal effects.

Most receivers use only one stage of IF amplification. The selectivity of any receiver is largely dependent on the number of tuned circuits employed, so that, with only one IF stage, selectivity is adequate for normal requirements since there are four tuned circuits in addition to the local oscillator and signal-frequency stages. Where two IF stages are used, great care must be taken with circuit arrangement to avoid self-oscillation and instability, due to the extremely high gain obtained. Sometimes IF transformers, with tapped secondary windings, are used, as this arrangement gives increased selectivity, but with a slight reduction in gain. Fig. 7 shows typical IF amplifier circuits.

On the design of the IF transformer depends the selectivity of the stage but, not only is the Q of the tuned circuit important, but the degree of coupling between windings. Fig. 8 illustrates response curves obtained with a TRF receiver; curve A is taken with the regeneration control advanced to give maximum efficiency. There is reasonable selectivity but substantial non-uniformity of sideband

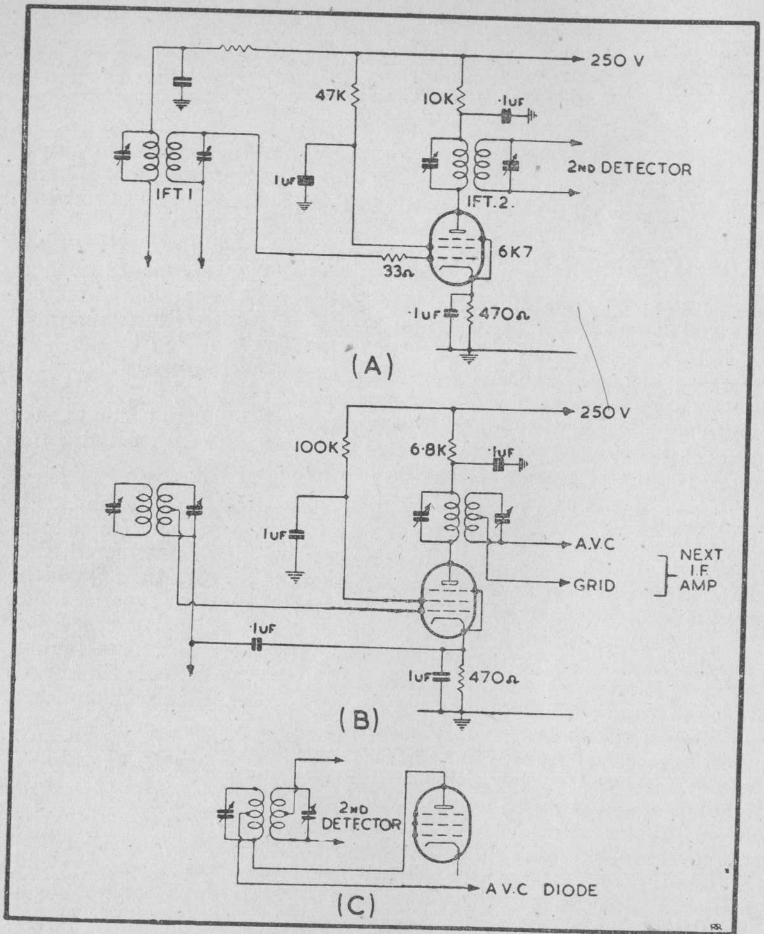

Fig. 7. IF amplifier circuits: (a) Using conventional IF transformers; (b) With centre-tapped secondary; and (c) with both windings centre-tapped.

response—low frequencies will be amplified at strength but the high notes will be extremely weak.

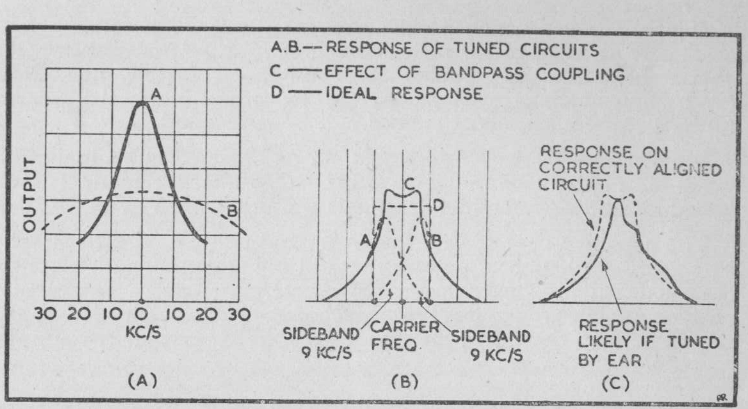

Fig. 8. Selectivity response curves: (a) TRF; (b) Superheterodyne IF amplifier showing how tight coupling of coils produces band-pass characteristics; (c) Showing how the response of an IF amplifier can be distorted when aligned without proper test equipment.

Without regeneration, the tuned circuit will have a higher effective resistance, resulting in a curve B. Here the sidebands are fairly uniform, but selectivity is poor, and interference will be experienced from stations operating on adjacent channels.

With the superheterodyne, high selectivity can be obtained, but the problem of sideband cutting has to be overcome. The coupling of the tuned circuits has an interesting effect on the response curves. If the coupling is loose, a sharply peaked curve (not unlike that of the regenerative TRF) is obtained which, of course, does not allow good reproduction. By tightening the coupling a double-humped curve is the result (Fig. 8c) which, although the sidebands are satisfactorily accommodated, there is a trough at the mean frequency.

If the coupling is further increased the peaks and the trough become even more pronounced. In practice, the resistance and coupling are arranged so that the trough is filled in, leaving a comparatively flat-topped curve with rapidly falling sides of sufficient width to accommodate the transmitted sidebands but little else. Adjustments are made to obtain a compromise between selectivity and sideband response which, of course, holds good for any signal received. In some cases, where sidebands are cut to preserve high selectivity, the audio amplifier is designed to accentuate the higher frequencies.

In short-wave communications receivers the problem of selectivity and sidebands is somewhat different, since these receivers are concerned mainly with the reception of CW stations.

Due to the congestion on the amateur bands, high selectivity is absolutely essential if any serious listening is to be undertaken. To obtain this razor-sharp tuning there are three possible methods—(a) by introducing regeneration, (b) by fitting a crystal filter, or (c) by a variable selectivity control.

Regeneration in the IF amplifier can be obtained in a number of ways—all of them basically the same. One effective method is to introduce feedback between the anode and grid as at Fig. 9a.

The capacitor C is of very low value and is often effected simply by soldering a length of wire to the grid pin and running it close to the anode circuit—making sure, of course, that once a satisfactory position has been found it is firmly anchored. The amount of feedback should be such that when the cathode voltage is very low (by adjustment of R) the valve begins to oscillate. The value of the potentiometer should enable the cathode voltage to be varied by some 30 volts. By bringing out R as a panel control, the selectivity and gain of the amplifier can be varied according to the tuning requirements and at maximum sensitivity (when the valve is on the verge of oscillation) the response curve will be extremely narrow. Fig. 9b shows an alternative to this scheme, a fixed bias resistor is used, but the potentiometer is arranged to vary the screen-grid voltage—with a maximum potential of about 100 volts. Two other methods are given; in 9d a tertiary winding is introduced in the IF transformer and is coupled to the cathode circuit. Fig. 9c shows how a third winding on the signal-frequency coil of the frequency changer can be used to obtain regeneration. The coupling is arranged so that oscillation commences when the control is almost fully rotated; if regeneration does not take place the inductance of the new winding should be increased. Normally the tertiary winding will require some 25% of the number of turns used for the main IF windings.

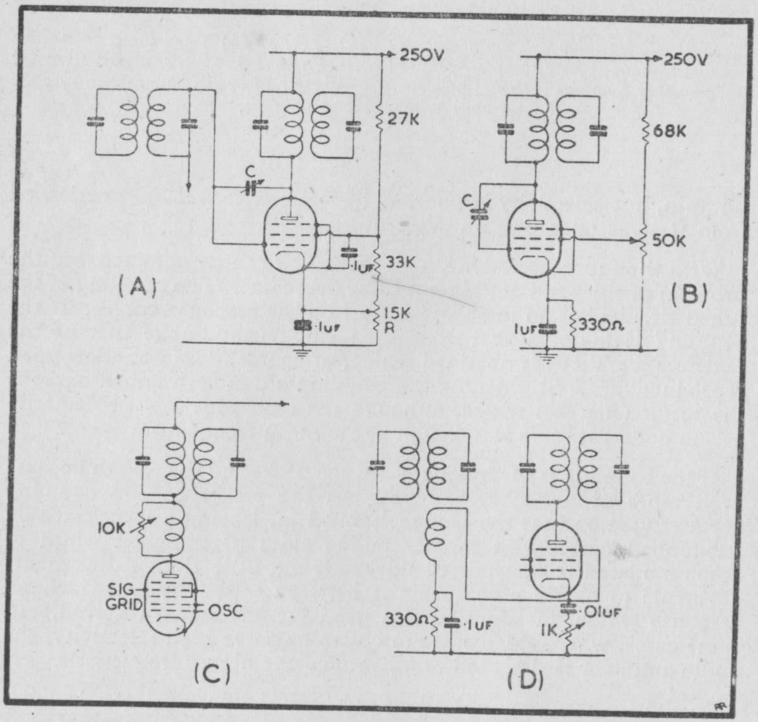

Fig. 9. Methods of introducing regeneration in an IF amplifier.

With these regenerative systems, selectivity approaching that of a good crystal filter can be obtained but, naturally, initial adjustments must be made with care if satisfactory results are to be obtained. A crystal filter is the best method of sharpening the response of an IF amplifier. An efficient circuit will enable the selectivity to be increased many times above that of a standard transformer-coupled amplifier. However, the design of such a filter presents many problems and care must be taken if serious loss of gain is to be avoided.

The more elaborate types of crystal filter may use up to four crystals to provide varying degrees of selectivity but for ordinary purposes the single-crystal bridge-type filter is adequate. Fig. 10 a-b-c shows various arrangements for this type of circuit, which can be regarded in theory as a four-arm bridge; each half of the centre-tapped secondary of T1 acts as an arm and the remaining two are the quartz crystal and the phasing-adjustment capacitor.

Series circuits could be used, but since the selectivity is so sharp, severe distortion in sideband response would occur on telephony if no means were provided to vary the selectivity.

In the circuits shown, the reactance of the crystal is high when a signal, somewhat removed from the intermediate frequency, is applied, but some current will flow through the crystal due to circuit capacitances which are in effect shunted across it. Since the voltages at either end of the T1 secondary are of opposite phase, the phasing capacitor can be so adjusted that it will pass a current equal to that through the crystal due to strays and as these two voltages will be in opposite phase they will cancel out.

On the other hand, the crystal will offer very low resistance when a signal at intermediate frequency is applied; very slight losses will be incurred. The phasing capacitor is usually brought out as a panel control, since the shape of the response curve (which is that of the crystal itself) can be adjusted to give sharp anti-resonances either side of the desired frequency (Fig. 10d). From the practical point of view, I.F.T. should be of the iron-cored variety. The existing fixed capacitor should be removed from the secondary and replaced by two series capacitors, each having twice the capacitance of the original component, their junction taken to chassis, to provide the necessary centre tap. The output tuned circuit should resonate at the IF, so that it can be taken from an existing IF transformer; it must, however, be adequately screened.

A bandwidth control is useful, a circuit incorporating this feature being shown at Fig. 10b. It operates on the principle that the voltage applied to the crystal is proportional to the parallel impedance of the T1 secondary winding. This voltage increases as the effective resistance increases and the gain of the receiver is not greatly affected within a bandwidth range of some 10 : 1. Maximum selectivity is obtained when the parallel circuit is tuned to be substantially reactive; minimum when the parallel circuit is tuned to resonance. The variable capacitor acts as an effective selectivity control.

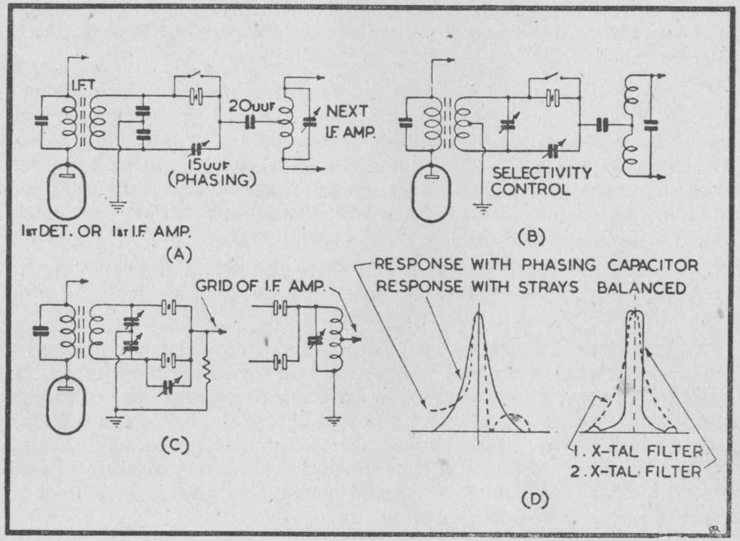

Fig. 10. Crystal filter circuits.

In this arrangement the output transformer consists of two windings, the lower having only a few turns and closely coupled to the upper winding. In this way, improved efficiency of the circuit is obtained due to the matching of the crystal circuit to the high-impedance grid circuit in the subsequent amplifier.

Receivers using crystal filters usually incorporate two IF amplifiers, because of the losses incurred in the filter circuit. In such cases, the filter is often inserted between the two amplifiers. Where only one IF amplifier is used, the filter is fed from the first IF transformer.

Variable selectivity is possible in a number of other ways. One uses IF transformers in which the degree of coupling between the primary and secondary can be varied mechanically by a panel control. A second method is to connect a tertiary winding to the IF transformer secondary, this winding is in series with the secondary and is provided with tapping points at intervals. Switch selection to these tappings enables varying degrees of selectivity to be obtained. Another system provides two degrees of selectivity—one for normal listening and one for high-quality (wide bandwidth) reception. This relies on normal operation for high selectivity and the switching in of a coupling capacitor between the primary and secondary windings to flatten the rosponse and thus broaden the bandwidth.

The intermediate frequency adopted in modern receivers is between 465 and 478 mc/s, this being chosen as a suitable compromise between the greater selectivity but poor second-channel characteristics of the lower IF and the good second-channel rejection but broader response of the higher IF.

As will be seen in Chapter 4, second-channel interference is more troublesome on high frequencies, and in amateur communications receivers covering bands down to 30 mc/s the effect can be quite troublesome. This could be overcome by using a higher IF, but this would considerably flatten the response curve and result in decreased gain and selectivity.

One way of providing all three desirable features—high gain and selectivity together with substantial second-channel rejection—is to use a " double superheterodyne." As the name implies, the circuit consists of a superheterodyne circuit preceded by another, the principle is shown in Fig. 11. The signal is amplified at carrier frequency and mixed to provide an IF signal of high frequency (usually around 1,500 kc/s). This is fed into a second frequency-changer stage to produce a normal IF (465-478 kc/s). The remainder of the circuit is as in standard practice. It is claimed that this system is superior in performance to receivers using a two- or three-stage pre-selector unit, since it achieves high selectivity and has a comparatively low noise level.

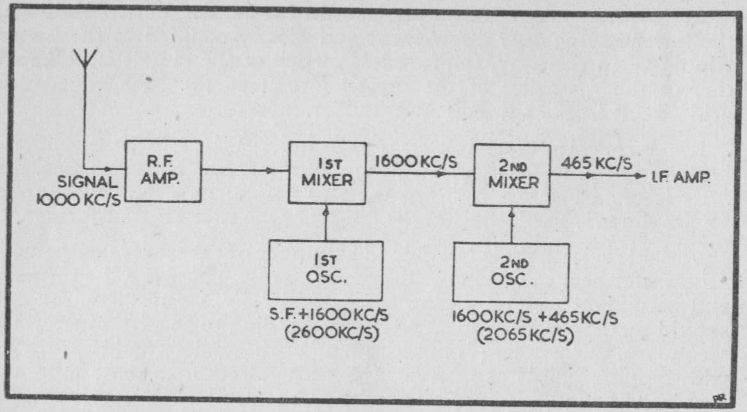

Fig. 11. The double-superheterodyne in block outline.

A poorly designed receiver will generate considerable noise in the RF and IF amplifiers with the result that many weak signals are swamped out of existence. From this it will be appreciated that the signal-to-noise ratio is of major importance when a high-grade receiver is being designed. A good receiver will give a signal-to-noise ratio of 6 db for an input of 1 micro-volt, that is, a ratio of 2 : 1.

There is little to be said concerning the construction of IF amplifiers. Connecting leads should, of course, be kept short and adequate decoupling and screening provided in order to prevent instability. Anode and grid circuits should be kept apart, and all IF transformers screened. Commercial types are supplied screened, but where special coils are needed as in the crystal filter circuits described, these must also be shielded. Either " X " cut or " Y " cut type crystals can be used, but an " X " cut crystal has a greater resonant impedance and consequently is more efficient. Where a phasing capacitor is used, its connecting leads must be kept short, and if the unit is away from the chassis front an extension spindle control should be used. Valves, if not of the metal types, are better provided with screening cans.

CHAPTER FOUR

PRE-SELECTORS

One of the incidental peculiarities of the superheterodyne receiver is the fact that two different signal frequencies can produce the same beat frequency. Assuming the IF to be 500 kc/s, signal frequencies of 1,000 and 2,000 kc/s will both produce the beat note (oscillator frequency 1,500 kc/s). It will be seen—and this holds good for any arrangement of signal, oscillator and beat frequencies—that the two signal frequencies are spaced equally around the oscillator frequency and differ by an amount equal to twice the beat frequency.

If no precautions are taken to stop the unwanted signals reaching the mixer stage, they will be heard in the loudspeaker. Put in another way, it can be seen that every station can be received twice—once on its fundamental frequency and once at a frequency equal to the fundamental less twice the IF—provided the receiver tunes to the ranges. On short-wave bands this trouble, known as *second-channel* or *image* interference, can be very annoying.

To take a practical example : Assuming the use of 470 kc/s IF, all stations will be heard as second channels 940 kc/s lower in frequency. In this way broadcasting stations in the 19-metre band (15,000 kc/s) are also heard in the 20-metre amateur band.

The ability of a receiver to reject unwanted signals of this type is

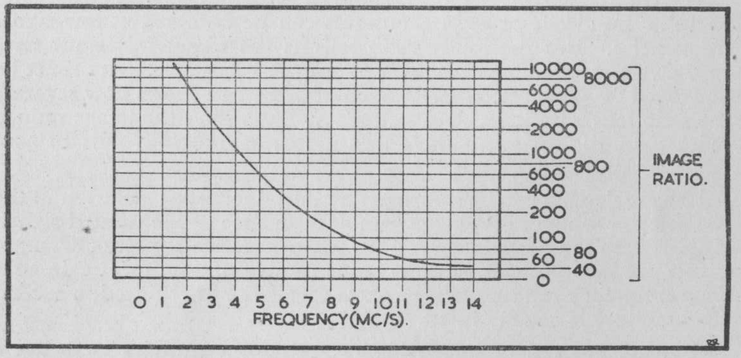

Fig. 12. The second-channel rejection ratio decreases as the signal frequency increases.

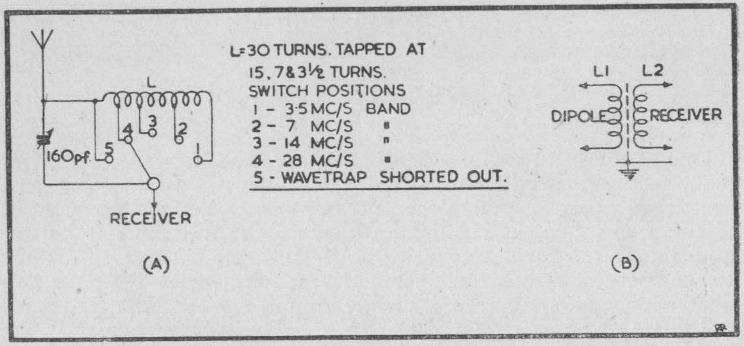

Fig. 13. (a) Tunable wavetrap to reduce second-channel interference over selected bands; (b) An electrostatic shield between the aerial circuit and the receiver will improve the signal/noise ratio.

called the *image ratio*, being the ratio of image signal voltage to the wanted signal voltage required to give the same output voltage. To obtain reasonable rejection it is necessary to fit a stage of RF amplification, or, as it is often called, a pre-selector. This is a normal RF stage, incorporating a tuned circuit, so that it will amplify the wanted signals but not the signals which could cause image reception. Incidentally, the pre-selector does not amplify the stronger signals to such an extent as it does weaker signals. This increases the sensitivity of the receiver as a whole.

With one stage of pre-selection, and an IF of 470 kc/s, an image ratio of a few hundreds or even thousands can be obtained at low-signal frequencies. But the image ratio falls as the signal frequency rises so that, on ranges above 10 mc/s or so, the input selectivity must be improved for good rejection. The chart of Fig. 12 shows how severely the ratio falls with increasing frequency. At 1 mc/s the image ratio is more than 10,000, at 2.5 mc/s it is 4,000, at 6 mc/s it falls to 300, whilst around 14 mc/s it is as low as 50.

Image rejection can be improved by introducing regeneration in the pre-selector which raises stage gain at resonance of the wanted signal. This system is unsatisfactory, even when negative feedback arrangements are incorporated, since it tends to give non-uniform gain over wide frequency ranges. Where extra selectivity is required, a second RF amplifier is usually fitted.

Another method of improving pre-selector selectivity is to use a wavetrap filter arrangement in the aerial circuit. Whilst accepting wanted signals, the filter presents high impedance at unwanted frequencies. It has been shown that images are most troublesome at a frequency removed from the wanted frequency by twice the IF; the tuned filter circuit should, then, be resonated at 940 kc/s above signal frequency.

Such a filter will improve the image ratio by several times but has the disadvantage that tuning of the trap must be separate. However, the passband is broad and a given trap can be used over any one waveband without adjustment. (Fig. 13a.)

Images can be caused by stray capacitances between the aerial and input circuit of the first receiver valve. A method widely used in the early days, but much neglected to-day, is the fitting of a Faraday shield. This is essentially a matching RF transformer (1 : 1 ratio) with an electrostatic screen between windings (Fig. 13b) and not only reduces image interference but provides a matching transformer for use with a dipole aerial. It also reduces other various noise pick-up from reaching the receiver stages.

Pre-selectors have another advantage, they will improve the signal/noise ratio, an all-important factor on the higher frequencies. Unfortunately it is necessary to compromise, because the signal/noise ratio is, to a great extent, dependent on the image ratio and sensitivity required.

For instance, whilst signal/noise ratio is best when the coupling is very tight, image rejection is best when coupling is loose. The ultimate sensitivity that can usefully be employed depends on the

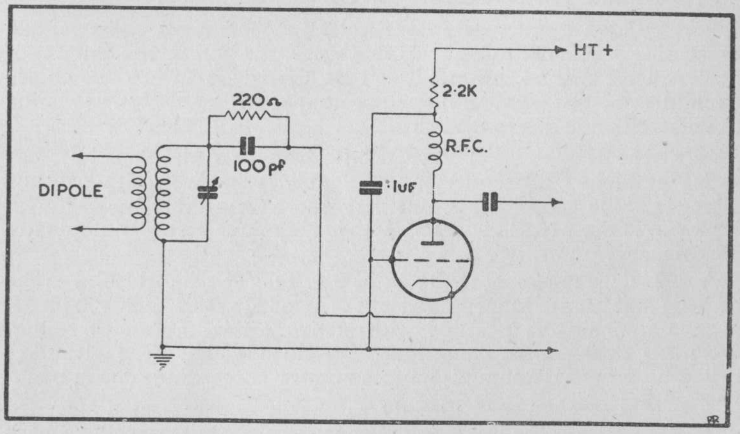

Fig. 14. A grounded-grid RF amplifier.

noise originating in the RF section of the receiver—electronic variation in the valves (shot effect), and thermal agitation in the tuned circuit.

These extraneous noises are distributed throughout the spectrum and, therefore, will be subjected to frequency changing and amplification together with the wanted signal. All valves generate " noise " voltages. The electron stream is often regarded as regular flowing of current; actually the constituent electrons travel as separate units—this produces valve " noise." The noise produced by the average valve is seldom more than 15 micro-volts and is usually nearer 10 micro-volts. This, in an audio stage, is of no consequence whatsoever.

But in the mixer section of the receiver the noise voltage is more troublesome because the signal voltage is often very low and the signal/noise ratio also low. It is of great importance, then, that where low signal levels are encountered (such as on the short-wave bands) a pre-selector is incorporated to feed a higher signal voltage to the mixer grid. In order to combat the apparent effects of receiver noise the signal voltage in the first tuned circuit is made as large as possible and the maximum gain obtained from the first stage so that the signal voltage is large compared to valve noise.

One stage of pre-selection generally provides a much greater gain than the frequency changer so the conditions required are easily obtained. It is interesting to note that thermal agitation (in the tuned circuits) is more predominant at lower frequencies, where the impedance of the circuit is higher, and falls off as the frequency rises. In other words, at low frequencies thermal agitation predominates but at higher frequencies valve noises are the main problem.

At very high frequencies, valve noise can be serious. The general broad rule is that the more grids in a valve, the greater the amount of noise voltage will be produced, so that a triode is an obvious choice from this point of view. But triodes, used as RF amplifiers, are prone to self-oscillation due to feedback.

In recent years, special VHF triodes have been developed for use as RF amplifiers. The electrode assembly is small, resulting in low inter-electrode capacitances and very short connecting leads. With such valves the use of the *grounded grid* technique virtually eliminates self-oscillation.

A typical arrangement is shown in Fig. 14. The signal is fed to the cathode and, as the input impedance is somewhat less than 100 ohms, a good matching is possible with standard low-impedance feeder. With this arrangement the output impedance is high; the advantage is that no serious damping is imposed on the succeeding tuned circuit.

The grid is connected directly to chassis and acts as a screened electrode between the input and output circuits, thus preventing back coupling and, consequently, self-oscillation. A pentode RF amplifier, using standard RF transformer coupling, will have an input impedance of anything up to 10,000 ohms and since the Q is measurable quite small feedback voltages could result in self-oscillation.

A pre-selector is also valuable in eliminating other defects. It has been seen how second-channel interference can cause the reception of unwanted stations, but another effect is also possible. With the receiver tuned to receive a station on 1,000 kc/s and with an IF of 500 kc/s (oscillator—1,500 kc/s), an unwanted station on 2,000 kc/s will produce a beat of 500 kc/s. Now if the unwanted station is not exactly on 2,000 kc/s, say 2,002 kc/s, it will produce an IF of 502 kc/s.

Both will be passed to the IF amplifier, which is not selective enough to reject the 502 kc/s signal, so that wanted and unwanted IF's will be fed to the second detector. This valve will combine the two signals to produce a continuous note of 2 kc/s, the difference frequency. It would be heard as a tunable whistle.

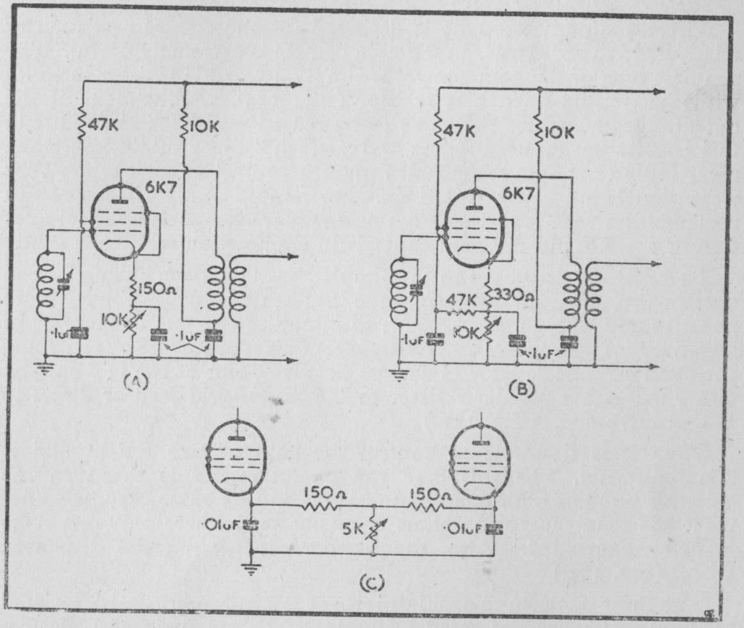

Fig. 15. Fitting an RF gain control: (a) Simple arrangement; (b) improved system; (c) Method used when more than one stage is simultaneously controlled.

This effect was particularly troublesome in early receivers which used an IF in the region of 100 kc/s. Modern sets, using a higher IF, are not so prone to the effect since the separation between wanted and unwanted signals is greater. Even so, on short-wave bands tunable whistles can be annoying and as the frequency increases so the percentage difference between wanted and unwanted stations (twice the IF) decreases. And, even though an unwanted station may be well separated from the wanted signal, it may be thousands of times stronger and may break through, especially if close to the receiving site.

A more obscure trouble is the reception of a whistle on every station received. This is usually caused by a station operating in the IF band itself penetrating into the IF amplifier circuits. A single RF stage normally cures the effect.

In the same category is *beat interference*, caused by a powerful station operating at oscillator frequency. This, and various other similar troubles, is in almost all cases remedied by improving the RF selectivity—in other words, fitting a pre-selector.

Where a superheterodyne is designed for short-wave reception of relatively high standards, an RF gain control is extremely useful. The simplest type of RF gain control is simply a variable resistor in series with the normal fixed bias resistor (Fig. 15a). Adjustment of the potentiometer enables the valve to be biased well back as required; this enables background noises and "mush" to be minimised when receiving strong signals and also gives a control of gain when very weak signals are being picked up. Experienced operators can obtain remarkably strong reception from normally weak signals by manipulation of the RF and AF gain controls in conjunction with each other.

There is one drawback to the simple control shown. The electron current through the valve falls as the grid becomes progressively more negative and this, in effect, tends to minimise the rate of increase in negative bias with increasing resistance. This is overcome by returning the fixed cathode resistor to a more positive point of the HT supply, either through a bleeder resistor to the screen-grid feed or direct to HT positive line. (Fig. 15b.)

Often it is desirable to control the gain of two RF amplifiers simultaneously. In this case the potentiometer is taken to the "earthy" end of both fixed bias resistors and its value may be somewhat less than the 10,000 ohms normally used where only one stage is being controlled. Also, the bleeder resistor may be dispensed with. (Fig. 15c.)

Care must be taken to avoid the risk of RF instability and associated troubles. To prevent stray coupling—both magnetic and electrostatic—the RF stage or stages must be completely screened; this also prevents external fields reaching the RF amplifier components and wiring. A common partition wall below chassis may not be a satisfactory method of screening the RF stage(s) because it may, in fact, increase inter-stage coupling. A complete compartment, in the form of a metal box, is decidedly better and, to keep losses low, it should be constructed of some low-resistance, non-magnetic material such as copper or aluminium. Certain losses will be experienced because the fields created by the components and wiring cause a current flow in the screening which, of course, results in some loss.

The placing of components can be planned to reduce these losses and consequent resistance of the tuned circuit. Since losses due to electrostatic fields are negligible, capacitors may be mounted close against the compartment walls should this be desired in the interests of compactness. Losses due to magnetic fields can, however, be considerable and, accordingly, coils should be spaced from metal walls by a distance at least equal to their diameters.

Anode and grid wiring must be isolated as far as possible. High-gain valves such as EF50 should be fitted with a metal screen across the valveholder to isolate the grid and anode sections. On other single-ended valves (6SK7, etc.) it is a good idea to mount the screen-grid by-pass capacitor over the valveholder so that the metal foil acts as a screen; it should be noted that the foil should be connected to chassis (this is marked on most capacitors). Grid leads should not be made with screened cable as this will introduce losses.

Above chassis, screening requirements are not so important, although screening cans should be fitted to valves unless they are of the metal type. Incidentally, a metal cabinet is a great asset as it prevents direct pick-up of signals on receiver wiring.

Chapter Five

DETECTION, AVC AND AF AMPLIFICATION

The majority of TRF receivers use a triode, pentode or tetrode detector in a leaky-grid arrangement, except in the case of high-quality local-station receivers. The advantages are that the circuit is sensitive to weak signals, particularly if a pentode is used, that the valve functions both as a diode detector (using the grid-cathode path) and as an amplifier, and that the provision of some form of regeneration control enables the maximum possible selectivity and sensitivity to be obtained. The disadvantages are several but the main points were discussed in Chapter 1.

Superheterodynes, on the other hand, invariably use a diode detector. A diode does not amplify the applied signal, but as it presents a low resistance in the direction of current flow it is not so liable to introduce distortion on strong signals as are triode or pentode detectors. In any case, amplification is not required since there is sufficient amplification in the IF amplifiers. The aim is for minimum distortion rather than sensitivity.

As readers may not be familiar with diode detectors, a few notes may not come amiss. The valve will only pass current when the anode is positive with regard to the cathode, so that when an RF signal is applied, current will only flow through the diode circuit when the signal swings the anode positive—the valve being non-conductive during the negative half-cycles. Thus the signal waveform is cut in half, leaving only the upper part of the envelope.

Referring to Fig. 16a (a basic diode-detector circuit), the filter capacitor C offers a low impedance to RF but high impedance at the IF. Thus, it filters out the RF component as it opposes rapid changes of voltage and demodulation is achieved. On positive half-cycles, C becomes charged and the resistor R (the diode-load resistor) is necessary to prevent the charge held by C from biasing the diode to cut-off conditions. In fact, the time constant C/R must be chosen so that the circuit conditions are restored to normal almost instantaneously. Resistor R passes the DC component to the AF amplifiers.

The filter capacitor C must not be too high in value otherwise it will not only bypass the RF component but some of the audio frequencies, thus causing high-note attenuation. A typical value is 100 pF. The load resistor should be of such a value that it allows the charge across C to leak away to avoid distortion but if too low resistance is used it will tend to damp the tuned circuit considerably. A value of 0·47-1 megohm is normal

This detector is virtually linear in response except at very low input voltages but it has one disadvantage in that it tends to damp the

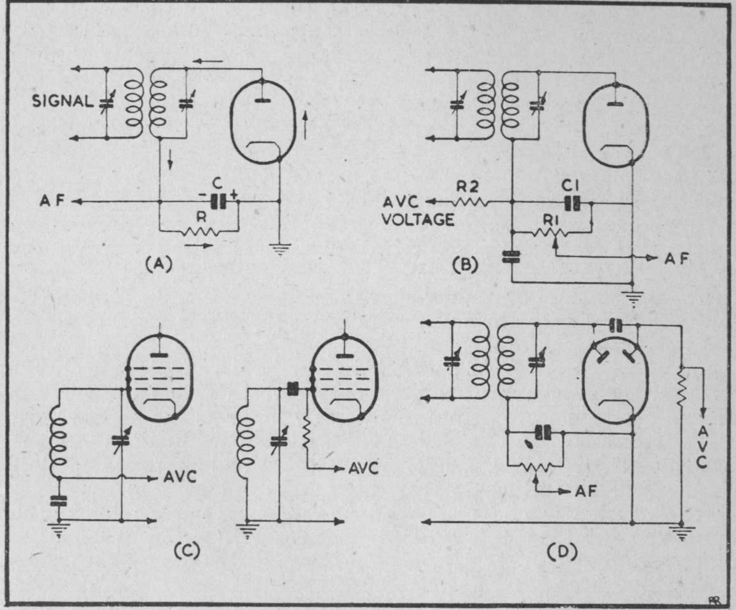

Fig. 16. The diode detector and AVC: (a) Basic diode detector; (b) Simple AVC; (c) Alternative methods of applying the AVC voltage to controlled valves; (d) AVC using separate diodes for detector and AVC rectification.

tuned circuit, flattening the response curve and reducing selectivity and output. In practice, however, this trouble can be largely overcome.

Practically all superheterodyne receivers have some form of *automatic volume control* (AVC), or, more correctly, automatic *gain* control, fitted. AVC can be fitted in TRF receivers but since pre-detector amplification is normally small it is seldom practical.

Basically, AVC is an attempt to level out all signals to a comparable strength, so that both weak and strong signals are reproduced at about the same volume—according to the setting of the manual volume control. It is extremely valuable in short-wave receivers as it obviously will minimise the effects of fading. Additionally, AVC is useful in reducing the strength of extremely powerful signals and so preventing overloading in the amplifiers and/or loudspeaker.

Fig. 16b shows a basic AVC arrangement where R1 and C1 are the filter components already discussed. It will be seen that the load resistor is variable. This is the manual volume or gain control · It is convenient to introduce the control at this pont in the circuit as it keeps distortion low, since the signal can be kept large at the detector and small at the amplifier. The steady current flowing through R1 as a result of normal detection processes produces a voltage drop across the load resistor which is proportional to the amplitude of the signal voltage. There is, in fact, a DC negative voltage available which is, strictly speaking, a waste product. However, if this voltage is fed back to preceding stages it can be used to increase the grid bias, thus reducing the mutual conductance and, of course, the gain.

R2 and C2 comprise the AVC decoupling filter and prevent AF signals from reaching the controlled valves and causing variations due to AF changes in the modulation waveform. The capacitor cannot charge up instantly or rapidly alter the voltage because it is, theoretically, in series with the resistor. Fig. 16d shows a form of simple AVC using a separate diode.

Valves which are AVC controlled must have variable-mu characteristics, such valves have a response curve in which the slope or mutual conductance becomes increasingly lower as the negative grid bias is increased. In this way, AVC levels out fluctuations in signal strength—if the signal fades, the DC potential at the diode-load resistor will be smaller so that the voltage fed back to the AVC-controlled valves will be smaller and the gain of the stages automatically increased when the bias is reduced. Conversely, a powerful signal will produce a greater AVC voltage so that the valves are biased farther back with a subsequent decrease in gain.

AVC may be applied to the valve grid in one of two ways (Fig. 16c). The usual method is to insert an isolating capacitor at the " earthy " end of the tuning inductor to prevent the AVC voltage being shorted out to chassis. This component must have a low impedance to RF so that the inductor is still virtually earthed so far as the oscillatory circuit is concerned. The second method is to isolate the grid end of the tuned circuit with a small capacitor.

In many circuits it is usual to apply separate AVC voltages to each valve affected, with individual decoupling. This is to prevent distortion which would probably arise if certain valves were over-biased. Normally, full AVC is applied to RF amplifiers, but a lower voltage to the frequency changer and IF stages.

This arrangement is called simple AVC. Although it certainly levels out variations in signal strengths it has several inherent disadvantages. In the first place, when weak signals are being received the background noise is unduly high. Secondly, the full gain of the receiver is not available because the diode will always produce *some* bias for feeding to the pre-detector stages.

For instance, if the AF amplifier following the detector requires 4 volts input for full output, it follows that 4 volts of bias (at least) is applied to pre-detector stages via the AVC line. Therefore, all stations not capable of providing this voltage will be unable to supply full output. Under these conditions the sensitivity of the receiver may be only one-hundredth, or less, of its possible sensitivity.

It is possible to arrange the circuit so that some 1·5 volts only is required for full output; this AVC voltage would not drastically reduce the overall sensitivity but, the stronger signals would produce an excessive output. Put in another way : the ratio in output produced by weak and strong signals would be higher, and much greater adjustment of the manual volume control would be necessary between extremes.

A great improvement can be obtained by the use of *Delayed AVC* which lowers the power output ratio and levels the AVC curve. This system, which is that used in the majority of modern receivers, consists of biasing the diode negatively so that only signals above a given reference level will be subjected to AVC control and those below this level are not controlled by AVC. The delay, then, is in terms of voltage and not of time.

Fig. 17a shows the basic circuit. If the anode of the AVC diode is 5 volts negative with regard to cathode, a signal voltage of at least 5 volts is required in order to develop an AVC voltage ; a signal of 10 volts would produce an AVC voltage of 5. The power output ratio obtainable with delayed AVC is something like 20 : 1, as against the 200 : 1 of simple AVC. It is important to note that with large voltage delays it is necessary to reduce the gain in the AF amplifier.

It is common practice to use a double-diode-triode, with one diode for detection, one for AVC, with the triode for AF amplification (Fig. 17b). This circuit is typical of present-day practice, self-bias is used and, since this is normally from 2-3 volts, a suitable delay is produced without complication. Note that the AVC bias on the

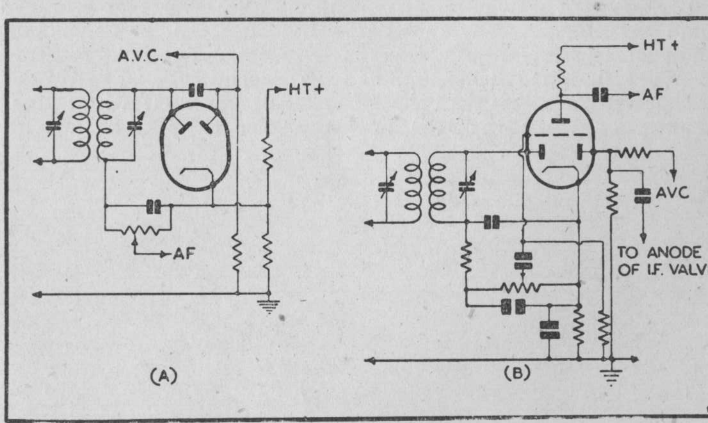

Fig. 17. (a) Delayed AVC; (b) Delayed AVC using D.D. TRIODE.

controlled stages is zero until the peak voltage on the AVC diode exceeds the delay voltage. In this circuit the AVC diode is fed from the primary of the final IF transformer as the selectivity is lower at the primary than at the secondary, which is to be expected since the number of tuned circuits has been reduced, " sideband shriek " is avoided. This effect occurs as signals are being tuned in. Quieter tuning is obtained because the AVC diode starts operating before the detector diode.

One form of AVC not often used is Quiescent AVC : this system has a noise limiter to minimise the effects of background noises at points on the tuning scale where no signals are being received. QAVC is quite complicated, and the principle is that instead of the AVC diode being biased (as in ordinary delayed AVC) the signal diode is biased to cut-off so that only signals of a certain minimum intensity overcome the bias and cause the diode to become conductive.

AVC should be applied to as many stages as possible in order to give the most efficient control. It is hardly practical with less than two stages, because the control action would not keep step with the signal-voltage level.

The controlled valves are usually fed as in Fig. 18, which shows a typical circuit for three controlled stages.

In many short-wave receivers an adjunct of the second detector is the beat-frequency oscillator (BFO). Reception of CW signals on a TRF receiver is usually obtained by adjusting the regeneration control until the detector is oscillating ; the slight difference in frequencies between that of the incoming signals and the tuned circuit provide the beat note (Fig. 19).

In the superheterodyne, reception of CW is made possible by the BFO which is a conventional oscillator of the ECO type working around the IF frequency (a separate oscillator can, of course, be used in a TRF receiver but normally CW reception relies on regenerative methods). The BFO is coupled to the second detector where the oscillator voltage mixes with the IF voltage to produce a beat note. If the tuned circuit of the BFO is made variable, the pitch of the note can be adjusted to suit personal taste and reception conditions ; the generally accepted ideal beat note being 1,000 c/s. In design it is aimed to provide a BFO voltage of the same order as the IF voltage at the second detector.

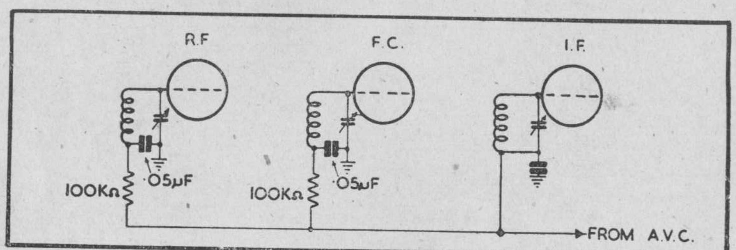

Fig. 18. A complete AVC decoupling system.

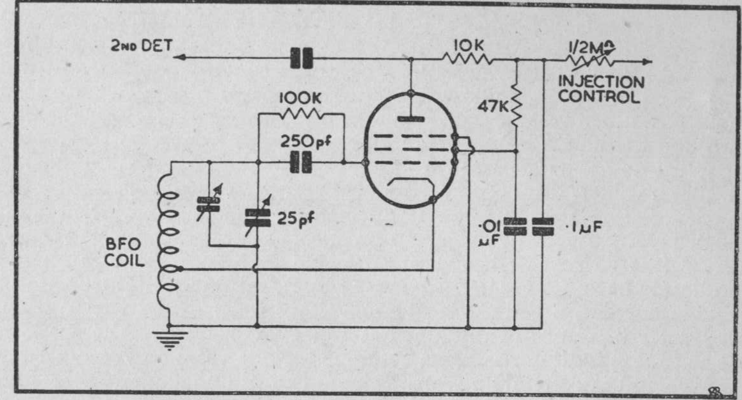

Fig. 19. A pentode BFO circuit.

It is important that the output (including the harmonic content) of the BFO be prevented from reaching the pre-demodulator stages of the receiver. To this end, the unit should be well screened (preferably in its own totally enclosed compartment) and the supply circuits to the BFO well filtered. Also, the oscillator should be run at as low an anode voltage as possible consistent with adequate output voltage. To enable manual adjustment to be made an " injection " control is sometimes incorporated ; this is usually a potentiometer to vary the supply voltage to the oscillator's anode and screen grid.

It will be obvious that the BFO cannot be operated when AVC is applied because the rectified BFO voltage will be a strong steady signal acting on the AVC-controlled stages and reducing gain. Thus, an AVC on/off switch must be provided in addition to a BFO on/off switch ; or, alternatively, a combined switch which cuts out the AVC when the BFO is functioning and vice-versa.

In more elaborate receivers a separate AVC rectifier and amplifier is used. Though increasing cost, this system has the advantage that the BFO voltage cannot affect AVC-control action (as it is coupled to the second detector and not to the AVC circuit) and thus the benefits of AVC can be obtained both on telephony and CW signals.

A useful addition is the tuning indicator, or " magic-eye " valve. Take the 6X6 as an example, it is similar in construction to a triode valve—it has a heater, cathode, grid and anode, as well as a special electrode called the " target." There is also an extension of the anode, called the " pencil," which is placed between the cathode and target.

The target is bowl-shaped and is coated with a fluorescent material so that the normal current flow through the indicator will cause the target to glow (usually green). Due to the construction, current will also pass to the anode circuit and, as this has a high-resistance load (see Fig. 20), a voltage drop will take place across the resistor thereby making the anode more, or less, positive with respect to the target.

With no anode current the whole face of the target is illuminated but as a voltage drop occurs across the resistor a shadow is cast by the pencil. The shadow then is affected by the anode current and, logically, by the grid voltage. In practice, the grid is connected to the AVC line so that as the received signal increases, the bias on the indicator becomes greater (more negative), resulting in a decrease in anode current, a reduction of the voltage drop across the resistor, a greater brilliance of illumination and a " closing " of the shadow. The tuning indicator is like a combined triode valve and cathode-ray device and is certainly a worthwhile aid to tuning stations correctly, especially in highly selective receivers where a slight mistuning will give rise to serious sideband distortion.

Short-wave communications receivers usually incorporate a different kind of indicator. Though the principle is basically the same (showing variation of signal strength) the reasons are somewhat different. Here it is desirable to compare visually the difference in signal strength rather than to provide an aid to tuning.

Fig. 21a shows a typical " S " meter circuit in which the AVC voltage is measured by a moving-coil meter in a valve voltmeter arrangement. The potentiometer acts as a " zero adjustment " control and is set so that with no signals it reads full-scale deflection. When signals are being received, the cathode becomes less positive and the meter will show backwards reading, signals of extreme power forcing the meter back to the normal " no reading " position. If the meter scale is then calibrated in the amateur " S " divisions (1-9) comparisons of signals received can be made. Note, however, that the divisions are not uniform but logarithmic—see Fig. 22.

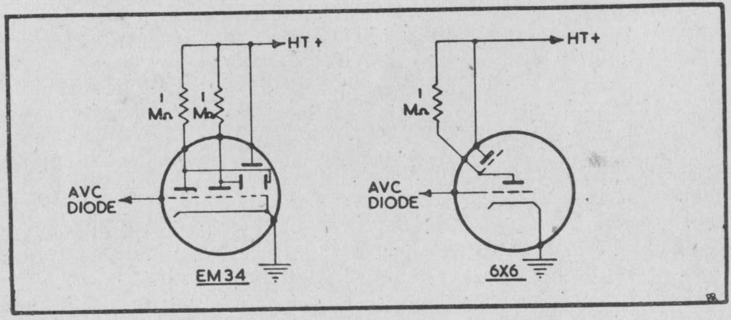

Fig. 20. How tuning indicators are fitted.

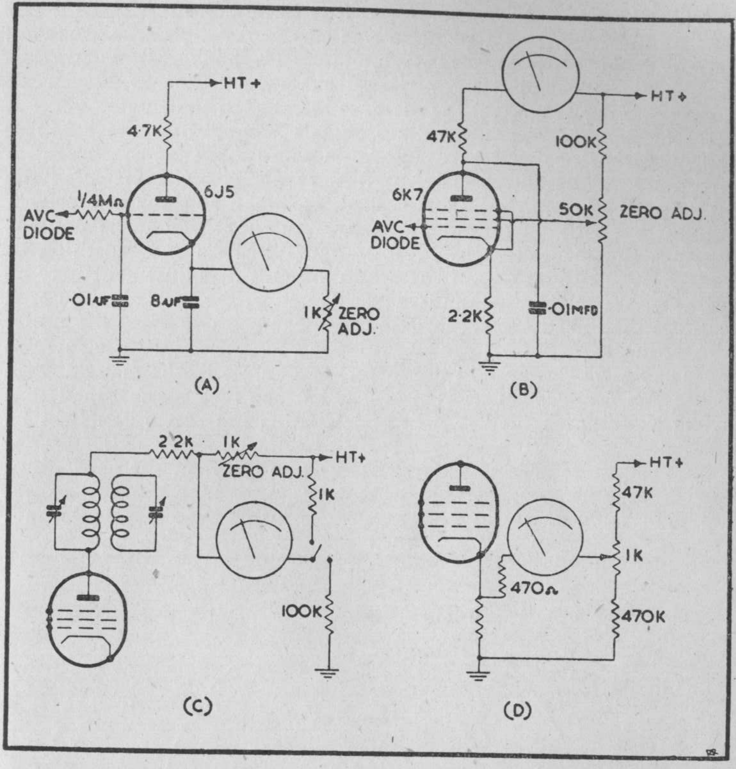

Fig. 21. Representative " S " meter circuits.

" S " meters are not necessarily correct in their interpretation of signal strength since the " S " unit has no universally accepted value. however, it is extremely useful in making comparative reports, in alignment and various receiver adjustments, in making aerial tests and as a tuning aid.

For operation a high-mu triode should be used. The meter can be 0-10 mA FSD, more sensitive movements can be used but the anode-load resistor must be increased accordingly. A better circuit, using a pentode, is that of Fig. 21b.

Where space restriction and/or cost is to be considered, the meter may be introduced at a point in one of the AVC-controlled stages, thereby saving separate valve stage. There are many possible arrangements, Fig. 21c and d show typical examples. The bridge circuit is very popular (Fig. 21c) the meter is inserted in the anode circuit of the IF amplifier and under " no signals " conditions the standing anode current provides zero deflection as adjusted by the potentiometer. The alternative (Fig. 21d) is to connect the meter in the cathode circuit. No reading will take place when no signal is received, but current will flow (and a reading obtained) when the cathode becomes more negative as AVC voltage rises on the reception of signals. With these circuits a certain amount of adjustment may be necessary on installation. In the bridge type, for instance, the feed resistors may need slight alteration ; in the cathode type, the upper resistor in the potentiometer may need to be increased if strong signals cause excessive response in the meter. An on/off switch may be fitted to the " S " meter ; this is useful when the receiver is tuned to a strong signal with the AVC in operation as the meter can then be isolated.

Noise limiters are, nowadays, used extensively on the short-wave bands. It must be understood, however, that such circuits do not eliminate valve noises or background " mush " which is sometimes predominant on the high-frequency bands. The purpose of a noise limiter is to reduce the effects of transient interference pulses such as those caused by car ignition systems and certain types of electrical motors.

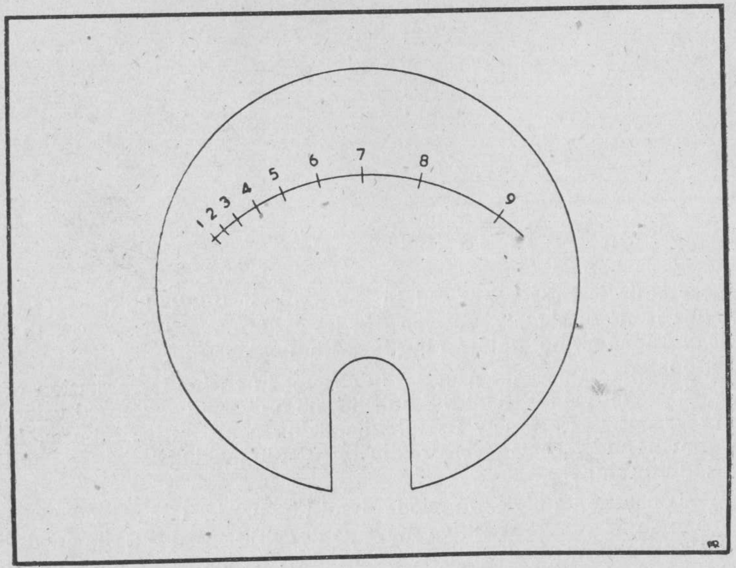

Fig 22. Suggested scaling for " S " meter calibration.

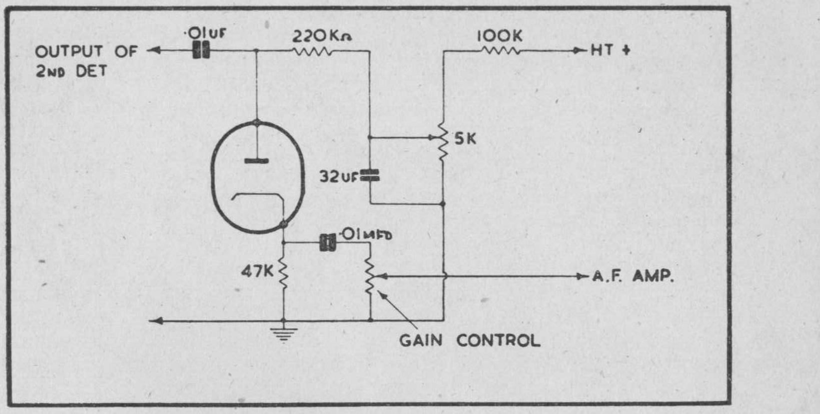

Fig. 23. The series noise limiter.

Noise pulses can be considerably reduced but the limitation of most circuits is that only pulses which appear the 100% modulation level can be " cut off." Further reducing the clipping level will not only cut off the interference pulses but part of the audio signal as well.

The most commonly used arrangement is the series limiter, in which a diode circuit is inserted between the detector and the AF stages (Fig. 23). The anode potential can be varied by the potentiometer VR1 from about 0 to 50 volts positive and is so adjusted that the diode will pass signals up to the 100% modulation level. Signals of greater amplitude, such as ignition pulses of high order, drive the anode less positive than the cathode so that the valve ceases to conduct. The pulses are of such short duration that the aural effect is simply a reduction in strength of the interference.

These notes only touch briefly on the question of noise limiters. In recent years much experimental work has been done in this direction and numerous circuits, many of them highly complicated, have been evolved in the quest for more effective noise suppression.

The audio stages following the second detector are quite standard and are the same as those found in TRF designs. Where a large output is required, it is usual to feed the output of the first audio stage into an amplifier designed for whatever output is required.

Chapter Six

ALIGNMENT

Aligning a superheterodyne is often a problem to the newcomer and yet, in fact, it is a simple logical procedure and does not require elaborate service equipment. A TRF receiver when first switched on can produce signals from the loudspeaker straight away—even if it does not do this, adjustment of the regeneration control will give some indications that the set is " alive." The average superheterodyne, when first switched on, usually brings forth nothing. This can be disheartening to the beginner but it should be realised that the number of tuned circuits involved makes initial alignment more exacting than that of a TRF circuit, especially in view of the fact that the tuned circuits must be adjusted to three separate frequencies, all of which must differ from the others by a pre-determined amount.

These receivers can be aligned with equipment such as an output meter, signal generator, oscilloscope, etc. On the other hand, with care and patience, they can be aligned without the aid of test gear. Obviously, the best results will be more easily obtained when service equipment is available, but in these notes alignment under all conditions will be considered.

The first step is to align the IF transformers. Indication of resonance may be achieved by the ear or visually—i.e. by using the existing loudspeaker or an output meter. The meter is best inasmuch as it is more accurate than the ear.

An output meter is simply an AC voltmeter provided with high- and low-impedance inputs and it is connected either to the primary (high impedance) or secondary of the speaker transformer. Accuracy of calibration is unimportant—all that is required is an indication of comparative output. When the speaker is disconnected, if an ordinary AC voltmeter is used, a dummy load should be shunted across the secondary of the transformer; its value should approximate that of the loudspeaker voice-coil impedance, and it should have an adequate power rating.

The IF transformers are designed to maximum efficiency at a pre-determined frequency. The transformers must be adjusted to that frequency otherwise the oscillator will be adjusted incorrectly and troubles such as whistles and incorrect tracking will result. A modulated signal (at whatever frequency the IF may be) is applied from the signal generator to the grid of the final IF amplifier and the trimmers, or cores, adjusted for maximum output indication on the output meter or through the loudspeaker. The injection is then transferred to the grid of the preceding valve (either the mixer or another IF stage) and the unaligned transformer peaked in the same way. This operation is carried out several times to ensure accurate alignment.

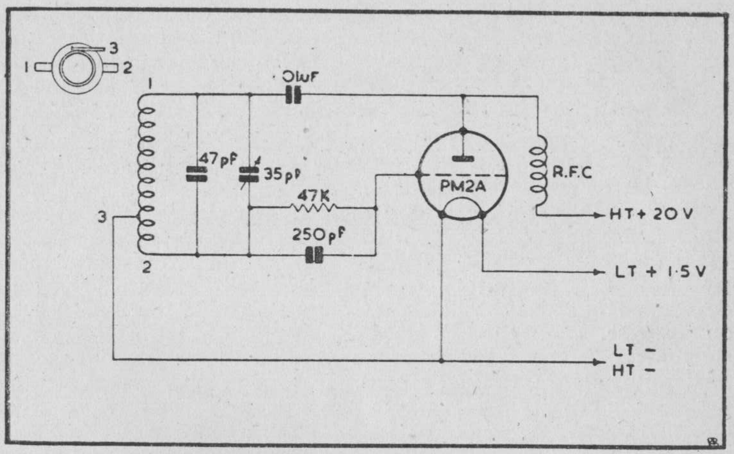

Fig. 24. Simple Hartley oscillator for IF alignment, using a Wearite BFO coil.

The output from the generator should be attenuated during the process of alignment (as gain is increased) otherwise the signal from the generator may be such at the second detector to produce an AVC voltage. If the AVC is in action the controlled valves will be biased back, the response curves flattened, and the results will be misleading. If an AVC on/off switch is provided it is better to switch out the AVC during alignment.

If no signal generator is available, the IF's can be set up quite easily. A simple IF aligner can be built up out of a few components in a short time. There are various methods, but a well-tried arrangement is a simple Hartley oscillator (Fig. 24) using a commercial BFO coil. This little unit is all that is required to align any receiver which has a 456-472 kc/s IF. To set up the aligner itself place it close to any receiver (the domestic radio will be satisfactory) which has a similar IF frequency. Tune the receiver to a station and then adjust the trimmer across the instrument oscillator coil. Adjust this trimmer until zero beat is obtained (minimum pitch of whistle).

As the instrument is unmodulated, no audio note will be heard when adjusting the IF's. However, the IF trimmers can be adjusted for maximum " hiss " or meter readings taken (a DC voltmeter across the cathode resistor of an AVC-controlled valve; maximum signal giving maximum reading). Only when the IF's are well off tune is it necessary to provide tight coupling between the instrument and the receiver—a length of flex, one end placed round the grid of the IF amplifier and the other near the instrument's coil, is usually sufficient.

When no equipment at all is available, the IF's can be roughly peaked if a signal of any sort, however weak, can be heard. Should no signals of any sort be audible, even on medium waves, a little ingenuity to create a signal is necessary. An electric drill, vacuum cleaner, dry shaver, hair dryer or other similar electrical appliance (which is not suppressed) should be switched on and placed in close proximity to the receiver; even if the IF's are well off tune a fair amount of radiated interference will be picked up, and the IF trimmers peaked on the noise. When the IF's are sufficiently aligned so that a few weak stations can be heard, switch off the interference source and make the final adjustments on actual signals. It must be appreciated that, by peaking the circuits in this way, while a degree of sensitivity will be obtained there is no way of determining the frequency to which they have been peaked and optimum results from the receiver will not be obtained unless a calibrated alignment instrument is used.

It is sometimes discovered after the IF's have been accurately peaked for maximum response that unpleasant " boomy " reproduction results. This is due to the overall response being too sharp so that the high-frequency sidebands are seriously attenuated. It can be overcome by " stagger tuning " the IF's a few kc/s (a fraction of a turn of the trimmer) to broaden the response; one of each pair of trimmers being adjusted higher in frequency and the other lower. Stagger tuning should not be resorted to unless reproduction is obviously much too boomy but if it is necessary, all IF trimmers should be first adjusted to the true peak frequency.

Some high-grade commercial receivers use band-pass IF couplings, the idea being to provide a flat response over a given band. It is essential that the alignment instructions provided by the designer should be strictly adhered to, since any attempt to peak such circuits will ruin the reproduction. So far no mention has been made of visual alignment. This system is by far the best and, for band-pass circuits and communication receivers using crystal control, is the only practical solution. By use of a suitable signal generator such as the Cossor 343, the IF (or the overall receiver) response curve is scanned and reproduced visually on an oscilloscope tube face. Adjustments to even the most complicated receivers are easily carried out by this system.

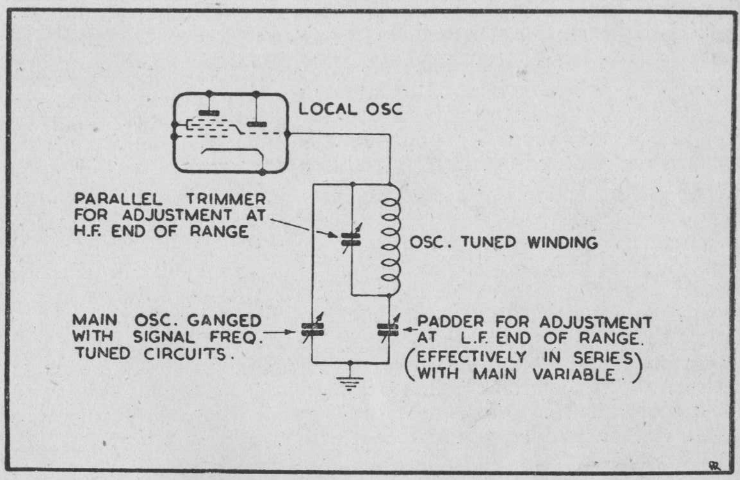

Fig. 25. Typical oscillator circuit.

After the IF section has been satisfactorily aligned, the oscillator and RF circuits can be adjusted. An outline of a typical oscillator circuit is shown at Fig. 25. The trimmers are necessary because, although the variable ganged capacitors may be accurately made, stray circuit capacitances can cause sufficient differences to require extra control. Trimmers are adjusted at the HF end of the tuning range where the main tuning capacitor will be fully " open " and the capacitance probably less than that of the trimmer plus any strays.

By adjusting the trimmers a balance between stages of both stray capacitances and inductance is obtained so that the tuned circuits should remain substantially in step as the gang is rotated. If the trimmers are adjusted at the HF end, any discrepancies at the low-frequency end will be due to inefficiencies in the components themselves.

When adjusting the oscillator trimmer it must be understood that it may be of sufficiently large capacitance to enable both the high- and low-frequency oscillation, which could produce the beat frequency, to be produced. The higher frequency is usual, unless the makers state otherwise, and the trimmer should be set at minimum on initial adjustment. If a given signal is heard more than once on adjusting the trimmer from minimum to maximum, the first strong reception point is the wanted one.

In Fig. 25 it will be noted that a second pre-set capacitor is provided in the oscillator section. This is the padder, and it is used to retain the correct difference in frequency between the oscillator and RF circuits over the wave ranges covered. Some receivers employ a capacitor with specially shaped vanes on the oscillator section in order to secure reasonable " tracking." These are seldom used to-day—the padding capacitor being more popular and easier to adjust.

In some receivers, particularly those used for high frequencies, the coils are iron-dust cored. This leads to more compact coil design and lower losses since less turns are required and a more concentrated magnetic field obtained. Alignment is identical—the dust core replaces the padder in general procedure.

The padder action is quite easy to see. As it is in series with the main variable capacitor, the total capacitance across them is something less than that of either individual component. Thus, the effective capacitance at the high-frequency end of the waveband can be made smaller (by adjustment of the padder) than the capacitance in the signal-frequency circuits. So that if the padder is adjusted at the LF end of the waverange and the trimmers at the HF end, tracking will be perfect at and around these points. There will, however, be errors between the two extreme points but these are not serious enough to affect performance. On the short-wave bands it is usual to dispense with a variable padder, and replace it with a fixed capacitor.

Many constructors will build a receiver which is to use a commercially made tuning scale with station names and wavelengths marked. It is important to determine what value tuning capacitors the scale is calibrated against. Most of those currently available are for 500 pF, with a 450 pF " swing "—that is to say the difference between minimum and maximum capacitance is 450 pF. Some manufacturers of coils and tuning packs give precise instructions on alignment procedure. Needless to say, these should be strictly adhered to.

General alignment procedure is as follows: switch the receiver on to the medium-wave band and inject a signal of 1,200 kc/s at the aerial; terminal. Many signal generators are supplied with a dummy aerial, failing this, the network shown in Fig. 26 should be used.

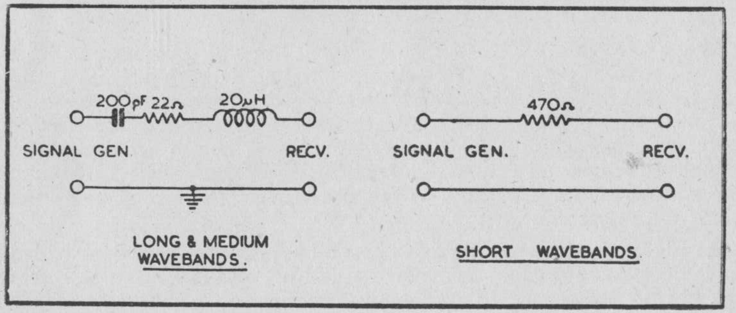

Fig. 26. Dummy load suitable for use with signal generator.

Search for the signal by means of the receiver tuning control and adjust the oscillator trimmer until the dial pointer coincides with 1,200 kc/s or 250 metres on the tuning scale. Set the generator to 600 kc/s (500 metres) and tune the receiver until the signal is picked up, set the dial pointer accurately, this time by means of the padder or, if fitted, the iron-dust core. This operation must be carried out several times since a change in value at one end of the scale will cause an alteration at the other.

When the dial calibration is correct, re-tune to 1,200 kc/s and inject a signal, peak the signal-frequency trimmers for optimum results. With air-cored coils there is not usually any provision for correction at the low-frequency end of the scale and alignment of the medium-wave band may be considered complete. In the case of iron-cored coils, the cores may be adjusted at 600 kc/s as for the oscillator, the whole operation being carried out several times as before.

If no signal generator is available, the oscillator calibration must be carried out on known stations such as the Light and Third programmes. Signal input should be kept as low as possible by use of as small an aerial as is practical, to avoid AVC action, since the results obtained would prove misleading.

On short-wave bands a similar procedure is followed, manufacturers usually issue spot-alignment frequencies for their products, but in the absence of such information, or in the case of a home-constructed receiver, trimming is carried out as before at the high-frequency end of the band and padding, if provided, at the low-frequency end.

Long-wave band alignment is usually carried out at 900 metres (332 kc/s) and 2,000 metres (150 kc/s), procedure is the same as for the medium-wave band.

CHAPTER SEVEN

A PRACTICAL RECEIVER FOR AC

By this time, no doubt, many readers will wish to construct a superheterodyne receiver for themselves. To cater for this, a simple yet very efficient design has been produced that can be constructed with confidence, even if the constructor has little or no previous experience of receiver construction.

To avoid unnecessary expense, AC/DC technique has been adopted for the HT supply. Reference to Figs. 27-28 shows that one side of the mains is connected to the chassis as with AC/DC or " Universal " receivers, as they are sometimes erroneously termed. It will be obvious from this that no direct earth connection can be made to the receiver chassis, the earth connection is taken to chassis by way of C23. Care should also be taken to ensure that under operating conditions the neutral pole of the supply mains is connected to chassis. If necessary a check should be made at the supply point to identify the neutral pole.

Connect an ordinary lighting bulb between a good earth (*not* a gas pipe) and each mains pole in turn, the neutral feed may be recognised by the pole on which the bulb fails to light up. Once this has been determined, use of a three-pin plug and socket will avoid accidental reversal when the receiver is in use.

The valve heaters are parallel fed from the 6·3-volt secondary of T2, which provides the advantages of normal AC practice, since the unpleasant surge usually associated with AC/DC heater circuits is avoided, as also is the need for wasteful dropping resistors or line cord which invariably run hot and can be a source of everlasting trouble. A metal rectifier was selected, since they are trouble-free and the necessity for valve replacement is avoided.

Note. When wiring up the receiver the two inner tags of the DRM2B must be connected together. Components have been kept to the minimum, consistent with good performance and, for the sake of simplicity, only one waveband provided. More experienced constructors can, of course, wire in a switched waveband assembly or use a coil pack such as is marketed by " Osmor." Actual chassis measurements are not provided because the layout is not highly critical and, so long as the general idea is adhered to, no trouble will ensue. Some constructors may wonder why an IF frequency of 470 kc/s is used when 465 kc/s is often called for in contemporary designs.

Since the Copenhagen plan for the medium and long wavebands was adopted, 465 kc/s has proved less satisfactory than originally and 470 kc/s represents a better choice in avoiding unnecessary whistles on certain B.B.C. transmitters. The IF transformers are prealigned by the manufacturers, Messrs. Allen Components Ltd., before despatch from the factory, thus simplifying the setting-up procedure for the constructor. For L1 and L2, coils from the well-known " P " range by Wearite are used. These are available at a very reasonable price and are both neat in appearance and efficient in performance.

Some capacitors in the components list have been provided with a voltage figure. This is the working voltage of the component; where no figure is quoted a working voltage of 350 volts will be found satisfactory. It should be remembered that variable capacitors for receivers, padders and trimmers are not usually given a working voltage, since their construction and function do not require it.

Where no specific manufacturer has been quoted, components by any good-class manufacturer may be used.

When purchasing a loudspeaker it will be found that they are available with various transformer-primary impedances. This is to suit the requirements of different types of output valve, in this case to suit an EL33 an impedance of 7000 is required, under which conditions a power output of over 4 watts is available.

Apart from the components listed a quantity of wire is required for wiring purposes. P.V.C.-covered wire, available in many colours, is admirable. A number of grommets, solder tags, flex for the mains and some single screened cable for certain grid leads is also required though, of course, all of these items will be familiar to most constructors.

The choice of a dial has been left entirely to the individual. There are many attractive dials on the market, some in glass and some in metal with painted faces. Any good supply house will be happy to provide guidance if required.

Pilot bulbs can be arranged to suit the dial chosen and may be wired to the valve heater supply.

After construction has been completed and the usual checks made, alignment procedure may be carried out as detailed in Chapter Six.

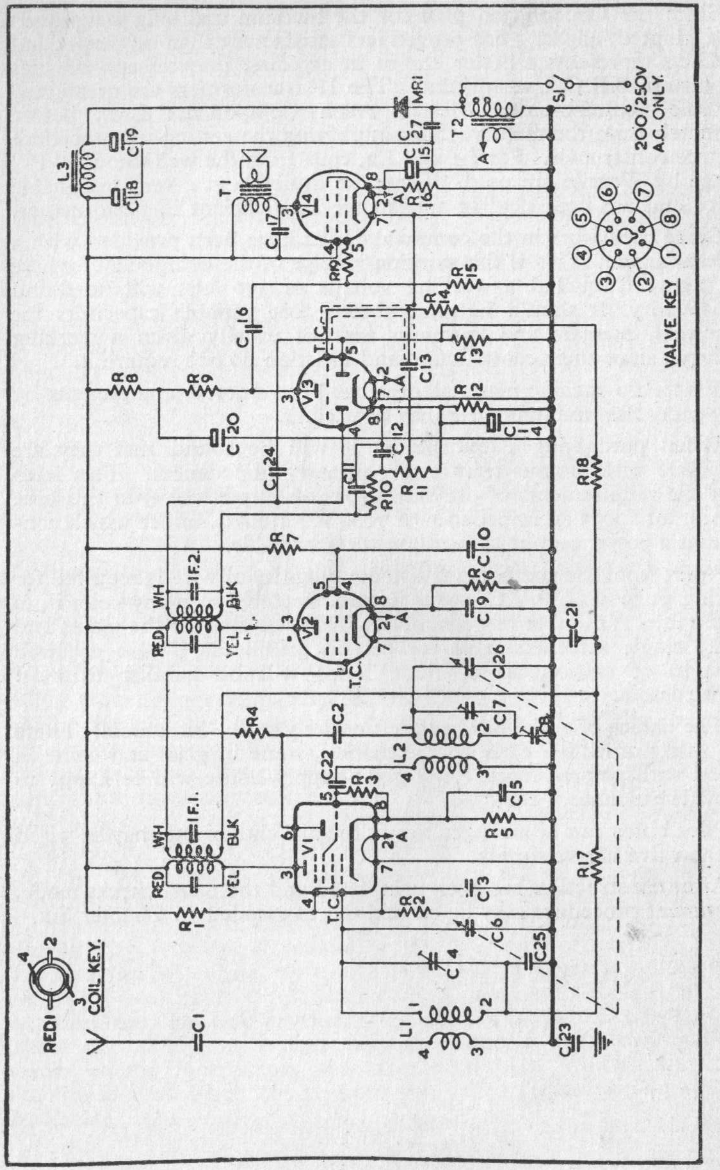

Fig. 27. Theoretical Circuit.

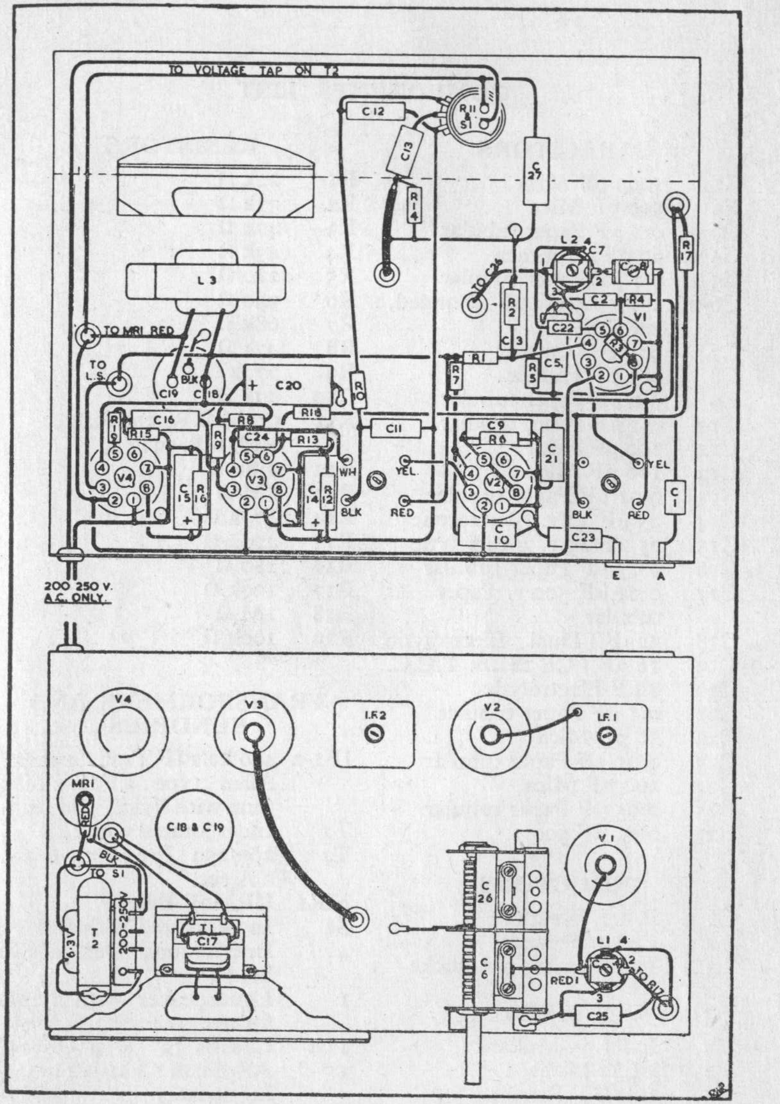

Fig. 28. Practical Layout and Wiring.

COMPONENTS LIST

CAPACITORS

C1	1000 pF Mica
C2	500 pF Mica
C3	0·1 μF Paper tubular
C4	60 pF Trimmer
C5	0·1 μF Paper tubular
C6-26	2 × 500 pF Ganged, variable
C7	60 pF Trimmer
C8	480 pF Padder
C9	0·1 μF Paper tubular
C10	0·1 μF Paper tubular
C11	100 pF Mica
C12	100 pF Mica
C13	0·01 μF Paper tubular
C14	25 μF 12 v. Electrolytic
C15	25 μF 25 v. Electrolytic
C16	0·05 μF Paper tubular
C17	0·01 μF 500 v. Paper tubular
C18	32 μF } Dual Electrolytic
C19	16 μF } CE 28LE. T.C.C.
C20	8 μF Electrolytic
C21	0·1 μF Paper tubular
C22	50 pF Mica
C23	0·01 μF Paper tubular
C24	100 pF Mica
C25	0·05 μF Paper tubular
C27	0·01 μF 500 v.

INDUCTORS

L1	P.A.2. Wearite
L2	P.O.2. Wearite
L3	10 henrys 80 mA choke

VALVES

V1	ECH 35 Mullard
V2	EF39 Mullard
V3	6Q7GT Brimar
V4	EL33 Mullard

RESISTORS

R1	22k Ω
R2	33k Ω
R3	47k Ω
R4	47k Ω
R5	220 Ω
R6	330 Ω
R7	68k Ω
R8	47k Ω
R9	270k Ω
R10	47k Ω
R11	0·5M Ω Potentiometer with S.P. switch.
R12	1·8k Ω
R13	1M Ω
R14	470k Ω
R15	470k Ω
R16	180 Ω
R17	100k Ω
R18	1M Ω
R19	100k Ω

TRANSFORMERS AND SUNDRIES

IF1-2	470 kc/s IF Transformers. Allen type I.F.T. 1001 (one with flying grid lead)
T1	Incorporated with L.S.
T2	200/250 Primary, 6·3 v. 2 A sec.
MR1	DRM2B Brimar
S1	Incorporated with R11
4	International Octal Valve holders
1	Loudspeaker with transformer (see text)
1	Chassis 12″ × 9″ × 2½″
1	AE-Earth Chassis mounting sockets
3	Grid Caps (small size)

BERNARDS RADIO BOOKS

56.	Radio Aerial Handbook	2/6
57.	Ultra-Shortwave Handbook	2/6
58.	Radio Hints Manual	2/6
61.	Amateur Transmitter's Construction Manual...	2/6
63.	Radio Calculations Manual	3/6
64.	Sound Equipment Manual	2/6
66.	Communications Receivers' Manual	2/6
68.	Frequency Modulation Receivers' Manual ...	2/6
69.	Radio Inductance Manual	2/6
70.	Loudspeaker Manual	2/6
71.	Modern Battery Receivers' Manual	2/6
78.	Radio and Television Laboratory Manual ...	2/6
80.	Television Servicing Manual	4/6
81.	Using Ex-Service Apparatus	2/6
82.	AC/DC Receiver Construction Manual... ...	2/6
83.	Radio Instruments and their Construction ...	2/6
84.	International World Radio Station List ...	1/6
86.	Midget Radio Construction	3/6
90.	Wireless Amplifier Manual No. 2	3/-
91.	Handbook of Radio Circuits No. 3	2/6
93.	Power Pack Manual...	4/6
94.	Practical Circuits Manual	3/6
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101.	Two Valve Receivers	1/6
102.	40 Circuits Using Germanium Diodes	3/-
103.	"Radiofolder" A. The Master Colour Code Index for Radio and Television	1/6
104.	Three Valve Receivers	1/6
106.	Radio Circuits Handbook No. 4	2/6
109.	High Fidelity Radio: Design and Construction. By N. Bonavia Hunt	3/6
111.	"Radiofolder" B. A Practical Oscilloscope	2/6
114.	"Radiofolder" E. An Inexpensive Tape Recorder	2/6
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117.	The Tele-King: Constructional Envelope ...	6/-
118.	Practical Coil Construction for Radio and Television	3/-
119.	The Practical Superheterodyne Manual ...	3/-
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	The Electronic Photographic Speedflash: How to Make It and How to Use It	3/6