"Amateur Wireless" Handbooks

THE PRACTICAL "SUPER-HET" BOOK

With numerous illustrations

"Amateur Wireless" Half-crown Series

The Practical Super-het Book

Written by a Number of Authorities and Including an Introduction by

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EDITOR'S PREFACE

Of the hundreds of wireless books very few indeed deal with the super-het, a name which is now the recognised shorthand term for the supersonic heterodyne wireless receiver. Special conditions gave rise to the super-het, special advantages accrue to its use, special difficulties arise in its operation, and it may fairly be claimed that this handbook is the first of its kind published in this country showing in simple language exactly how the super-het functions, how each component plays its part, and what that part is, and at the same time explaining with a wealth of detail, drawings and photographs, how to build typical super-het sets. This Handbook will be found to deal fully with tuning and management, and a letter to "Amateur Wireless" will ensure further information on any point mentioned in its pages.

It will be noted that the introductory matter is from the pen of Mr. J. Ashton J. Cooper, who has made a special study of his subject, and that many of the sets here described were originally designed and constructed in the workshop of "Amateur Wireless" and "Wireless Magazine."

Bernard E. Jones,
Editor, "Amateur Wireless" and
"Wireless Magazine."

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THE PRACTICAL SUPER-HET BOOK

CHAPTER I

What the Super-het Does

The principle involved in the super-het (the supersonic heterodyne—to give its full name) is fairly well known, but for the benefit of those to whom the circuit is new a short explanation is here given. Those who have experimented with H.F. amplification on the broadcast and the shorter wavelengths, will have realised the difficulties of applying more than two stages of H.F. amplification to the initial signals, owing to the tendency of the set to oscillate at every conceivable opportunity. The shorter the wavelength the greater do these difficulties become, until when we arrive at wavelengths of 100 metres or so the proposition is almost hopeless. The super-heterodyne receiver overcomes this difficulty in a delightfully simple and efficient manner. The incoming signal on the grid of the so-called first detector valve is heterodyned by a separate oscillating valve (*see* Fig. 1, p. 3), the frequency being changed into one of a lower order (or higher wavelength). On this changed wavelength (generally about 5,000 metres) high-frequency amplification is perfectly stable and controllable, and four H.F.

amplifiers in cascade are generally used to amplify the signals before they are passed to the second detecting unit. This H.F. amplifier is known as the intermediate amplifier. It will be admitted by the reader that this is perfectly simple and straightforward, and that there is no mystery about it. In fact, there is no circuit, apart from a straight circuit, that is easier to control than the super-het receiver, provided that the operator has the little bit of useful knowledge which will enable him to know exactly what is happening at the various points of his set and what components to put into it. It is best to forget the mystery and the awe-inspiring title and treat the set as you would an ordinary regenerative set.

Practical Considerations—The "First Detector."—The diagram (Fig. 2) illustrates the theoretical circuit, and the blocks outlined are: (*a*), first detector; (*b*), oscilator; (*c*), intermediate amplifier; and (*d*), second detector. First of all consider (*a*), with its detecting gear and other apparatus. Upon this portion of the instrument depends the range of reception. A little consideration shows that this stage is nothing more or less than a straight circuit with its attendant tuning devices, a variable condenser, and an inductance or frame aerial. We know that in the ordinary receiver great care has to be taken to see that the utmost efficiency is obtained, even when receiving powerful near-by signals. The slightest irregularity in insulation or the presence of dielectric losses in the condensers, etc., considerably diminish signal strength. The valve has to be supplied with a suitable grid leak and condenser, and a proper potential must be applied to the anode. Furthermore, we know from experience that the filament brilliancy is somewhat critical with most valves.

If we turn to the supersonic receiver again we

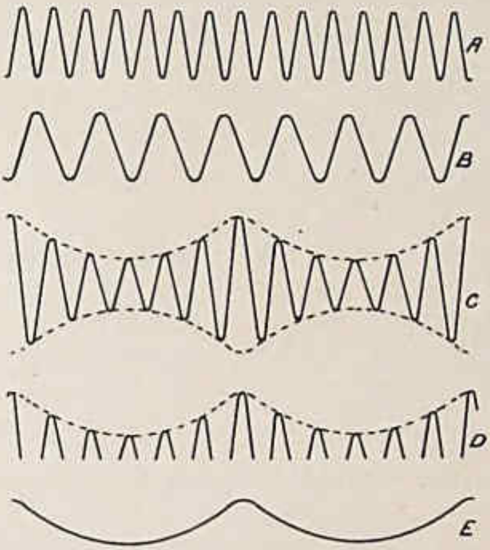


Fig. 1.—Diagrams Explaining the Principle of Super-heterodyne Reception: *A*, Current due to Carrier Wave; *B*, Current due to Local Oscillator; *C*, Combined Currents of Carrier and Oscillator; *D*, Resultant Currents Rectified; *E*, Resultant Lower-frequency Current

notice that exactly the same problems confront us, and that, furthermore, in the circuit shown by Fig. 2, we have no reaction to reduce damping in the tuning circuits and make up for high resistances and other sources of loss in the condensers and coils.

How much more important it is then, that we

UNDERSTANDING THE "SUPER-HET"

How Each Valve Functions

As amplification on the short waves is not always as stable as could be desired several methods have been developed to overcome this disadvantage, the outstanding example being that which is incorporated in the "super-sonic heterodyne" receiver, popularly known as the "super-het," the action of which, in a typical seven-valve arrangement, may be explained as follows:

No. 1, FIRST DETECTOR VALVE, receives the broadcast waves at *very high frequency* for the "mixing" operation (see pages 6 and 12).

No. 2, INDEPENDENT OSCILLATOR, mixes the high-frequency impulses from valve No. 1 with its own local oscillations, thus creating a new set of oscillations at a lower or *intermediate frequency* (longer wavelength). These are passed to

Nos. 3, 4 and 5, LONGER-WAVE or INTERMEDIATE FREQUENCY AMPLIFIERS, which amplify the oscillations and pass them to

No. 6, SECOND DETECTOR VALVE, which detects the oscillations, transforming them into a series of unidirectional impulses, which are sent to

No. 7, LOW-FREQUENCY AMPLIFIER, which amplifies at *low* or *audible frequency* and passes the impulses to the loud-speaker.

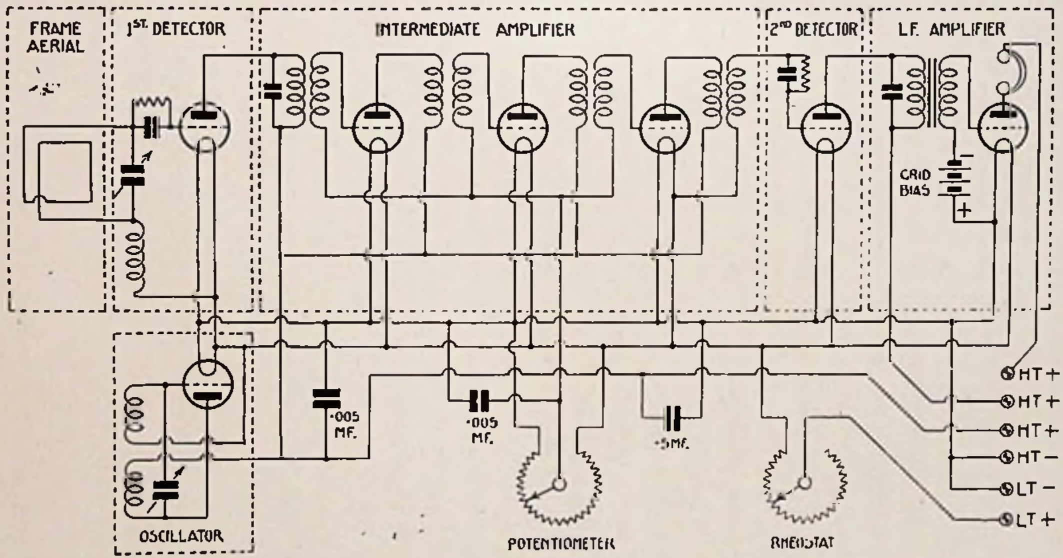


Fig. 2.—Typical Super-het Circuit with Units shown in Dotted Panels

should treat this first valve with even greater care than we would our ordinary regenerative receiver, since we hope to receive signals which we cannot hear on an ordinary closely-coupled set, and, moreover, to receive these signals at considerable strength, and this on a frame aerial! It is true that we are using an oscillating valve to heterodyne the signals, but it is not regenerative reaction in the sense that we generally know it. For the time being we must treat this valve as an ordinary straight circuit without reaction.

If we are unable to find the wanted signals by ordinary methods with an ordinary receiver we cannot hope to receive our distant signals; and correspondingly, if by reason of losses caused by badly designed coils, condensers, or frame aerials the extremely weak oscillations in the first-valve circuit of the super heterodyne receivers are damped out of existence, no amount of amplification will bring them up to audibility, and they cannot proceed through the amplifier to their ultimate destination in the telephones.

What the First Detector Does.— Now this so-called first detector has several functions (*see* p. 12). It is in reality a radio-frequency amplifier, and in many cases it will function perfectly well without the grid leak and condenser, which is shown in Fig. 2. This, however, will depend upon the valves used. The purpose of this auxiliary apparatus when used is to provide the grid of the valve with a suitable potential so that it will function in the desired manner; that is, as an H.F. amplifier. It is true that valves so fitted will rectify, but often valves will rectify without grid leak or condenser, according to the values of H.T. and filament potential. The primary object is to see that the valve amplifies the carrier wave without respect to the modulation caused by the speech from the transmitting station.

In this connection, valves primarily intended for H.F. work do not, as a rule, rectify without a grid leak and condenser, and even then not efficiently, but for efficient amplification exact values of H.T. potential and critical filament control are essential. This should be borne in mind when fitting up the first-valve stage, which is commonly termed the first detector.

Efficiency.—All this obviously points to an expenditure of much time and patience in rendering the first valve as efficient as it is possible to make it. A few experiments with grid leaks and condensers, using the valve as an H.F. amplifier in an ordinary receiver, will soon determine the best value to use, or whether it is neces-

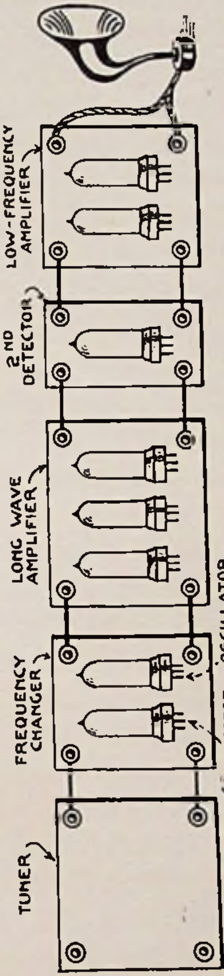
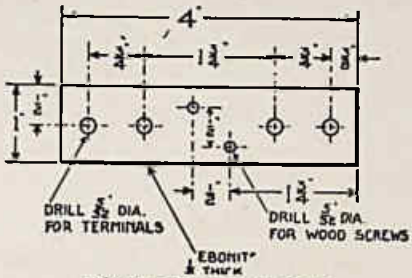


Fig. 3.—Super-heterodyne Receiver shown in Diagrammatic Form

sary to use them at all. Air is the only insulator which should be used on the leads, and attempts should be made to obtain one or other of the low-loss coils on the market if tuning coils are to be used in the circuit. Most super-heterodyne receivers are designed for operation on a frame aerial, mainly because it then becomes extremely selective, and a minimum of interference from statics and unwanted stations is experienced. Another point is that the use of the set on an open aerial may cause serious interference to other listeners on a slightly higher or slightly lower wavelength, and therefore such use should not be contemplated on broadcast wavelengths.

The Frame Aerial.—There appears to be an impression that any old frame aerial will do providing that its wavelength range will cover the wanted band of wavelengths. Some experimenters and manufacturers simply rig up a couple of sticks on the cross principle and swathe it with sufficient wire to form a suitable inductance. Now, as previously pointed out, efficiency is the watchword for the first detector unit. The frame aerial takes the place of the inductance coil, and due regard should be paid to the question of losses and the like. As an experiment 5 I T was received on a coil in London without a frame aerial, the coil being one of the low-loss type. On substituting an ordinary cylindrical coil of equal inductance for the low loss, 5 I T was reduced to a mere whisper in comparison. This simple experiment shows that great attention should be paid to efficiency in the " loop " or frame aerial.



Ebonite Terminal Strip

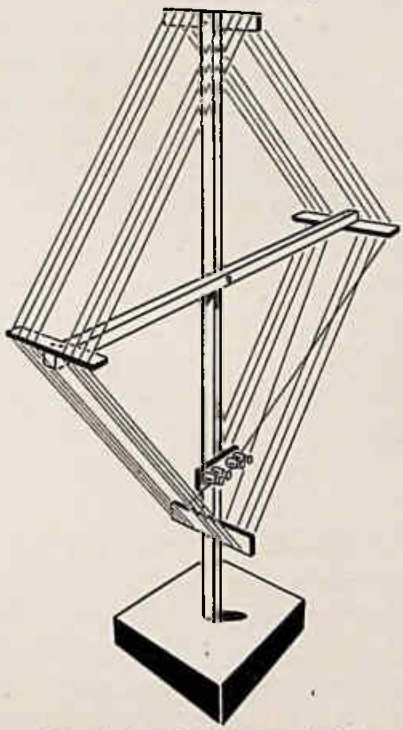


Fig. 4.—Typical Frame Aerial

A frame aerial, theoretically sound in design and which in practice will be found to give results equal to some of the extremely cumbersome arrangements used by amateurs, can be made up on a 2-ft. cross; that is, the arms of the cross are a foot long from the centre. The turns of wire, thirteen in number, are wound on the side of the frame and let into saw-cuts, already made in the wood, or in small lengths of ebonite strips screwed to the wood. The ebonite strips should be 4 in. long, and should have fourteen slots cut $\frac{3}{16}$ in. apart; the turns of wire should not sag so that they touch (*see* Fig. 4). No. 20 enamelled copper wire is recommended for the aerial.

Coils.—Should home-made induction coils be used in the first detector tuning circuit, it is recommended that these should be of the "skeleton" type. Strips of ebonite, supported on three ebonite rings sawn from a 4-in. ebonite tube to form a coil former, may be wound with a double winding No. 20 d.c.c., and one of the windings removed after completion. An efficient air-space coil will then be obtained, and results obtained by it difficult to beat with any but the best manufactured product.

Tuning Condensers.—It should be remembered that if a frame aerial is used, this should comprise the entire inductance if a maximum of signal strength is desired, and therefore the practice of using loading coils in series with the frame aerial should be abandoned. Much has been written and said in the past concerning the features which constitute a low-loss air condenser. Suffice it to say, that the points to be looked for on such a condenser are positive pig-tail connection to the moving vanes, vanes made solid with the supports, low value of self-capacity by reason of good spacing between sets of vanes and end plates, a minimum of solid dielectric material, and absence of useless metal work.

It is important to bear in mind that when inserting variable condensers in a super-heterodyne receiver the moving vanes should always be connected to the filament side of the tuning circuit, and that the fixed plates go to the grid circuit. By following this rule a minimum of hand-capacity effect will be experienced when tuning the set.

Grid Leaks, Grid Condensers and Wiring.—Unfortunately, the grid condenser and grid leak are often the source of great losses and noise in the super-heterodyne circuit, and only reliable makes should be obtained. With reference to the grid condenser it is recommended that air-dielectric fixed condensers should always be used with low wavelengths. It is of advantage to test the valve in an ordinary circuit and apply suitable electrical values to it, as found by experiment.

As regards wiring, the usual rules hold good. All wires should be kept as short as possible. This does not necessarily mean that the components must be crammed up together in an uncomfortable heap, but rather that they should be provided with sufficient room for ease in wiring, and that the wires should take short cuts to their respective terminals and not fitted up with sharp right-angle bends. Bends should be hand-made with the finger and thumb, and should be easy sweeps, but should only be made where absolutely necessary. The wire should be of medium gauge, for it is possible to overdo the fetish of thick wiring and add considerable self-capacity to a set by employing wire of too heavy a gauge. In the circuit of the first valve, especially, these rules hold good, and in all cases the grid wires should be kept short.

We can say nothing more about the first stage of the super-het receiver, except that it is desirable to bear in mind that its function is that of an amplifier of radio-frequencies first and foremost, and that its rectifying propensities should be suppressed as much as possible, consistent with good amplification.

The Oscillator.—This stage is perhaps best considered in conjunction with the first. The two stages can be considered as a kind of *subtractor of frequencies*, acting in a mechanical manner. We cause the oscillator to set up oscillations, which are mixed with the signal already in the first valve circuit. The oscillations set up by the oscillator are of a frequency which will produce a difference in frequency between the oscillator wavelength and the signal wavelength equal to that of the required wavelength. This is better understood by referring to wavelengths as frequencies, and considering all wavelengths as frequencies. To find the frequency of a signal we divide its wavelength into 300,000,000. Therefore, for, say, 300 metres, we have a frequency of 1,000,000.

Suppose we tune the oscillator to 286 metres, our frequency is 300,000,000 ÷ 286, which equals

1,050,000 (approximately), and 1,050,000 minus 1,000,000 equals 50,000; 300,000,000 ÷ 50,000 makes our new wavelength 6,000 metres. This computation is, as can easily be seen, merely simple arithmetic. All we have to remember is that to find the frequency of a signal whose wavelength we know we divide 300,000,000 by the wavelength, and to find the wavelength when we have the frequency we divide 300,000,000 by the frequency.

Supposing now we have settled upon 6,000 metres as being the wavelength on which we are going to carry out our intermediate amplification; we can build our oscillator coils so that they will cover a wavelength band which will produce frequencies which, when combined with the frequency of the incoming signal, will produce signals of a higher wavelength. For this purpose it can be seen that the oscillator coupler can be built to the same dimensions as an ordinary receiver tuner, which has a tuned grid and plate circuit. The plate and grid coils are of exactly similar electrical properties, and are tuned by a variable condenser across the whole between the grid end of the grid coil and the plate end of the plate coil.

Any coils upon which it is possible to receive the desired wavelength band in a closed secondary circuit may be used for the purpose, but both coils must be of the same size. It is of interest to note here that the oscillations of the oscillator valve may be produced either below or above the frequency of the incoming wave in order to produce the new wavelength. This is useful, inasmuch as there are two points on the oscillator-condenser dial at which the same station may be heterodyned. The same interference is not likely to be experienced on both settings, and advantage of this may be taken when such interference is prevalent on one of the settings.

It will be abundantly clear that the tuning condenser used in this circuit should be of robust construction, and should employ a vernier device; anybody who has had experience of working any type of heterodyne will realise the difficulties of manipulating badly-made or "sticky" condensers without a vernier attachment. This condenser is likely to have far more wear than the average receiving condenser, hence it is imperative to employ only the best, and it is of material advantage to so arrange it that the moving vanes are joined to the plate lead of the valve in order to avoid hand-capacity effects.

The Intermediate Amplifier.—We have now seen that we can create any longer wavelength by heterodyning an incoming signal by means of a local oscillator at a frequency above or below its fundamental frequency, and that such wavelength is positively determined by the tuning of the oscillator. We can, by decreasing or increasing the frequency of the oscillator, cause our fundamental wavelength to have a very high, or a moderately high, amplifying wavelength, but it remains for us to determine which wavelength we intend to use. This brings us to the intermediate amplifier, the design of which is likely to be the subject of a great deal of experiment and disappointing results, unless the problem of high-frequency amplification is intelligently understood. In this connection it is of interest to note that the first or last stage of the intermediate amplifier acts as a kind of filter, through which only signals of a frequency to which it is tuned will pass.

The actual wavelength at which we amplify is therefore determined by the amplifier and not by the oscillator settings. The factor of primary importance in design is the nature of the signals which it is desired to obtain. Remembering that we are entirely dependent upon the amplifier for amplication of the signals received on the grid of the first valve, we have to consider which property we most desire: selectivity, quality, or efficiency. It might be stated right away that unless the design of the intermediate transformers is correct selectivity cannot be obtained together with quality, nor can the highest possible sensitivity be obtained if quality is to be kept and distortion avoided. It would, indeed, be an ideal receiver which embodies all three of these properties.

CHAPTER II

The Intermediate Transformers

THE amateur who is at the present time interested in making or obtaining transformers suitable for use in the intermediate amplifiers should pause and consider the technical points which will make for success.

Those who have experimented with high-frequency amplification know that distortion arises when using more than one stage of amplification on broadcast wavelengths, especially when using selective or sharp methods of amplification, such as the tuned-anode method.

On the other hand, there is a tendency to believe that high-frequency amplification is naturally distortionless, and possibly this has arisen owing to the fact that the use of iron-core transformers for note-magnifying purposes has been so persistently upheld as the cause of all the distortion in loud-speaker work. Therefore, it is only natural that these same people would arrive at the conclusion that amplification on the high-frequency side of the detector is a cure for all troubles in this respect. This is, unfortunately, not the case.

High-frequency Distortion.—In order to understand how high-frequency distortion arises it is necessary to consider what takes place at the transmitter end. Here we have a steady carrier wave being modulated by speech frequencies. The carrier or continuous wave may have a frequency of 1,000,000 cycles, which will be equal to a 300-metre wavelength. If this carrier wave is properly modulated, variations in frequency will take place for a side-band frequency of approximately 10,000 cycles on each side of the carrier wave. It will be seen from this that in reality a 300-metre station will transmit speech and music on a wavelength slightly above and below that of the fundamental wavelength, and that if faithful reproduction is to be observed, provision has to be made in the intermediate amplifier of the super-heterodyne receiver for the inclusion of one or the other of these side-band frequencies, so that they may be amplified in the same proportion as the fundamental wavelength, and the modulation "peaks" not be lopped off. It is plainly apparent that with selective H.F. amplification, such as "tuned-anode," this cannot be done.

What Happens in the Super-het.—Before going further into the design we must also consider what happens in the super-heterodyne receiver. We know that we changed the incoming wavelength into a wavelength of a lower frequency (or high wavelength) by means of the oscillator so that we could conveniently and easily amplify it at radio-frequency. The extent to which we change the wavelength depends upon the settings of the oscillator valve, or the rate of the frequency which we superimposed upon the incoming signal.

If we heterodyne an incoming signal at 400-metre wavelength with a frequency of, say, 385 metres or 780,000 cycles, we get a wavelength equal to the difference in the frequency of the fundamental signal and the oscillator, in this case 780,000 – 750,000, which

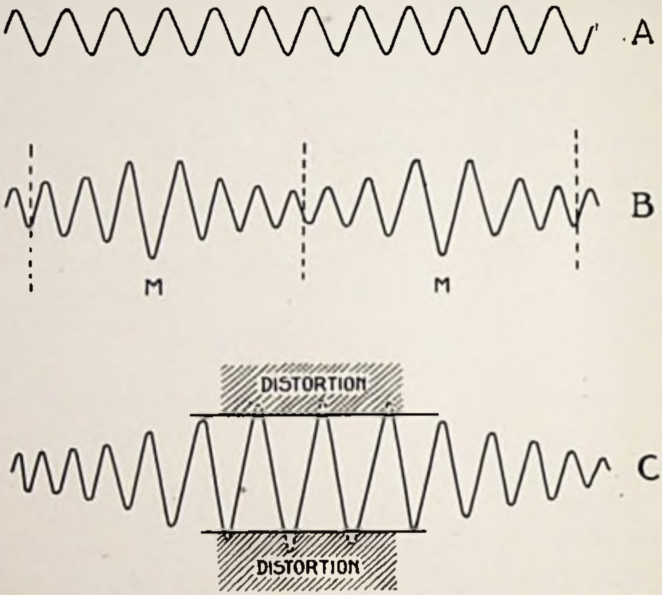


Fig. 5.—Cause f Distortion. *A*, **Steady-carrier Wave.** *B*, **The Modulated-carrier Wave.** *C*, **Distorted Reproduction**

equals 30,000 cycles, or 10,000 metres wavelength (approximately).

If we have a signal, say, 10 metres above this, and heterodyne it at the same rate, we get 780,000 – 730,000; which equals 50,000 cycles, or 6,000 metres. We can now see one of the reasons why the super-heterodyne receiver is selective, and also why within wide limits we need not make our transformers ultra-selective.

Our signals, although originally only 10 metres apart, have now increased their difference to 4,000 metres (approximately) when heterodyning the incoming signals with the same setting of the local oscillator. Whether we amplify at the wavelength of 6,000 or 10,000 metres or not depends upon the wavelength at which we fix the intermediate-frequency transformers. We could, if we wished, use both wavelengths by tuning these transformers by means of an iron core, the coupling of which is variable to the transformer, or by means of a variable condenser; but since one of the primary objectives of the super-heterodyne receiver is to receive long-distance short-wave signals with ease, the use of a multiplicity of controls of this nature is what we wish to avoid.

If we fix the wavelength at which our intermediate amplifier functions we must heterodyne all our received signals to that wavelength, or thereabouts, otherwise we shall not receive them at the detecting end of the amplifier, that is, the second detector stage. Therefore variable tuning of the oscillator valve by means of a variable condenser is resorted to, as this simplifies matters considerably. This condenser has already been referred to.

Assume that we receive a 300-metre station and heterodyne it so that it is changed to a wavelength of 2,000 metres, and incorporate a transformer to amplify at this frequency; and suppose we have also a station transmitting on 310 metres. This 310-metre station, although heterodyned together with the 300-metre signal, will not cause interference on our 2,000-metre amplifier, because its wavelength has become far longer in proportion, as is evidenced by our earlier considerations. Our oscillator in this case would have been adjusted to 354 metres in order to heterodyne our 300-metre signal to 2,000 metres, and our 310-metre signal will have become 2,650 metres, a separation of 650 metres as against the original 10 metres. It is obvious that the higher the wavelength we use the wider does this separation factor become.

Utilising the Separation Factor.—This factor of separation can be turned to good account, and simplifies the design of the intermediate transformers, inasmuch as these need not be sharp in their tuning to within fairly wide limits in order to ensure selectivity. Another useful feature is that this safety area, through which we cannot be jammed by stations closer together than 10 metres, allows us to receive all our side-band frequencies and preserve the original signals in their undistorted form.

Experience with signals transmitted on the wavelength of 2,000 metres will show that it is not difficult to build transformers which will receive and amplify over a band of wavelengths of 2,000 metres, plus the necessary additional 10,000 cycle band to include the side frequencies of the modulated signals. We shall soon find, however, that it is an extremely difficult matter to make four air-core transformers *exactly alike in electrical properties!*

Amplification of Parasitic Signals.—How far can we make our set ultra-selective and at the same time preserve the clarity of received music and obviate unwanted interference, such as locally-generated noises of the nature of dynamo hum, spark noises from electric bells, and the like? We have seen that the higher the wavelength at which we amplify the more selective our receiver is likely to be, since the width of our safety area increases when frequency is lowered, but we must recollect that the higher we go in amplifying wavelength, the nearer we approach the audibility frequency at which noises of all kinds will be picked up on the transformers and wires and amplified to the same or a higher ratio as the required signals, to the detriment of long-distance reception.

Therefore, although many amateurs may be tempted to use long-wave amplification with iron-core transformers because such transformers need not be so carefully matched, and in order to obtain super-selectivity, the practice will be unsatisfactory on account of the "noise" limit, which is really the limitation of any super-sensitive receiver. In the super-heterodyne receiver this noise limit is doubly important, because of the near approach to the audible frequencies in the intermediate amplifier.

The Use of a Filter.—A method of overcoming this difficulty is to use an air-core sharply-tuned transformer in the last stage of amplification to cut out all but the wanted signal and reduce interference from statics or other unwanted interferences. This is generally referred to as the filter unit. Owing to the broadness of the tuning in the amplifiers themselves this interference is more likely to be experienced on long-wave amplification than on the shorter, and the use of the filter unit is essential with such long-wave amplifiers.

Another point which might be considered in transformer design, with special reference to the higher waves, concerns the principle whereby we are able to amplify at a wavelength equal to the sum of the oscillator frequency and the fundamental frequency, or the difference between them, a possibility already referred to. Thus a station is always received on two settings of the oscillator-condenser dial with the same setting of the inductance or aerial-tuning condenser, the difference or distance between the settings of the oscillator condenser depending upon the wavelengths at which we amplify. This is, perhaps, none too clear until we study the principle involved, but the higher the amplification wavelength used the closer together become these settings of the oscillator, until we find that we are receiving the shorter wavelengths at the same time or in advance of the longer ones on the oscillator dial, and in close proximity to one another. This of itself will be confusing, and added to it will be the difficulty of extreme delicacy of touch in selecting our wanted station from a maze of unwanted ones. Therefore, in spite of the fact that there seems to be at least two arguments in favour of the use of these long waves (increased selectivity and ease of matching), the use of such long waves is likely to result in a noisy receiver, the sensitivity of which is wellnigh useless on account of atmospheric interference and noises which are always present to a greater or lesser extent. Its use cannot therefore be recommended, in spite of the advantages, which are more apparent than real.

Quiet Amplification.—We will again turn to the shorter wavelengths of about 2,000 metres. Here we know that comparatively little difficulty will be experienced in making an air-core transformer with the necessary flatness in tuning to include the side-band frequencies. This is because the side band does not cover such a wide stretch on the lower wavelengths as on the higher. Take, for instance, 300 metres less 10,000 cycles (which makes our reception band from 287 to 300 metres) and heterodyne this to 2,000 metres. For our changed wavelength we have 2,000 metres less 10,000 cycles, which makes the necessary band 1,870 to 2,000 metres, or to cover 125 metres. This is a fairly easy proposition.

The Flat Peak.—If, however, we use 10,000 metres we have 10,000 metres less 10,000 cycles, or 30,000 cycles plus 10,000 cycles, which equals 7,500 metres. On subtracting 7,500 metres from 10,000 metres we see that our transformer must cover a band of wavelengths of 2,500 metres, and amplify evenly over that frequency; hence the necessity for an iron core in the transformer.

A further example we will take is 6,000 metres. Here 300,000,000 divided by 6,000 equals 50,000 cycles, the frequency of the fundamental carrier wave in the amplifier. To include the side-band frequencies we must add 10,000 cycles; 50,000 cycles plus 10,000 cycles equals 60,000 cycles, and 60,000 divided into 300,000,000 equals 5,000 metres. On subtracting

5,000 metres from 6,000 metres we see that our amplifying band must be 1,000 metres broad, and unless we do include this the side-band frequencies will be cut out of the amplifier and lead to distortion, but it is not an easy matter for the amateur to make a transformer with sufficient flatness in its tuning to cover even this band.

A Summary.—Having gone thus far we will again examine our shorter-wave amplification problems. Here we see that our selectivity is suffering somewhat on account of the fact that the separation area is curtailed. The question which arises is, then, what wavelength *shall* we use? The conclusions are summarised as a guide in this respect. For this reason we will divide the wavelengths into three bands and consider the problem from the point of view of construction and also operation.

Long Wavelength

(7,000-10,000 *metres.*)

Operation.—*Points in Favour:* Increased selectivity on account of wider "separation area," greater amplification, stability.

Against: Amplification of noises of audible frequency or origin, complications in tuning caused by closer positions of reception on oscillator dial, hand-capacity effects noticeable.

Construction.—*Points in Favour:* Ease of matching of transformers as the use of these wavelengths in the amplifier has naturally selective properties, and critical matching not important because a very broad, flat peak may be used.

Against: Difficulty of construction of such transformers owing to their size and the difficulties of obtaining suitable iron laminations. (It might be stated in passing that these laminations must be very thin.)

Medium Wavelength

(4,000-7,000 *metres.*)

Operation.— *Points in Favour:* Good selectivity by reason of good separation area, good stability, comparative absence of audio-frequency amplification, especially on lower end of the scale, good amplification, absence of hand-capacity effects, especially on lower end of the scale.

Against: Noisy on top end of scale, slightly decreased amplification, hand-capacity effects noticeable on higher end of the scale.

Construction.—*Points in Favour:* Ease of construction for inclusion of flat peak, ease of matching wavelength of transformer.

Against: As compared to long wavelength there is nothing against.

Short Wavelength

(2,000-4,000 *metres and below.*)

Operation.—*Points in Favour:* Absence of amplification on sounds of low-frequency origin, absence of hand-capacity effects.

Against: Lack of selectivity, low amplification, not quite so stable.

Construction.—*Points in Favour:* Ease of manufacture on account of narrow, flat peak to include side bands.

Against: Matching must be carefully carried out. (A few metres out in either direction will be a serious matter.)

Hand Capacity.—Hand-capacity effects, it has been stated, are more noticeable on the longer waves than on the shorter. This is due to the fact that the longer the wavelength used the greater the difference in frequency between this and the fundamental or incoming signal, and therefore any hand-capacity effects which take place on the operating devices will naturally be increased to the same extent as the ratio of increase in wavelength. The capacity effects are not in the amplifier itself, but between the oscillator and the first stage of amplification. When stability is mentioned we refer to the natural stability of the H.F. amplifier, which, it is well known, increases with the wavelength, even when the amplifier is in its most sensitive condition, but decreases when we attempt to use the short wavelength, so that we have to render the grids of the valves slightly positive in order to stabilise them, and thus cause a drop in our amplification factor.

CHAPTER III

Design and Equipment

HAVING the foregoing in mind we are at liberty to decide what appears to be the best range of wavelengths to use for amplification purposes. It will be seen that the best we can do is to effect a compromise and use a wavelength of about 5,000 metres. Should we be purchasing transformers it would be as well to obtain the manufacturer's chart showing the behaviour of the component, with special reference to the "peak" of the signal and the amplification factor. He will be a wise man who will insist on getting all the available information possible about his contemplated purchase before buying.

For the painstaking amateur who proposes to make his own transformers there is obviously only one wavelength suitable to his requirements, and that is the short one.

It is not particularly difficult to wind the transformers which have an air core, but extreme care must be taken with the matching, and if possible this should be done on the actual valves he intends to use. The long wavelength transformer with its compulsory flat top "peak" is a matter with which he should not deal unless he is prepared to experiment considerably with iron-core transformers. It is not an easy matter for him to acquire the desired curve, although for the manufacturer possessed of unlimited laboratory, constitutional- and other resources it is of course only a simple matter.

The Component Parts

When purchasing the component parts for a superheterodyne receiver it is as well to be sure that these are the best obtainable. It will undoubtedly mean an outlay of a few more shillings than would be expended in cheap and nasty material, but an economy in time and patience will be effected in the long run.

Condensers.—As regards the condensers only air-dielectric condensers of a sound mechanical structure should be obtained, and it is imperative that they should be of the low-loss type. Condensers which appear likely to cause scraping noises should be avoided, and these can often be found amongst those with rubbing contacts. On the other hand, there are some designs with rubbing contacts which will wear perfectly well, and many amateurs prefer these to a "pig-tail" connection.

The Potentiometer.—The potentiometer, although a simple instrument, is one which is likely to give endless trouble owing to the nature of its duties. It must be robust, and there should be no doubt about the firmness of the contact between the selector switch and the resistance wire. If this is at all noisy in action searching for weak signals cannot be undertaken. It is always advisable that the potentiometer should have a high resistance.

Jacks.—The switching in and out of valves is important when running a large number of them, and on the grounds of economy it is often desirable to embody suitable switching devices in the set. Telephone jacks, which are designed not only to switch in the anode circuit, but also to break the filament circuit of the valve following, are now available, and these avoid the necessity of loading the panel with an unnecessary number of switches. These jacks will be the seat of a lot of trouble unless strongly built, so, also, for that matter will be switches, but telephone jacks are more apt to give trouble in this respect owing to their peculiar construction. They are, however, all things considered, the best accessory to use for the purpose.

Rheostats.—As in the case of a bright emitter set, these are often called upon to carry a heavy load of current, the wire should be of a large gauge, otherwise overheating will take place.

The Oscillation Coupler.—This, generally speaking, is not called upon to carry any received H.F. current, except in the case of the small rotor or pick-up coil, which possesses a comparatively few number of turns. There is, therefore, no need to insist on a low-loss coupler, except in those circuits where a portion of the inductance forms the main portion of the tuning circuit.

Precautions.—Before commencing to mount the components on the panel or sub-base it is always desirable thoroughly to inspect the parts before so doing, as sometimes slight mechanical faults may be present which will cause considerable anxiety and delay in starting up the set. All couplers and transformers should be "clicked" with a pocket flash-lamp battery and a pair of 'phones, and variable condensers should be tested in a similar manner. In the latter case no loud click should take place when the phones and battery are placed across the two sets of vanes. The writer well remembers a couple of hours spent in trying to test a set in which the only fault appeared to be a broken rotor wire. The symptom in this case was a clearly defined heterodyne of many carrier waves, but no modulation of the signals!

Obtaining Results.—When a super-heterodyne receiver has been built, apparently in full accordance with specific instructions, the constructor is tempted to expect that he should be able to manipulate the dials and receive all the long-distance stations with the same facility as he can receive nearby powerful stations on an ordinary receiver, especially if he has read glowing accounts of the behaviour of the particular type of receiver which he had constructed. Now, although the super-heterodyne receiver is one of the simplest and most sensitive of circuits to operate *when once it has been properly tuned up*, it requires a little care and patience to get it going to the highest pitch of efficiency.

Because, for instance, it has been mentioned in a constructional article that 2 B D (Aberdeen) has been received at loud-speaker strength on a 12-in. frame aerial in London it does not necessarily mean that the constructor will simply turn his control knobs and get the same result at the first attempt. The beginner should be moderate in his expectations, and he will find that his D X station will come in time. In all probability he will fail to hear 2 B D until he has "tuned up" the set.

Adjusting the Sensitive Amplifier.—It will be found that in all super-heterodyne receivers where a potentiometer is employed for oscillation or volume control, the amplifier is extremely responsive to a critical filament voltage at certain settings of the potentiometer, especially when dull-emitter valves are used.

In order to ascertain exactly where this position is a few experiments will be necessary, starting off with the full-rated anode potential on the valves. The amplifier may scream at all settings of the potentiometer, but the pitch of the scream or oscillation will be controllable to within certain limits, thus showing that it is the amplifier which is oscillating and not the first "detector" or the local heterodyne valve.

If this should happen it is advisable considerably to reduce the anode voltage and set the potentiometer selector in a midway position on the resistance, and then turn the filaments on very slowly. It will be found that there is a position where maximum amplification is obtained, and that in many cases this will occur before the filament has had its full-rated voltage across it. It will be defined by a slight hiss in the telephones. Increasing the filament voltage after this will merely result in reducing signal strength or causing distortion.

The potentiometer selector may now be turned slowly towards the negative side of the filament, and signals will become gradually louder, until at the extreme end the amplifier should commence to oscillate and signals become slightly "woolly." If this happens everything is working quite satisfactorily, but if the set shows no sign of oscillation slight increases of H.T. potential should be tried until there is a tendency to oscillate.

If the receiver goes into oscillation with a "plonk" whilst doing this, further slight variations of filament brilliancy should be tried until the regenerative effect is smooth.

An Obstinate Receiver.—Sometimes the amplifier will refuse to get into this very sensitive condition of mild oscillation in spite of all the juggling that can be done with the H.T. and filament, and this often happens when correctly designed transformers are used with the proper type of valve. If this should happen an auxiliary grid battery starting at 1½ volts should be tried, and in some cases it may be necessary to increase this voltage to 4½ volts. The method is illustrated diagrammatically in Fig. 6.

It is not, of course, essential that the intermediate amplifier should oscillate to any great extent, but some perfectly good amplifiers may be classed as useless because the operator is unable to get them into a sufficiently critical state of sensitivity. For this reason it is as well to have just a little oscillation available in order that the operator should know that he is able to "tune up" the amplifier to a very sensitive pitch if desired, and the foregoing tests may be carried out quite easily on a nearby broadcast station with the frame aerial against the signals, that is, the frame is flat to the oncoming signals and not pointing in their direction, as is necessary in order to get full volume.

We are then, in the case of these experiments, damping down our extremely strong signals to almost a whisper, so that the input to the amplifier is very small and we are better able to judge the sensitivity of the amplifier. We do this because the human ear cannot so readily detect variations in the volume of sound when signals are at great strength.

Another feature of interest about the amplifier and "tuning up" is that the second detector is really a detector, and the best detecting valve available should be used. It is of little or no use expecting a valve designed for H.F. amplification to work in this position, and if the valve which we use works best in a straight circuit with a positive grid leak, such an arrangement should be used in this set.

Noisy Receivers.—Very often a "noisy" intermediate amplifier will result in the entire loss of weak signals. This noisiness may not be due to "statics," atmospheric conditions or dirty contacts, and the like, but rather to battery and valve noises. There is a tendency among amateurs to feed a number of valves performing the same function, that is, H.F. or L.F. amplification, by one H.T. feed wire, and thus a common anode voltage is imposed on the valves. It will often be found that this "noisiness" can be greatly decreased by giving each valve a separate value of anode potential, starting at the "first detector" end with a comparatively low voltage and increasing each stage to the maximum voltage at the second detector. Each of these leads should be shunted by a high-value reservoir condenser of a capacity of not less than half a microfarad.

Sometimes "noisiness" in the super-het is caused by faulty grid leaks. Only the best obtainable should be used, especially in the "first" detector, and substituting other grid leaks will speedily show whether it is this which causes the trouble.

Other sources of noise owe their origin to the usual causes, bad or dirty contacts, microphonic noises owing to faulty construction of the valves, gassing accumulators, broken L.F. transformers and 'phone windings, or shorted or partially shorted fixed condensers. Such noises are often steady and constant, and will continue when the set is not vibrated. They must be tracked down by withdrawing each valve one by one from the first stage until a sudden stoppage will show where the trouble lies. If the noise gradually subsides on withdrawing the valves one by one, the fault should be looked for in the battery leads and condensers and in the batteries themselves.

Valves.—Some valves are extremely noisy when run in cascade, the noise in this case being something akin to "frying." Such noises are due to the electron flow between the filament, plate and grid, or are located in the point of entry of the filament, and are caused by the use of improper materials in the construction of the valve. It is obviously not possible to give a list of noisy valves, as very often a manufacturer will produce a number of such valves, even though his usual product is quiet in operation, neither would it be fair to mention any particular make of valve as being noiseless in work of this nature.

It will be found that changing over the positions of the valves in the intermediate amplifier will often result in a great increase in signal strength, especially when the wavelength range of the transformer has no

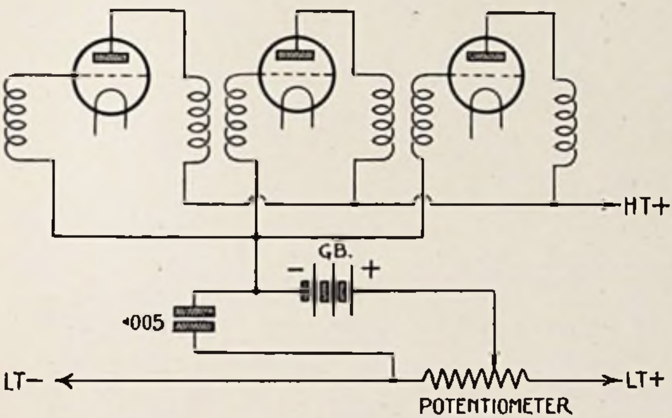


Fig. 6.—Introduction of Auxiliary Grid-bias Battery

means of adjustment, such as a variable condenser has. This is, as just stated, because the electrical properties of valves vary considerably in different batches, even though they are of the same manufacture.

Tuning-in Weak Signals.—The best method to adopt is, first of all, to note the relative position of the oscillator and tuning-condenser knobs when receiving strong signals. Assuming that this is 10 degrees we can commence to search, keeping this difference between the condenser all round the dial, except at the top end, where the distance may broaden out somewhat. It is best to slowly advance the oscillator dial, at the same time rotating the tuning condenser backwards and forwards over a distance of 5 to 7 degrees. Should signals or a rustling sound be heard this may then be properly tuned in. The searching should always be carried out with the potentiometer on the negative side so that the intermediate amplifier is in its most sensitive condition. Should squeaks be heard, this denotes the presence of a carrier wave, and the potentiometer should be brought back to positive so that the music or speech can be received.

Short-wave Working.—Invaluable as the super-heterodyne receiver is for receiving broadcast signals over considerable distances, it is even more useful for reception on the very short waves, and, indeed, such a receiver in conjunction with a small loop aerial is far better for short-wave reception than any receiver fitted to an open aerial. K D K A of America has, for instance, been repeatedly received in London at loud-speaker strength (one L.F. amplifier) with such a receiver on nights when it was impossible to receive that station on an open aerial, and amateur short-wave C.W. stations, both home and foreign, can be picked up by the dozen. If the reader has already built for himself a super-heterodyne receiver suitable for broadcast reception, and the oscillator coupled just covers a band of wavelengths between, say, 200 and 500 metres, this is suitable for short-wave reception in spite of the comparatively long fundamental wavelength of the coupler.

Harmonics.—In this case we utilise the harmonic period method of reception. We know that an oscillating valve generates oscillations at harmonic periods in arithmetical progression below the fundamental wavelength, that is, at one-half, one-third, etc., of the wavelength. We can utilise this by heterodyning short-wave signals by the harmonic of our local oscil-

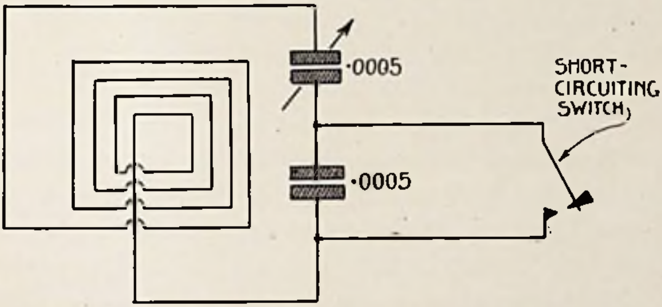


Fig. 7.—Sharp-tuning Arrangement

lator. Thus, if we set our tuning condenser at a position which we know will bring in 200-metre signals we can, by inserting a suitable short-wave coil or loop aerial in the tuning-circuit receiver, also bring in signals on the wavelength of 100 or 33 metres on this setting when the aerial is tuned to that frequency.

It will be seen from the foregoing that it is possible to receive short waves on any standard broadcast super-heterodyne receiver, and all that is required is to alter the main tuning inductance, be it loop aerial or coils. Reception on the very short waves is rather a different proposition to receiving broadcast. The tuning is extremely sharp, and capacity losses must be avoided at all costs in the manner which has already been indicated in connection with the first detector.

As regards sharp tuning, it will be found that an ordinary .0005 microfarad condenser, even when fitted with a vernier dial, is somewhat coarse or cumbersome in its operation, and it will be found desirable to incorporate in the set a fixed condenser of equal value to the oscillating-tuning condenser and in series with it, and a short-circuiting switch to short-circuit this condenser when broadcast is being received.

The condenser should be of the low-loss type, and its use will halve the capacity of the tuning condenser, thus making for easier tuning, since the short-wave signals will be further apart on the dial and comparatively flat. (*See* Fig. 7.)

Super-het Interference.—There is no doubt that the super-heterodyne receiver is capable of causing a great deal of interference to near-by neighbours, even when used on a frame aerial. This interference is only momentary, however, since the radiation takes place below or above the wavelength of the station which is being received. Such interference will be caused mostly by those persons who are always on the search and cannot settle down to any particular programme, and will cause an endless succession of "chirrups" in the neighbouring receiver when the station which is receiving is passed over.

It would be a pity if the popularity of the super-heterodyne receiver were marred owing to this characteristic, and it is suggested that users would do well if they refrained, as far as possible, from passing over the carrier of the local station when they have a neighbour a few yards away who is listening to that station.

On the other hand, when using the set on a frame aerial it is unlikely that any interference will be caused to a neighbour four or five doors away, and it is still more unlikely that two super-hets situated in close proximity one to another will heterodyne the same distant station at exactly the same frequency and cause mutual interference.

The chances of an operator heterodyning a distant station at the same frequency as the local station are also remote, so far as we in England are concerned, since we have a fairly wide area between our stations. But the fact remains that this *is* possible, and care should be taken to see that the operator does not unduly interfere with the pleasure of nearby listeners.

CHAPTER IV

Faults and Their Remedies

Total Absence of Signals.—This will occur through a broken circuit in the oscillator or first-detector stages. The wiring should be carefully checked over and valve pins opened out so that they make good contact with the grid and anode leads. The loop aerial should also be inspected for a broken terminal wire. On the other hand, the oscillator may not be functioning. This is checked by putting a pair of phones in the + plate lead of the oscillator valve, removing all other valves and touching the grid or plate terminals of the valve when the filament is alight. This should result in a loud " plonk " in the phones, due to a sudden rush of current in the anode lead. The H.T. battery leads being reversed will also cause absence of signals, as also might the reversal of the L.T. leads. By-pass condensers should be inspected for possible short-circuits, and checked with phones and battery. If no *loud* click is heard these are quite in order. There will, however, be a slight click with high-value condensers.

Partial Absence of Signals.—This is characterised by an absence of comparatively high-power long-distance stations, whilst the near-by stations appears to be of good strength. Assuming that the experimenter knows how to tune the set, the H.T. and L.T. leads should again be inspected for reversal. Check over the intermediate amplifier and note whether the nearby station increases in strength as the potentiometer is moved to the negative L.T. side. If this does not happen additional negative grid bias should be applied between the selector switch of the potentiometer and the grid leads to the amplifier. It is also as well to see that the L.T. voltage is up to the required standard before testing the potentiometer, as indicated.

Strong signals will often pass through a four-valve amplifier when one valve has been removed, but weak signals will be absent. Check over the valves for bad contacts, or, if dull emitters are used, test the filaments for continuity with a dry cell.

If the tuning condensers are not of the best, suspect these of losses and try different values of grid leak for both the first and last detector.

See that the frame aerial or the set is not against a metal body of large surface area, which may screen it, and keep it away from the influence of an outdoor overhead aerial. Such an aerial often screens the set and annuls its directional properties, or in some cases changes them.

See that the frame is pointing in the proper direction to receive the wanted station. Sometimes a badly-wired set will have serious losses in the H.F. circuits. See that all wires of opposing polarity are kept far apart and as far as possible uninsulated, except by air. See that flux or resin has not insulated the fixed condenser or other soldering tags from their contacts.

Capacity Effects.—Hand-capacity effects will be noticeable in a receiver, the intermediate amplifier of which is operating on a very long wave. The remedy is to reduce the wavelength.

The stationary vanes of variable condensers should always be connected to the grid of the valve, and should they be otherwise this will cause hand-capacity effects.

By-pass condensers of adequate value (half a microfarad) should be placed across each positive and negative pair of leads from the H.T. battery, and all other small values of capacity inserted in the circuit where a high resistance to H.F. currents is presented by the components.

It is of material advantage always to place such a condenser across the telephone leads, and this may have a value of .002 mfd. to .005 mfd.

All isolated metal work, such as tin condenser sheaths, iron fixing brackets, L.F. transformers, iron cores, and the like, should be connected by means of suitable leads to the negative side of the L.T. battery.

Capacity effects may be noticeable when the body comes across the directional side of the aerial, and this is, of course, easily avoided. Earthing the accumulators will result in the removal of a large percentage of capacity effect.

Double Signals.—This is not a fault, but a characteristic of the super-heterodyne receiver. The same signals will be received on two settings of the oscillator dial provided that the aerial-tuning condenser is not altered. These positions should be about 10 degrees apart for comfortable working, but they may be 30 or more degrees apart. They should certainly be not less than 5 degrees apart, otherwise difficulties will be encountered in tuning. The small separation area denotes the short-wave intermediate amplifier.

Frying Noises. — These may be due to bad battery contacts, or a faulty valve, or to static conditions. Disconnecting the aerial will prove whether it is the latter, and if that is the case it cannot be avoided until the weather is more favourable.

Fading. —This is characterised by an intermittent reception of distant signals when they get slowly weak and then increase in volume. In some cases they entirely disappear. This is an atmospheric condition, not due to the receiver, and varies according to the time of the year and time of day. It is very prevalent at sunset and during the dark hours.

Fading might be caused by a faulty H.T. battery, and this should be tested to stand up to the correct voltage with a load in milliamperes, according to the valves used, allowing about 2 milliamperes per valve. Another source of trouble may be in one of the valves in the amplifier going "soft" after it has functioned satisfactorily for some time.

Howling. —This may be traced to the L.F. amplifier. The application of suitable negative grid bias and earthing, or connecting the iron core to the negative L.T. side will cure the trouble. Also see that there is no coupling between the windings of the transformers, and that they are nicely air-spaced, not less than 4 in.

Howling may take place in the intermediate amplifier, and it may be governed by the potentiometer or by dimming the filaments. If it is not controllable the trouble may be looked for in the first detector. See that this is not oscillating through some form of capacity coupling in the wiring, and reduce the H.T. potential slightly. Should the howling be variable with the tuning of the frame aerial, it is almost certain that it is this valve.

The oscillator will sometimes set up an audible howl if the coupler is placed in close proximity to the intermediate-amplifier transformer, or near the aerial tuning condenser.

Intermittent Clicks.—This may be due to "key click" from a neighbouring high-power wireless station, or to a local noise from a sparking dynamo commutator, or the like. The remedy is to screen the set by means of a wooden box lined with tinfoil glued on to the woodwork. It may be necessary to treat the ebonite panel in the same manner, cutting away the tinfoil in places where the component parts would otherwise make electrical contact with it. Another form of intermittent click is experienced when the potentiometer-selector switch is making poor or no contact.

Jack Troubles.—Jack switches are always likely to be the source of trouble owing to their construction, and they should be periodically examined, and care taken that the various contacts are "making" properly. When they are first installed in a set the intrusion of flux and resin between the springs should be prevented, or this will lead to considerable trouble at a later date.

Lack of Modulation.—This may be due to the intermediate amplifier oscillating, or to a fault in the aerial circuit. It will be found that numerous carrier waves can be received, but no speech or music.

If the trouble is in the intermediate amplifier the potentiometer should control it, and the grids of the valves made slightly more positive to kill the oscillation and bring in the modulation. The amplifier should, strickly speaking, only just oscillate right at the negative end of the potentiometer, and a reduction in H.T. voltage should be tried if the oscillation is pronounced, when the potentiometer is set in any other position.

The aerial portion of the oscillator coupler may have a break in the windings, and this will result in the reception of carriers, but no modulation.

Parasitic Noises.—The parasitic noises of a superhet are many and various. They may be due to static conditions, intermittent or dirty contacts, or to the valves themselves. Should the noise cease on removing the frame aerial it is static. On the other hand, if they persist, a half-hour or so spent in overhauling the entire set must be contemplated. This should first of all take the form of removing the valves one by one, commencing with the first detector, and should the noise suddenly cease the trouble is in that circuit. If, on the other hand, the noise gradually decreases it is fairly safe to assume that it is in one or other of the batteries. Clean up all battery contacts, and have a good look around for possible poor contacts in the set itself, both in the valve feed leads and in the H.F. circuits. Always look for trouble in variable condensers which have no positive connection to the moving vanes, and also in the valve pins and sockets. Blow out all dust with a pair of bellows, or brush it out with a small, good-quality camelhair brush, taking care that the brush does not deposit any hairs in the set. It is also as well to suspect the by-pass reservoir condensers across the H.T. and examine the insulation to see that there is no leakage. Check over the grid leaks.

Operational Noises.—There is nothing more aggravating than a set which is noisy when tuning in signals. Badly-made variable condensers will cause so much noise that it will be wellnigh impossible to wear the phones. Potentiometers are notoriously noisy, and there is only one noiseless one known to the writer, this being the one manufactured by the Central Laboratories of America. Cleaning up the surface of the resistance wire with a piece of glass-paper will considerably reduce the scraping noises found in ordinary potentiometers. Whether or not this type of noises will be prevalent in a set depends upon the judicious selection of good parts by the constructor. A further seat of operational noise is in loose contacts, when the set will chatter to such an extent that the constructor would be speedily reduced to a state of "nerves" if the trouble were not removed. Some types of geared vernier dial are noisy because the gears are not permanently in mesh.

Typical Noises.—In a well-constructed set there should be no noise unless the intermediate amplifier is working very close to the negative side of the potentiometer resistance. The noise in this case will take the form of a faint hissing, but this should only be experienced when the aerial and oscillator are in tune. If noise of this character is prevalent at all settings of the condensers it is in the valves themselves, and there is no remedy, neither for that matter is such necessary, except that the presence of the hissing only when both oscillator and aerial are in tune is a great help to searching.

Lack of Oscillation.—Under the heading of absence of signals a method of detecting lack of oscillation has been explained. This trouble may be due to improper values of H.T. and filament voltage, or to wrong connections of the oscillator coupler, or a broken wire in the circuit.

If the wiring and coupler winding appears correct different values of both H.T. and L.T. might be tried. Reducing the latter will often set the valve into oscillation, and the former may be increased or decreased according to which gives the best results. It is often beneficial, where a mixed assortment of valves is used, to employ a separate H.T. feed for the oscillator, since some valves are critical of their treatment in this respect.

Rheostat Troubles.—Slight troubles may be caused with faulty or badly-designed filament rheostats. One such trouble is inability to control the filament voltage within narrow limits, and this is very marked when using dull-emitter valves.

Reversal of Direction.—Sometimes when the receiver is earthed by means of a long earth lead it will be found that the directional properties of the aerial are reversed or altered. For instance, signals which should come from the north may be strongest from the east or west, or vice-versa. The remedy is to remove the earth or provide a very short wire leading direct to earth and not to a water-pipe, unless this enters the ground immediately.

Squeals.—A receiver will squeal if the intermediate amplifier is oscillating violently, or in some cases if the aerial is far out of tune with the oscillator. To check violent oscillation the potentiometer is brought into play, although such squealing may be caused by an electrostatic or magnetic coupling between the transformers. A broken lead between the secondary of the H.F. transformer and the potentiometer may also cause squeals. In cases where reaction is taken from the first detector to the aerial or tuning inductance, care should be taken that the amount of reaction applied is not excessive.

Lack of Selectivity.—This is often due to too tight a coupling between the rotor and stator of the oscillator coupling or defective grid condensers. If the transformers are correctly designed a modification of the oscillator coupling will have the desired result.

CHAPTER V

The Tropadyne Six-valve Super-het

Advantages of the Tropadyne.—The tropadyne system is an alternative method of super-heterodyne reception, its main advantage being that economy in valves is effected by dispensing with the usual separate oscillator employed in the ordinary super-heterodyne. It is easy to operate and the tuning is constant, therefore records of dial readings may be kept for future occasions. It is the only super-heterodyne receiver that does not pass high-frequency oscillations into the aerial, and may therefore be used on an outside aerial without fear of causing interference to other listeners.

In the circuit described in this chapter, and known as the tropadyne circuit, a self-heterodyning detector valve is employed, this having two independently tuned circuits arranged so that the tuning of one has no effect on the tuning of the other; therefore one of the valves of the ordinary super-heterodyne (the separate oscillator) is dispensed with. The word tropadyne is derived from the Greek *tropia*, to change, and *dyne*, meaning force; the term referring to the single valve acting both as detector and frequency changer.

Other points of interest in connection with this receiver will be cited as the description of the construction of the instrument proceeds (*see* Figs. 8, 9 and 11).

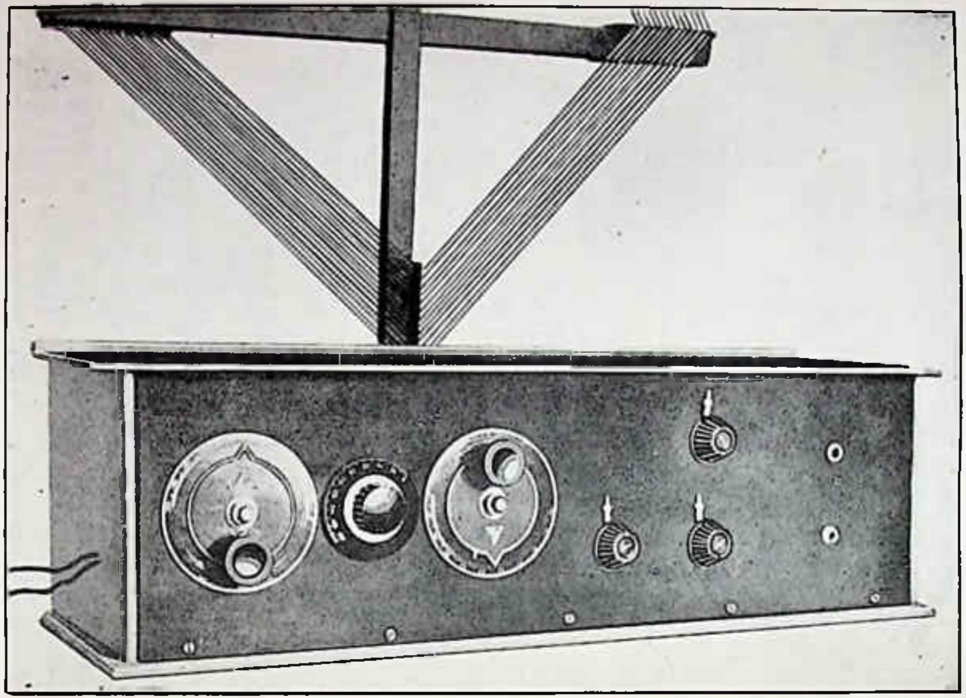


Fig. 8.—The Complete Tropadyne Receiver

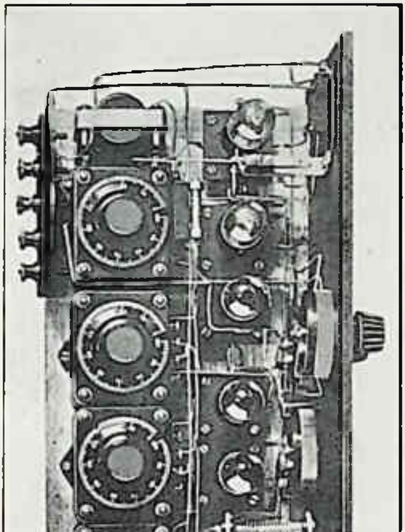


Fig. 9.—Plan View of Tropadyne Receiver

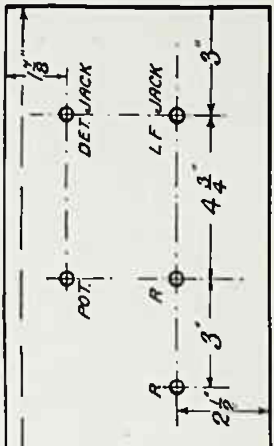


Fig. 10.—Layout of Panel

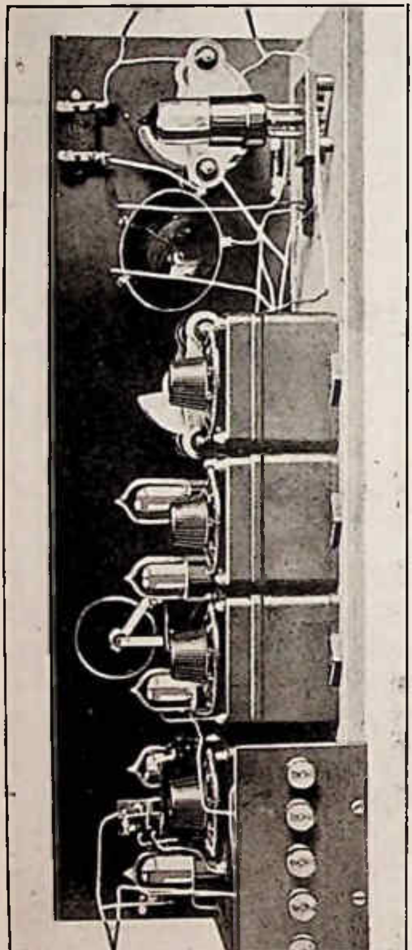


Fig. 11.—View of Back of Panel of Tropadyne Super Receiver

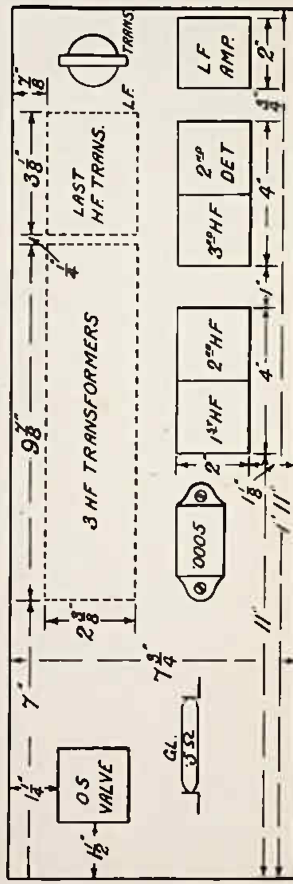


Fig. 12.—Plan of Baseboard

The Panel and Baseboard.—The layout of the panel is shown in the diagram (Fig. 10). In order to obtain ease in working, it is recommended that a full-size drawing of the ebonite should be prepared, allowing a 2-in. overlap round the edges, and that this paper should be laid on the ebonite with the overlap folded under the panel after the latter has been properly trued up, and the holes centre-punched through the

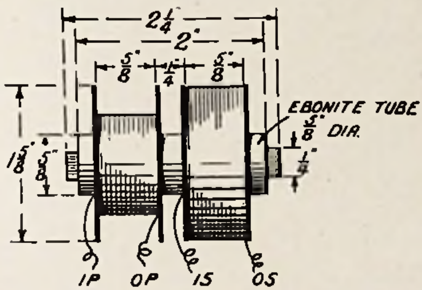


Fig. 13.—Constructional Details of H.F. Transformer

paper. The panel may then be drilled, and engraved where considered necessary.

The baseboard is shown in Fig. 12. It should be of hard wood ½ in. thick.

High-frequency Transformers.—The H.F. transformer is shown diagrammatically in Fig. 13. Although these transformers are not difficult to wind providing that the amateur has the facilities for so doing, it will perhaps be desired in most instances to purchase them ready made. A suitable type of transformer is that known as the Tropaformer.

If it is desired to make a transformer, the iron core should be 2¼ in. long by ½ in. wide, and be composed of thin silicon steel laminations built up to ¼ in. thick; the laminations should be the thinnest obtainable. The primary coils consist of 500 turns of No. 30 s.s.c. wire wound on a bobbin 1⅝ in. in diameter by ⅝ in.

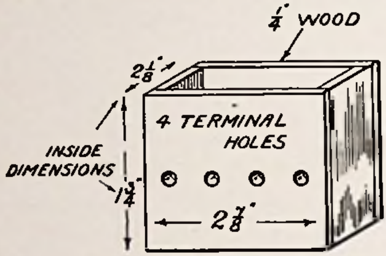


Fig. 14.—Box for Transformer

wide and with a ⅜-in. hole through the centre. Each layer of wire may be separated with thin wax paper. The bobbins may be made up from a ⅜-in. tube with a pair of washers to form the end checks. The secondary coils are similar in construction, but the bobbins are

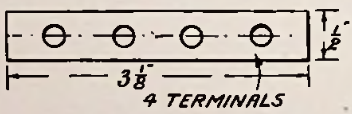


Fig. 15.—Terminal Strip

wound with 1,000 turns of No. 30 s.s.c. wire. The number of turns is not critical. The two bobbins are spaced ¼ in. apart, and both windings are put on the formers in the same direction, sufficient wire being left to connect to the four terminals on a terminal plate.

The transformers are enclosed in small wooden boxes made from ¼-in. fretwood, as shown in Fig. 14. The box is previously drilled for four terminal wires, and four small terminal strips are prepared, as shown in Fig. 15. Next, the box is lined with tinfoil. The transformers are fitted in the boxes and wired to the backs of the terminals on the strip, which is screwed to the outside of the box, leaving two extra leads on the I.S and O.S. terminals of the transformer. These leads are necessary for attachment to the tuning condensers.

The Tuning Condensers.—The tuning condensers have a maximum capacity of .0005 microfarad. Small mica-dielectric condensers of this capacity should be used, as they are readily mounted on the tops of the transformer boxes, thus keeping the wiring to a minimum. When once these condensers have been set at the required capacity they will not need to be altered. The spare leads from the O.S. and I.S. terminals are taken to each of the condenser terminals through holes in the top of the transformer box. The question of dielectric losses is not so important in this amplifier, as amplification takes place on wavelengths of from 3,000 to 7,000 metres, where such losses do not so readily occur. The object of lining the transformer boxes with tinfoil is to protect the windings from unwanted interference from signals emanating from long-wave stations.

The Oscillator Coupler.—The oscillation coupler is simple to make. The stator may consist of a piece of tube 3¼ in. in diameter and 2 in. long. This is fitted with a small bracket, as shown in Fig. 16; the coupling coil is provided with suitable fitments so that it may be rotated axially. By arranging the coupler in this manner a vernier movement is obtainable. The windings of the stator consist of 50 turns of No. 26 d.s.c. wire; the rotor has 26 turns of No. 26 d.s.c. wire. The stator has a tap taken at the twenty-fifth turn, and may for experimental purposes on shorter wave-lengths than broadcast be provided with four tappings of 10 turns each, taking two at each side of the centre

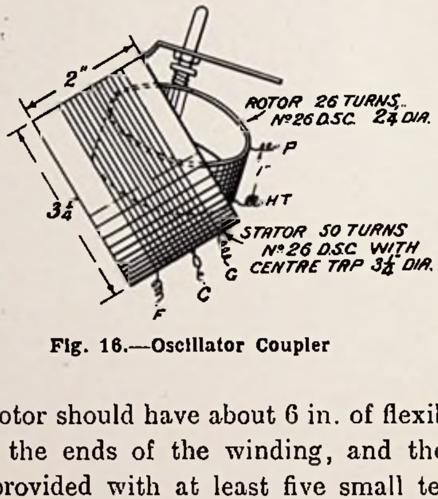


Fig. 16.—Oscillator Coupler

tap. The rotor should have about 6 in. of flexible wire soldered to the ends of the winding, and the stator should be provided with at least five small terminals to take both stator and rotor winding ends. Should the additional number of tappings have been taken, a corresponding number of terminals must be fitted.

The terminals should be marked HT and P; these are for the rotor windings. The stator windings should be marked, one set of tappings on one side of the centre tap F for filament, and the other set of tappings on the other side of the centre tap G for grid. The centre tap should be marked C, as this goes to the fixed condenser. The G and F terminals should be at what will be the base of the stator former when this is mounted on the panel, and the HT, P, and C terminals may be at the top.

The Valve Holders.—The valve holders are of the baseboard-mounting type. Should none of these be available, they may be readily made up as indicated in Fig. 17. Before they are finally screwed down to the

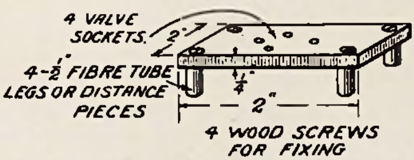


Fig. 17.—Valve Holder

baseboard they should each be provided with four short ends of bare tinned wire radiating from the valve sockets, these being of sufficient length for soldering purposes. Ordinary valve sockets are, of course, fitted to the little tables.

Components.—Having now completed making up these parts, the following additional components are required :

Four mica dielectric variable condensers, .0005 (for the L.F. transformers referred to if not already obtained) ; two .0005 variable air-dielectric condensers ; one low-frequency transformer (a Royal is used in the illustration) ; two filament rheostats ; one potentiometer, 300 to 400 ohms (this should be very robust) ;

one .0003-microfarad fixed condenser (grid condenser); two .0005-microfarad fixed condensers; one .003 to .005 fixed condenser; two Apex vernier dials; one dial for oscillator coupler (not more than 3 in. in diameter); two grid leaks (.25 to .5 megohms and 1.5 megohms); one single-circuit jack; one five-point jack; five brass terminals (large); sixteen small terminals (for H.F. transformers); five or more small terminals for oscillator coupler; about 50 ft. tinned No. 16 copper wire for

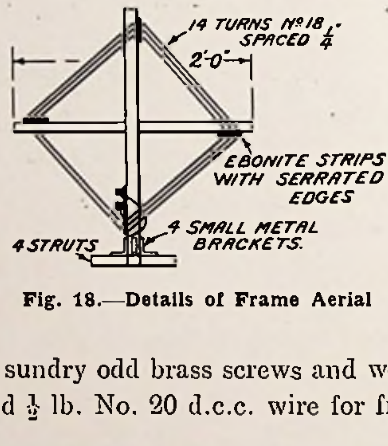


Fig. 18.—Details of Frame Aerial

wiring up; sundry odd brass screws and wood to make cabinet; and ½ lb. No. 20 d.c.c. wire for frame aerial; six valves.

The Frame Aerial.—Fig. 18 shows a suitable construction of frame aerial for broadcast reception. This may be easily made up from the diagram given.

Mounting the Components.—Fig. 12 shows the layout of the baseboard. It should be marked out in pencil on the wood; the relative positions of the parts are clearly indicated. After this the components should be screwed in their respective positions and

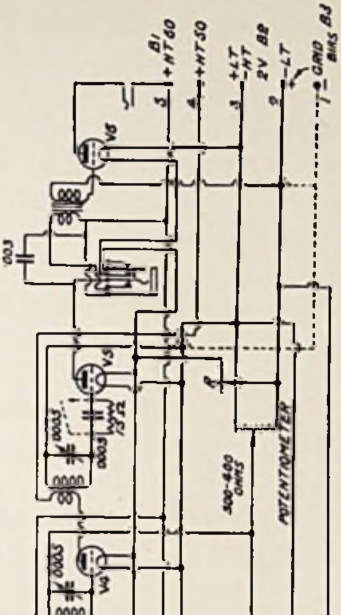


Fig 19.—Circuit Diagram of Tropadyne Receiver

the variable condensers, Apex dials, oscillator coupler, rheostats, potentiometer and jacks, etc., fitted to the panel. As regards the valve sockets on the baseboard, it will be noted that the second, third, fourth and fifth valves are paired as regards position. This is done in order to conserve space; the positive terminals of the filament sockets of each pair of holders are wired together so that the holders butt on to each other with a common feed wire. This wire should be attached to the filament sockets before the latter are finally screwed to the baseboard.

Wiring.—The theoretical circuit diagram is shown in Fig. 19 and the values of all components are shown thereon. In wiring, as little flux and solder as possible should be used. Use the binding nuts and washers on the terminals of accessories wherever possible.

First wire up the baseboard components. Commence with the oscillator end of the board and wire the filament circuits first, keeping all main L.T. leads in front of the sockets, as in Figs. 9, 11 and 24. The H.F. transformers and H.T. circuit should be wired next. It is a good plan to engage the requisite short lengths of wire behind the transformer terminals making the B + leads to the H.T. battery assume a vertical position with a short forward projecting tag sufficiently long to solder to the main H.T. feed wire. This wire will then be slightly raised above the level of all other wires, and will be out of the way. Next the grid, filament and plate leads on the transformers are wired as indicated. It will be noted that all these wires are very short. Finally, the L.F. transformer and five battery feed terminals at the rear of the set are wired up, remembering throughout this wiring that the leads have in some cases to go to the jacks on the panel, and therefore they must be sufficiently long to reach those components.

Fitting the Panel.—The panel has now to be

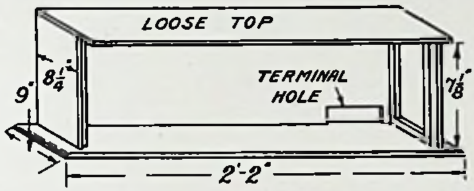


Fig. 20.—The Cabinet

wired up. Remember in this case also that the leads have to join others, so allow ample wire for these connections. The jack-to-filament wires are the only ones on the jacks which go to the baseboard; all the

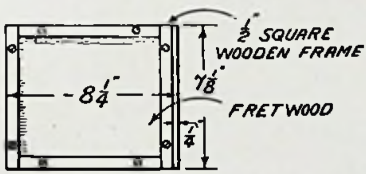


Fig. 21.—End Elevation of Cabinet

others are fed from the L.F. transformer and terminal panel. After wiring, it will be found that before connecting up to the baseboard, the panel will have to be fitted and the filament wires on the baseboard slightly adjusted so as not to short-circuit the two filament rheostats.

The panel may now be fixed to the baseboard and the wiring completed, after which it should be carefully checked for accuracy and possible short-circuits. A pair of flexible leads are attached to the tuning condenser c_1 and the positive filament terminals, and these are led through two holes in the side of the case for connecting up to the frame aerial.

The Cabinet.—A simple scheme for a cabinet for the instrument is given in Figs. 20 and 21. It is composed entirely of ⅜-in. and ¼-in. fretwood. Oak was used in the model shown in Fig. 8. The completed set should on no account be left uncovered or dust will speedily render it unusable.

The Tuning Inductances.—The set described was designed for use with a frame aerial, and no tuning inductances are required; but should the constructor so desire he may adopt it for use on the outdoor aerial by the addition of a pair of inductances wound on 3-in. ebonite formers. Fig. 22 gives details of suitable coils, and the ends of the windings are lettered to correspond with the insertion of the coil in the circuit in the manner illustrated in Fig. 23. There is insufficient room for the inclusion of this coil in the set so far described, so that it will have to be mounted in a separate cabinet. The two flexible leads on the tuning condenser and filament wires should be taken to a pair of terminals on the face of the panel, and a wire provided between these and the cabinet containing the inductances.

The set will not radiate and will not therefore cause interference if used in this manner, but it will be found that interference from static, etc., will be experienced when working on the outside aerial.

Operating the Tropadyne. — The tropadyne "super" is easy to manipulate, but requires some patience until the user learns the meaning of the

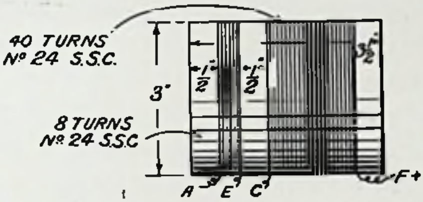


Fig. 22.—Inductance for Outside Aerial

different sounds he will hear. First of all the .0005-microfarad mica dielectric condensers on the H.F. transformers should be set at about 50 degrees. This is purely arbitrary, and greater amplification will be

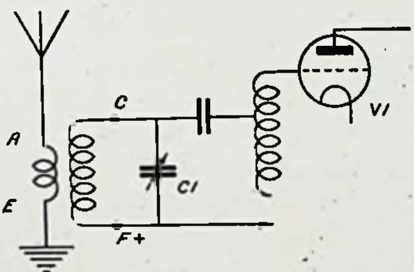


Fig. 23.—Circuit for Outside Aerial

obtained if they are set at a lower reading, say, 30 to 40 degrees. If they are used at a lower reading than this, distortion and other troubles may result, but the main consideration is to set them all alike in the first instance.

Using the Frame Aerial.—Now with the set attached to the frame aerial and with the aerial pointing in the direction in which it is hoped to receive (a nearby station is the best to commence with), set the oscillator coupler at a reading of about 20 degrees and the potentiometer mid-way on the resistance wire. If the oscillator condenser and the tuning condenser knobs are now rotated *very slowly* signals may be heard. The oscillator condenser should be moved only about two degrees at a time, and the tuning condenser moved a whole revolution for each of the settings. If no signals are encountered the potentiometer should be moved slightly more to the positive side of the L.T. battery, and the process repeated. Signals may be heard as a slight squeak, and should this occur the potentiometer knob should be turned to the positive side, after which the squeak will disappear, and the signal may be properly tuned in by slightly varying both the tuning condenser and the oscillator condenser.

When maximum results have been obtained, the H.F. transformers will require adjustment. Commencing with the transformer next to the second detector, tune this and the next three transformers for best results. The oscillator coupler may also be slightly altered, also the oscillator condenser and tuning condenser.

Searching.—Having succeeded in obtaining clear signals from the nearby station, a search may be made for stations farther afield. When one of these has been found by searching in the manner already described, the H.F. transformer condensers should be again varied to obtain the best results on weak signals. It will be found that whereas the tuning of the transformers made very little difference on strong signals, they are fairly critical on distant signals, but after this final setting they need no further adjustment. A note should be made of the four dial readings for reference in case they should be accidentally shifted at any time.

Should the receiver get into a state of oscillation which it is not possible to prevent by altering the potentiometer, the resistance of the grid leak R_1 should be reduced. Varying the coupling of the oscillator coupler may also have a governing effect on this oscillation. A steady beat note in the receiver indicates a broken connection, and this should be traced out and remedied. Inability to tune in speech and remove the carrier squeal may be caused by the oscillator coupler being too tight, or by sustained oscillations in the H.F. amplifier. In the latter case the potentiometer should be adjusted, and in the former loosening the coupling may have the desired result.

When the set is operating satisfactorily it should be possible to tune in all B.B.C. main stations on the frame aerial without hearing a squeak, the only indication of the presence of a carrier wave when modulation is not taking place at the transmitting station being a rustling sound in the phones. The set appears to function best in connection with the broadcast band of wavelengths, when the oscillator-coupler dial reading is between 15 and 20 degrees, or when both coils are almost parallel. The potentiometer will in this case be about a third of the total resistance from the negative side.

Grid Bias.—The terminal block at the rear of the

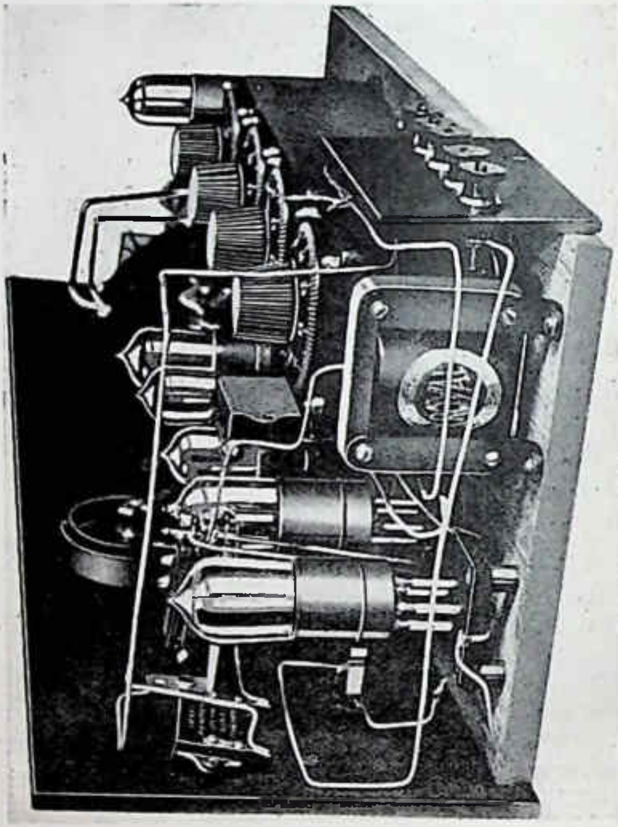


Fig. 24.—Back View of Tropadyne Receiver.

set has an extra terminal fitted for the attachment of a grid-biasing battery B_3 (*see* Fig. 19). This is introduced so that a grid-biasing battery may be used on the second detector valve at the lower bend of the characteristic curve in lieu of cumulative grid rectification. With Cossor Wuncell valves, however, this is not desirable, and cumulative grid rectification is more satisfactory. The terminals 1 and 3 are therefore shorted when the grid leak and condenser method of detection is employed, the battery having been previously removed. When the grid battery is used for operating on the lower bend of the curve the grid leak and condenser are shorted.

Results. — With the Tropadyne all the B.B.C. stations are easily receivable on the small frame aerial, such stations as Birmingham, Manchester, Bournemouth and Cardiff being at loud-speaker strength in London. 2 L O is very easily cut right out. Many Continental stations have also been received with the same arrangement. The wavelength range of the set with the frame aerial described is from about 200 to 600 metres, but if the aerial is made shorter it is possible to obtain good reception below this range.

Tuning is very sharp, as no signals will be received unless the heterodyne is almost in tune with the carrier of the wanted station. It is here that perhaps the operator will be at fault in his first attempts, as it is easy to pass over quite a large number of stations without knowing it. Results on the open aerial are rather marred by statics and mush, but reception over phenomenal distances is easily obtainable. The only signals which are definitely of an interfering nature are the broadly-tuned spark signals, but these may disappear when the receiver is tuned to a C.W. telephony signal.

CHAPTER VI

A Seven-valve Super-het

ALTHOUGH American "super-het" components are exceptionally well made and finished, they are not always the best from the point of view of the British home-constructor. To be more precise, a trouble with American intermediate transformers and other "super-het" accessories is to be found in the fact that they do not work efficiently with British valves.

American Components.—American valves and those manufactured in this country show widely different characteristics, so that it is not a matter of wonder that when an American transformer, designed with an impedance suitable for an American valve, is used with a British valve the results do not compare favourably with those obtained when a British valve and transformer are used together.

In the "super-het" described in this chapter, components manufactured by some of the most prominent British firms have been used.

The oscillator unit and the high-wavelength H.F. transformers are specially made by Radio Instruments, Limited.

Components Needed.—A complete list of all the apparatus necessary is given below:

1 ebonite panel, 9 in. by 7 in. by $\frac{3}{16}$ in. thick (any guaranteed ebonite will serve); 1 filter (Radio

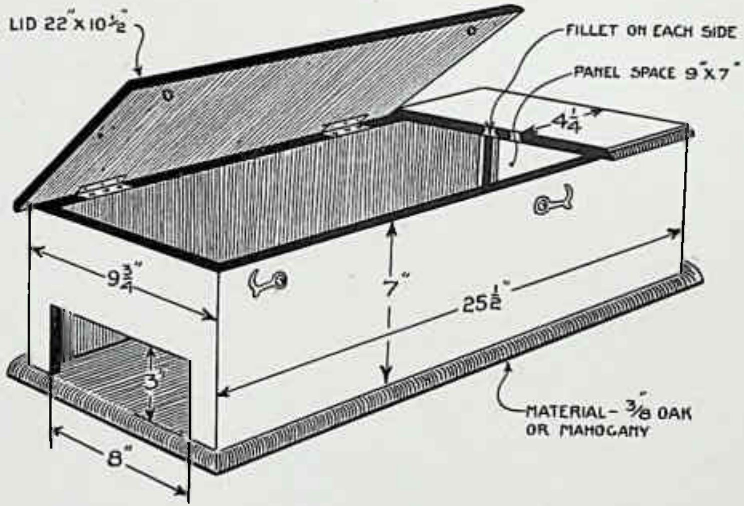


Fig. 25.—Details of Cabinet for Seven-valve Super-het

Instruments); 4 filament rheostats (Igranic); 1 master filament rheostat (Ericsson); 3 matched long-wave transformers (Radio Instruments); 1 oscillator coupler (Radio Instruments); 1 .0005-microfarad square-law variable condenser (Radio Instruments); 7 valve holders (Athol Engineering); 3 1-microfarad

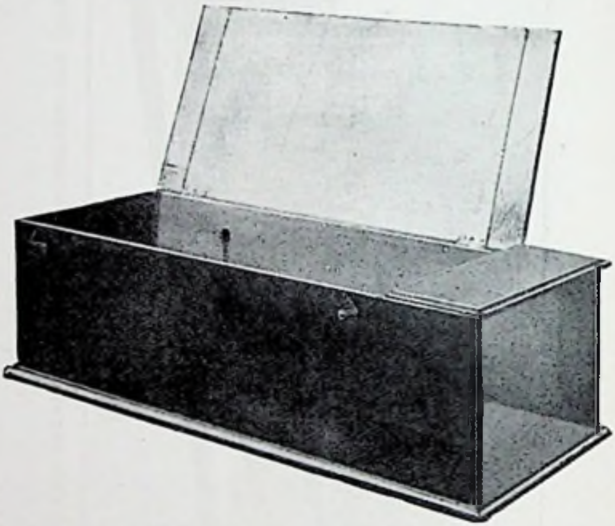


Fig. 26.—Special Cabinet for the Seven-valve Super-het

fixed condensers (Telegraph Condenser Co.); 1 .002-microfarad fixed condenser (Altas); 1 .001-microfarad fixed condenser; 2 .00025-microfarad fixed condensers (Igranic); 2 fixed grid leaks, 1.5 and 2-megohms; 1 4 to 1 L.F. transformer (Pye); 12 terminals (Belling Lee); 1 ebonite terminal strip, 3 in. by 8 in.; 1 wooden baseboard, 25 in. by 8 in. by ½ in. thick; 1 cabinet.

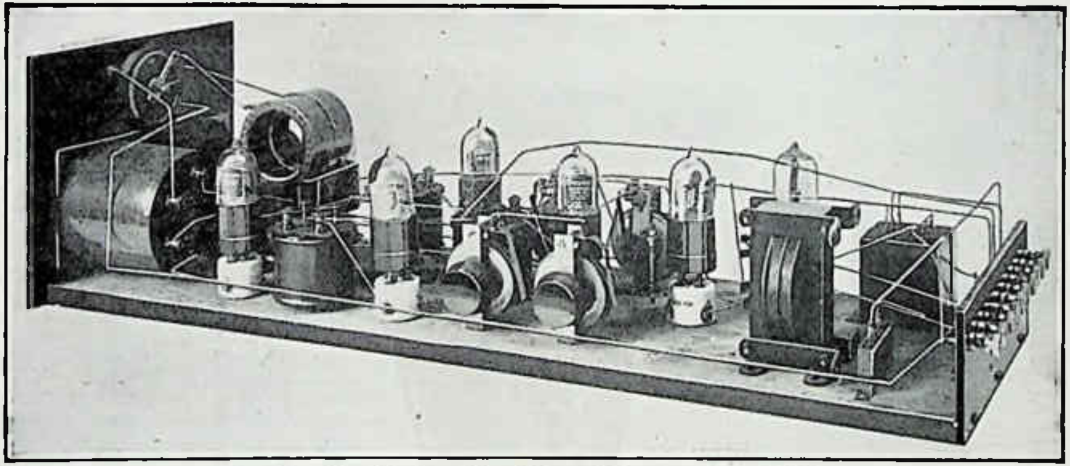


Fig. 27.—View showing Disposition of Components and Wiring

The Cabinet.—In order to keep the panel dimensions to a minimum and so save considerable expense, the cabinet has been specially designed, and is, as will

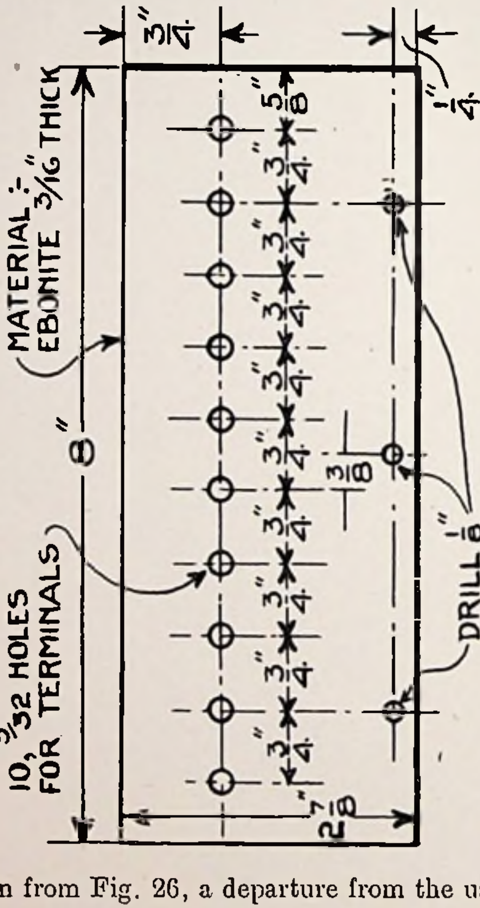


Fig. 28.—Layout of Terminal Strip of Seven-valve Super-het

be seen from Fig. 26, a departure from the usual type. A dimensioned view is given by Fig. 25 showing the construction of the cabinet.

The Panel.—The construction of the set may be conveniently started by cutting and drilling the panel to the size and dimensions given in the drilling diagram (Fig. 29). Only eight holes have to be drilled, including those for fixing the panel to the baseboard.

Provided the panel is obtained from the firm mentioned in the list of components (who stock this size

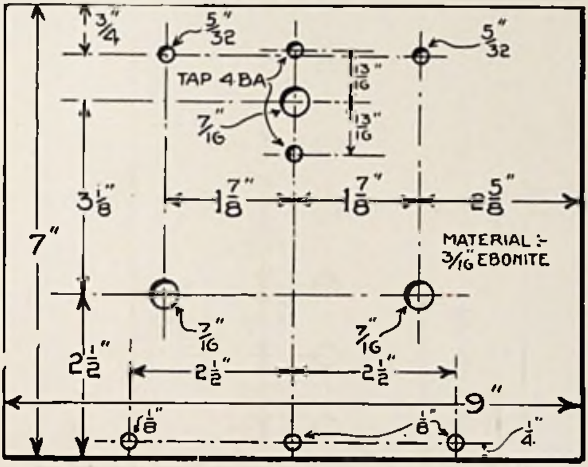


Fig. 29.—Layout of Front Panel of Seven-valve Super-het

as standard) no cutting will be required, thus saving a great deal of time and labour. The edges and corners are all trued and squared-up.

A good method of drilling the panel is as follows: Cut a piece of paper to the exact dimensions of the panel, that is, 7 in. by 9 in., and mark on the paper the positions and centres of holes to be drilled. Lay the paper flat on the panel and prick through the marks on the paper with a sharp steel point.

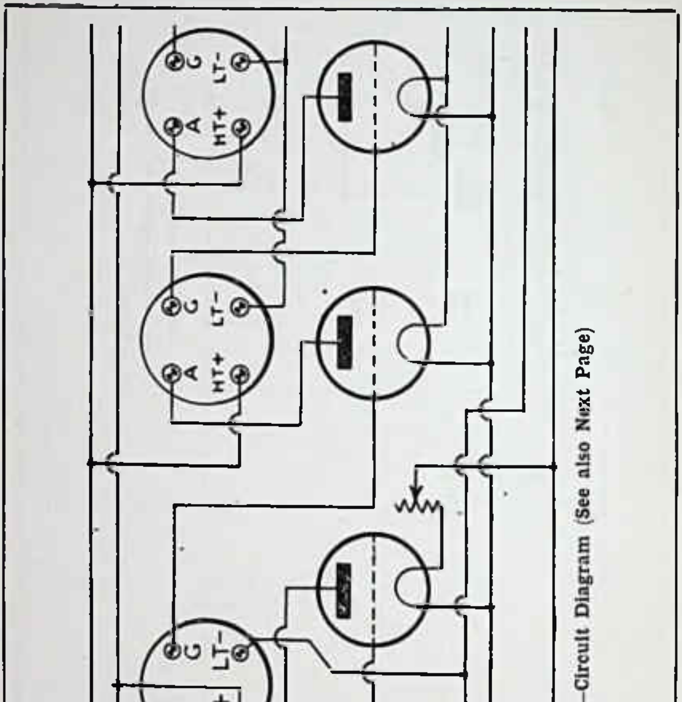


Fig. 30.—Circuit Diagram (See also Next Page)

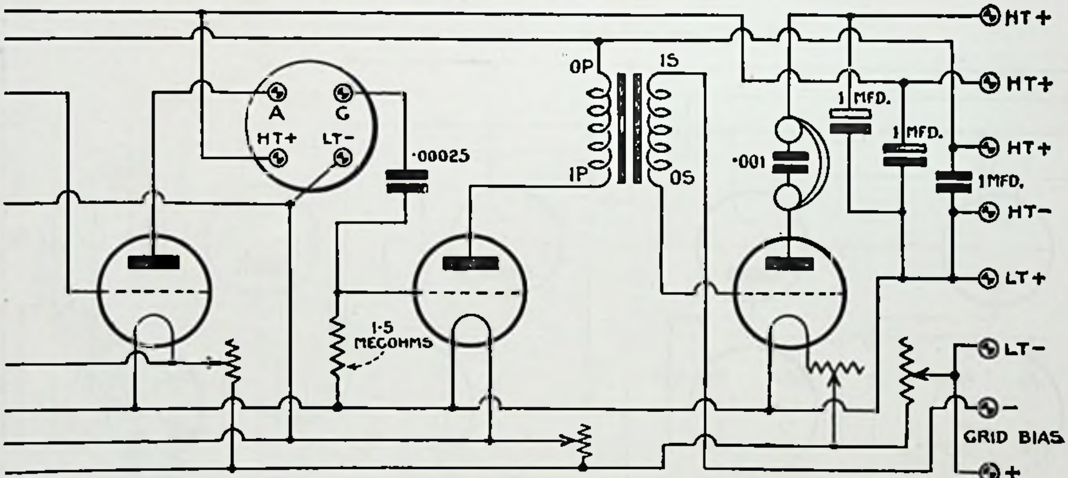


Fig. 30a.—Circuit Diagram (see also Preceding Page)

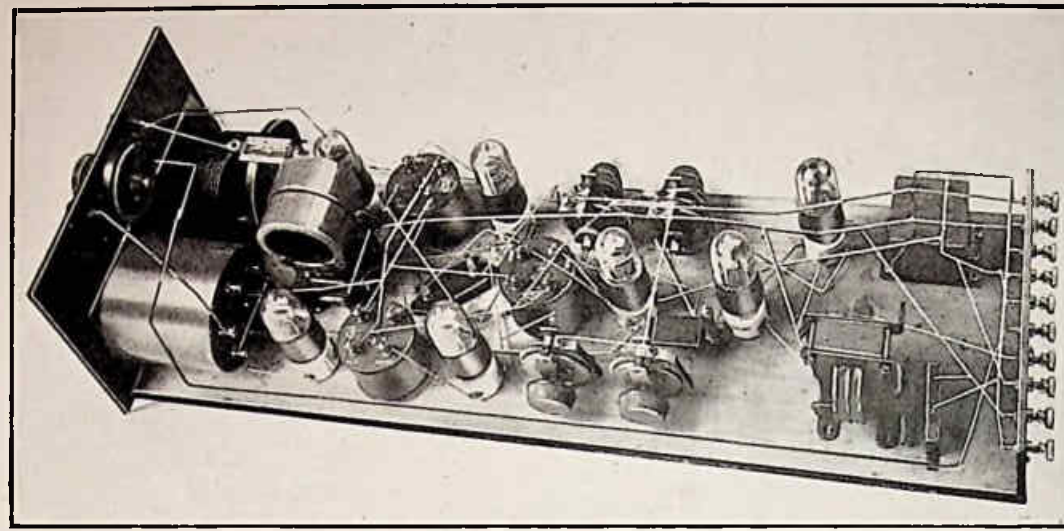


Fig. 31.—Plan View Showing Wiring

The paper template is then taken off the panel, through which holes of the sizes indicated in the lay-out are drilled.

Mounting the Components.—The next step in the construction is the mounting of the components on the panel and on the baseboard. All the main controls—the oscillator control, frame-tuning condenser, master filament rheostat—are mounted on the panel itself together with the frame aerial terminals. The remainder are screwed down to the baseboard in the positions shown in the wiring diagram (Fig. 32).

In order to eliminate as far as possible stray capacities existing between the wiring, the long-wave transformers have been placed in such a manner as to allow of the shortest possible connections between grid and anode.

Terminals.—For a similar reason the two frame-aerial terminals have been mounted on the panel close to the tuning condenser and first detector valve.

The remaining ten terminals are mounted on the ebonite terminal strip, which is screwed to the back edge of the baseboard and projects through the back of the cabinet.

Filament Control.—Four rheostats (excluding the master rheostat on the panel) are used to control the filaments of the seven valves. These rheostats are mounted on the baseboard. Before the set is finally enclosed in the cabinet they are adjusted to give best results, after which the brilliancy of the filaments are controlled by the single-master rheostat on the panel.

Wiring.—Having mounted all the components,

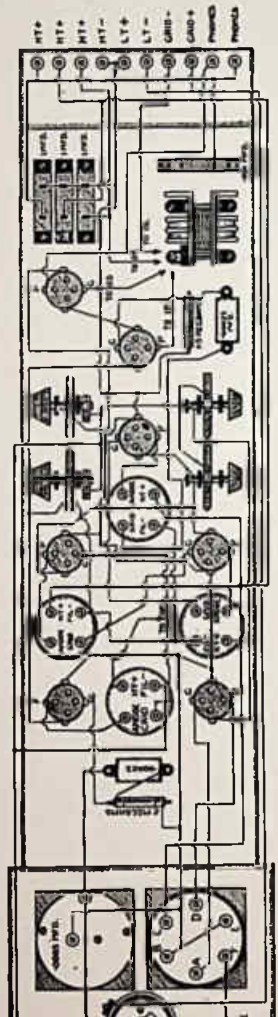


Fig. 32.—Plan View, Showing Disposition of Components and Wiring

wiring may be started. It is advisable to wire up a multi-valve set such as this in a systematic manner. A simple and convenient method is to divide the process of wiring into three parts—the filament, grid and plate circuits—making sure that each part is complete before proceeding to the next.

In this manner confusion is avoided, and the risk of leaving out or making a wrong connection is minimised.

No. 18-gauge square-section wire is used for connecting all the components, except for the two wires leading to and from the master-filament rheostat, which should be of a thicker gauge in order to carry (without overheating) the total current consumed by all the valves. No. 16-gauge wire would be suitable for this purpose.

It will be found that the thinner gauge of wire is apt to develop kinks and bends, spoiling the appearance of the finished receiver. The wire may be conveniently straightened by clamping one end of a 6-ft. length in a vice, holding the other end tightly in a pair of pliers and stretching the wire a few inches by pulling it. The actual stretching of the wire not only takes out all the kinks but also increases its rigidity.

It will be noticed from Figs. 31 and 33 that the two grid leaks and condensers have not been fixed to the baseboard, but are supported by the wires to which they are connected. As both of these components are small and light it is unnecessary to fix them down rigidly.

The Frame Aerial.—A super - het can produce

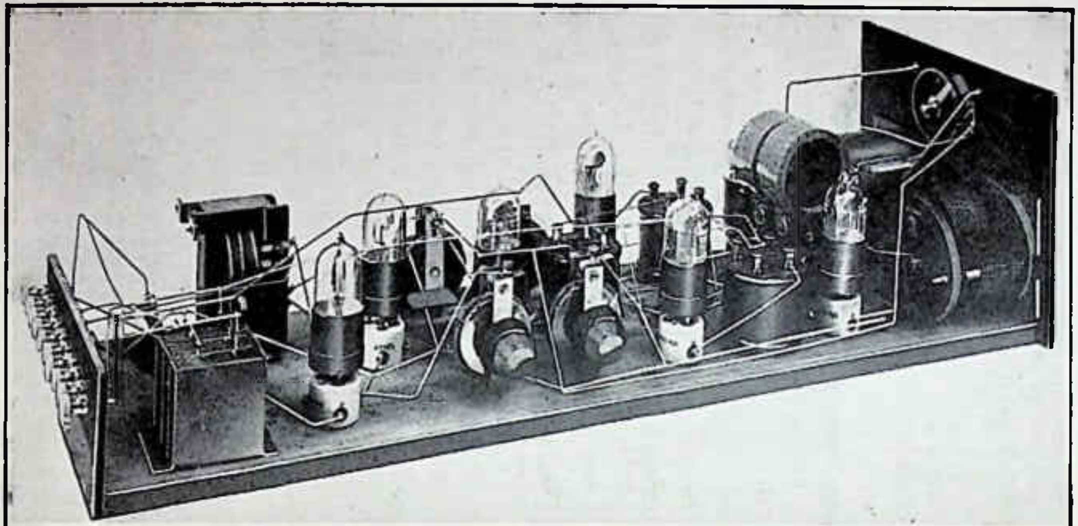


Fig. 33.—Side View, Showing Wiring, etc.

serious interference within a radius of several miles round if used in conjunction with an outside aerial, but apart from this it will be found that there is not much difference in the results obtained with a frame aerial and with an outside aerial.

A suitable size of frame is one having 3 ft. sides and wound with eight turns of No. 20-gauge wire spaced $\frac{3}{16}$ in. apart. The wire should be wound on slotted strips of ebonite. Provision should be made for the rotation of the frame, as aerials of this type possess sharply defined directive properties.

Preliminary Tests.—Before attempting to listen-in, the valve-filament lighting circuit should be tested for continuity and short circuits. It may be found, for example, that all the valves light up except one, in which case the filament circuit of that valve (including the rheostat) should be carefully inspected for some break or disconnection.

Before placing all the valves in their sockets it is advisable to connect a high-reading voltmeter across the filament sockets of each valve in turn, having previously joined the H.T. battery up to its proper terminals. This test will show whether the voltage of the H.T. battery is, by some short-circuit or wrong connection, applied to the filaments of the valves. Having thus made sure that there is no danger of burning-out the valves, the set may be connected up for listening-in.

Tuning-in.—To listen-in, first adjust the four rheostats mounted on the baseboard until a suitable filament temperature has been reached. Next search round for signals by slowly rotating the two dials on the panel. When signals are received, readjust the four filament rheostats and the + H.T. tappings for best results.

The filament temperature subsequently may be controlled by the master rheostat mounted on the panel.

It will be noticed that the same station may be tuned-in at *two* distinct settings of the oscillator dial, this, of course, being due to the oscillations produced by the oscillator-valve heterodyne above and below the incoming oscillations, as already explained in Chapter III.

Always remember to turn the frame aerial so that its plane lies in a direct line with the transmitting station you wish to receive.

No specific position has been allocated for the filter in the foregoing notes. The best position for this should be found by experiment. It may take the place of any one of the I.F. transformers.

On a very short test outside London the main B.B.C. stations were received at good strength together with several stations in France, Germany, Spain, and Holland. The set is extremely simple to control once the necessary adjustments have been mastered.

A further increase in signal strength and tone will be obtained by adjusting the positive wander-plugs of the H.T. battery and the negative wander-plug of the grid-bias battery.

CHAPTER VII

A Three-unit Super-het

This chapter deals with a very sensitive nine-valve supersonic-heterodyne receiver built in three distinct units (Fig. 34), and was originally described in the *Wireless Magazine* as "The Cosmopolitan Nine."

The advantages obtained from building a super-het on this principle are manifold. The tuning controls are located on the panel of the first unit, so that once the filament rheostats of the second and third units have been turned on, all the operating is confined to the first unit.

1.—The Oscillator and Detector Unit

Circuit.—Referring to the circuit diagram (Fig. 35), it will be seen that a special frame aerial is used having a tapping. The larger portion of the frame aerial, between the tapping and one end, constitutes the actual receiving portion of the aerial, and is connected between the grid (through the grid condenser) of the valve and L.T. (through a small pick-up coil).

The remaining portion of the aerial is connected through a small variable condenser to the plate of the receiving valve, giving a very smooth reaction control.

The plate and grid of the oscillator valve are coupled

Fig. 34.—Testing the Three-unit Super-het. Note the Frame Aerial on the left

together by two coils, one in each circuit. It is important that these coils are connected the right way round, otherwise the valve will not oscillate.

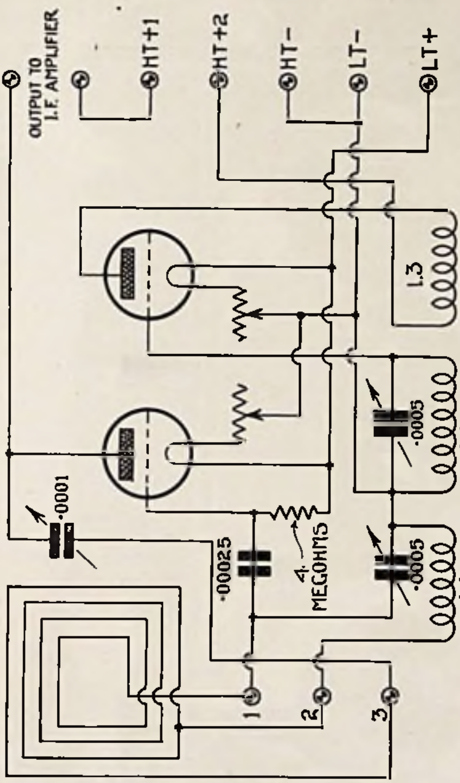


Fig. 35.—Circuit Diagram of the Oscillator and Detector Unit

In order that the frequency of the oscillations emitted by this valve may be varied at will, the grid coil is tuned by a variable condenser. The small pick-up coil inserted in the grid circuit of the detector valve collects the oscillations from the oscillator valve, and compounds them with those received at the aerial, the resultant beat frequency being supplied to the two output terminals.

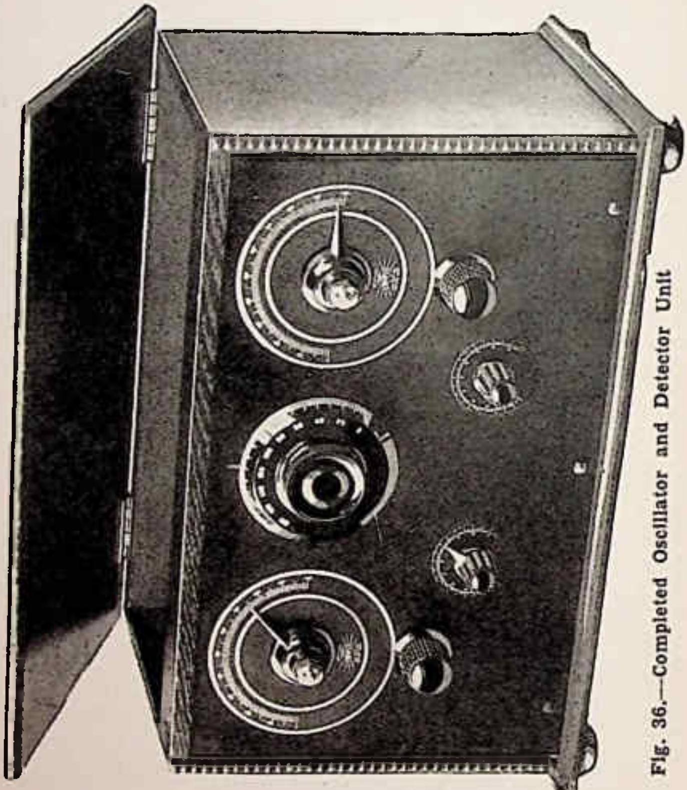


Fig. 36.—Completed Oscillator and Detector Unit

Components Required.—Coming to the construction of the first unit (Fig. 36), the following components are required: Panel, 12 in. by 7 in.; 2 valve holders, baseboard mounting (Benjamin); 2

35-ohm filament rheostats (Lissen); 2 .0005-microfarad variable condensers (Sterling Miniloss); .0001-microfarad variable condenser (Ormond); .00025-microfarad

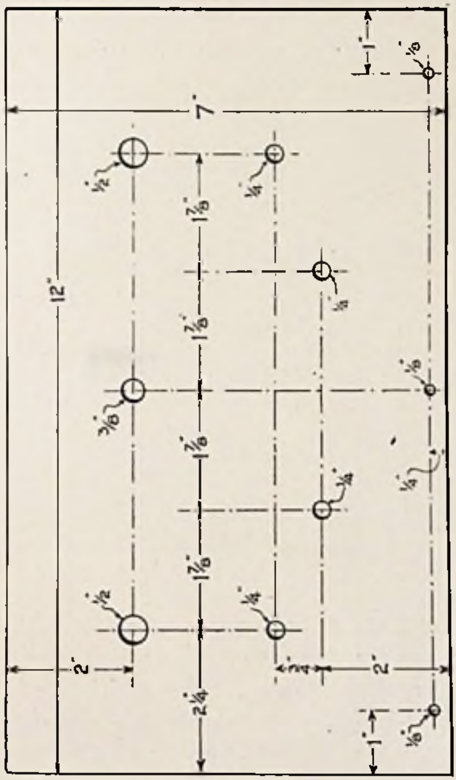


Fig. 37.—Layout of Front Panel

fixed condenser (Dubilier); 4-megohm grid leak with clips (Dubilier); 10 engraved terminals (Belling and Lee); 2 ebonite terminal strips, 6½ in. by 1½ in. and 2½ in. by 1½ in.; coil panel, 3 in. by 2½ in.; 3 coil plugs and sockets, panel mounting; cabinet and baseboard, 12 in. by 5½ in. by ⅜ in. thick (Unica Cabinet Co.).

Mounting the Components.—The panel, which should be obtained cut to size if possible, should be drilled according to the dimensioned panel-drilling diagram (Fig. 37), which shows the positions of the holes

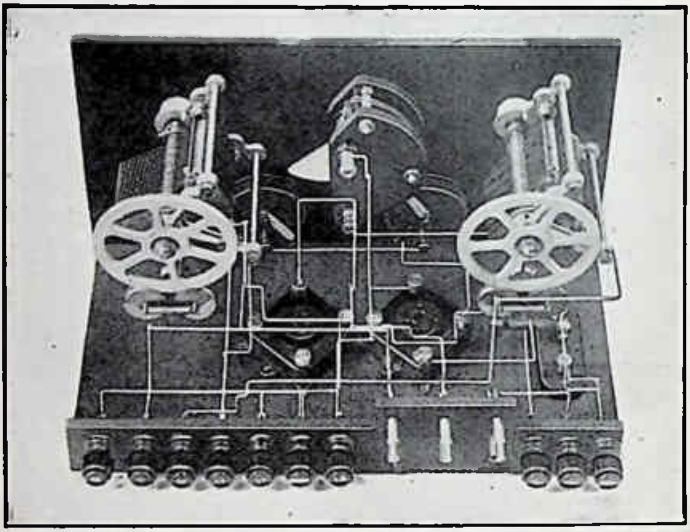


Fig. 38.—Photograph of Oscillator and Detector Unit, showing arrangement of Components on Baseboard

to be drilled and their sizes. The positions of the components and the method in which they are mounted are indicated by the back-of-panel photographs (Figs. 38 and 38A) and the wiring diagram (Figs. 39 and 39A).

The two large variable condensers are mounted one on each side of the panel with the small reaction variable condenser between them. Underneath, the two filament rheostats are mounted.

Having completed this part of the construction, the panel, with its mounted components, is left aside until the terminal strips and coil-mounting strips have been screwed to the back edge of the baseboard and the valve holders and fixed condensers mounted on the baseboard in the position shown in Fig. 39.

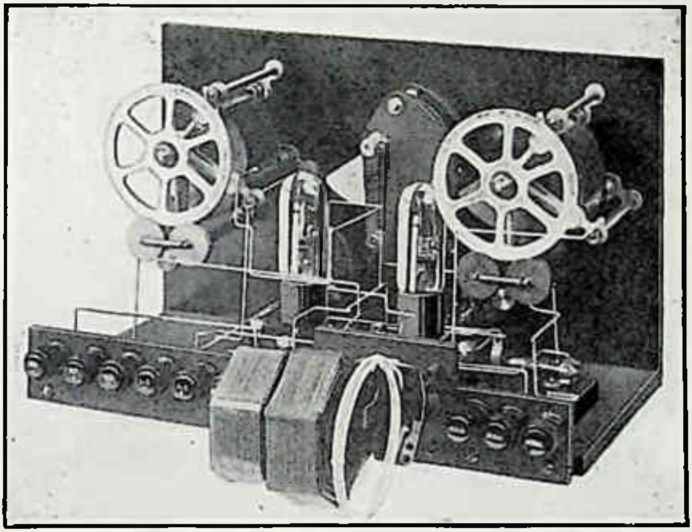


Fig. 38A.—Photograph showing Oscillator and "Pick-up" Coils in Position

Terminal Strips.—Two terminal strips are required, measuring $6\frac{1}{2}$ in. by $1\frac{1}{2}$ in. and $2\frac{1}{2}$ in. by $1\frac{1}{2}$ in. (Fig. 40). On the larger strip the H.T. and L.T. battery terminals are mounted together with the two output terminals for connections to the input terminals of the second unit.

It will be noticed that there are two H.T. + ter-

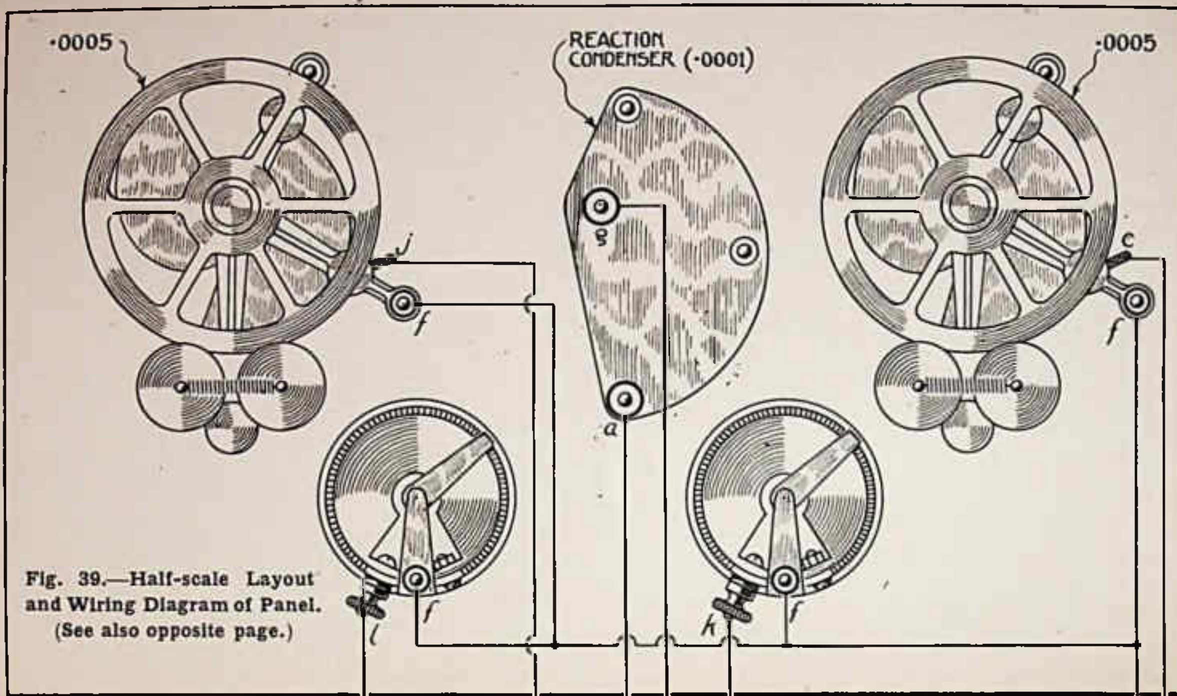


Fig. 39.—Half-scale Layout and Wiring Diagram of Panel. (See also opposite page.)

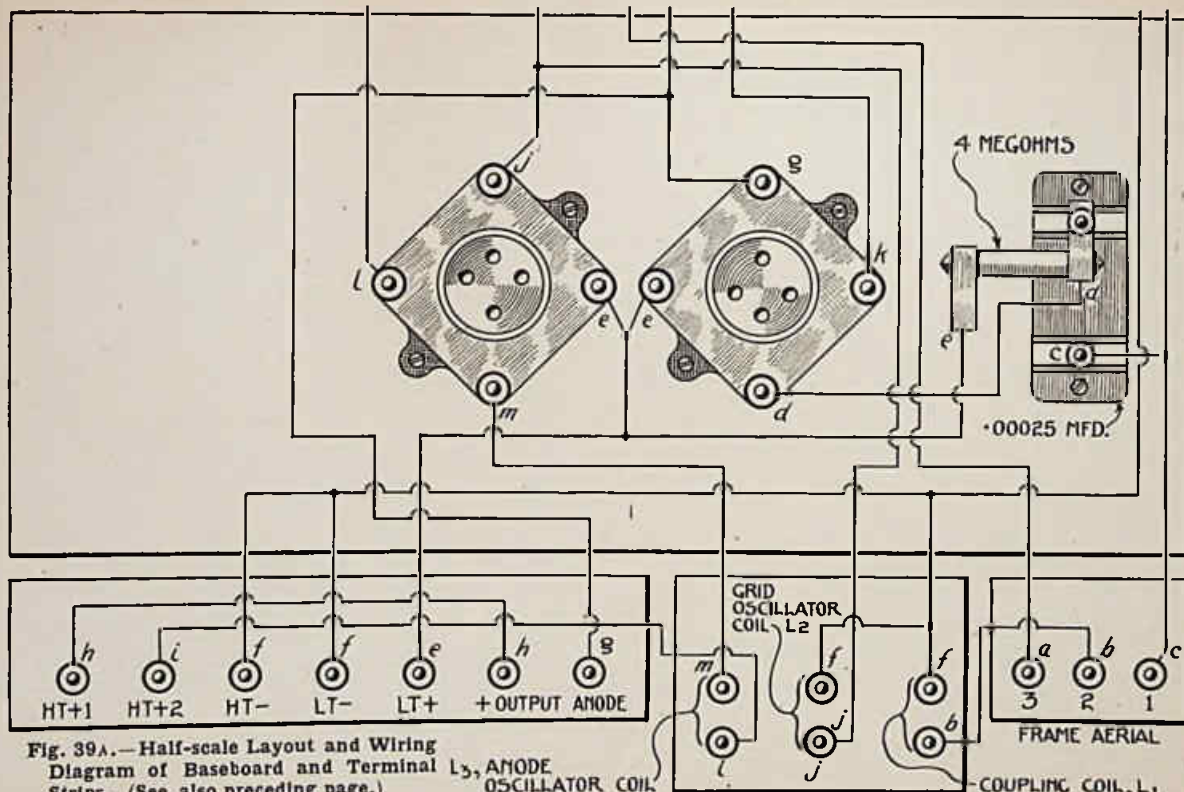


Fig. 39A.—Half-scale Layout and Wiring Diagram of Baseboard and Terminal Strips. (See also preceding page.)

minals, supplying a separate H.T. to the plates of the receiving and oscillator valves. This strip is screwed to the left-hand side of the back edge of the baseboard (looking from the back).

The smaller terminal strip, on which the three

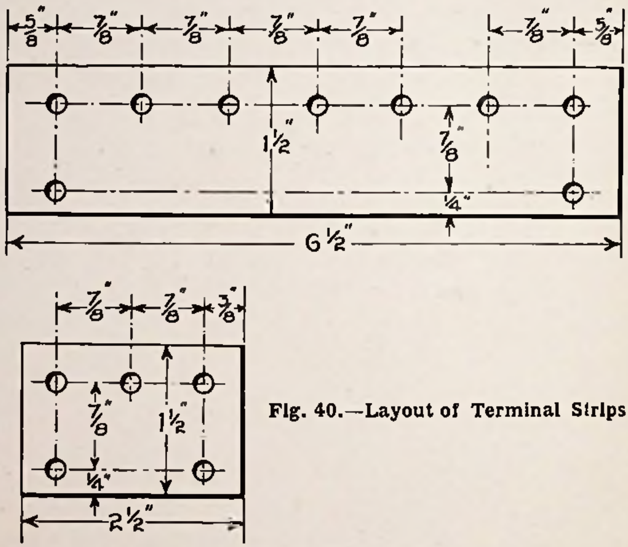


Fig. 40.—Layout of Terminal Strips

frame-aerial terminals are mounted, is screwed to the right-hand back edge of the baseboard.

Between these two strips a small panel (Fig. 41), measuring 3 in. by 2½ in., is mounted, carrying the three coil plugs and sockets.

Assembly.—The two valve holders are fixed to the baseboard in such a position that when the valves are inserted they fit in comfortably between the two large variable condensers, whilst the grid leak and condenser of the receiving valve are situated directly underneath the frame aerial tuning condenser.

Panel and baseboard may now be fixed together by three 1-in. brass wood screws passing through holes drilled along the bottom edge of the panel and screwing into the front edge of the baseboard.

Connecting Up.—Wiring should be carried out with a thick gauge of wire. The constructor should

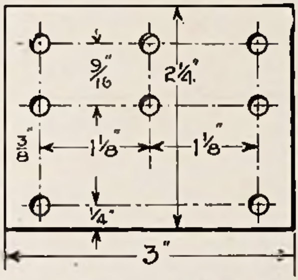


Fig. 41. Layout of Coil Strip

carefully follow the wiring diagram (Figs. 39 and 39A), which not only shows the method of connecting up the apparatus, but also indicates in what order the wiring should be accomplished. For instance, all those terminals marked *a* should be connected up first; then all those marked *b*, and so on.

Note that the grid leak is not connected in parallel with the grid condenser, but is joined between the grid of the receiving valve and L.T. +.

Connections to the middle plug and socket of the three mounted on the small panel at the back of the baseboard should be of a temporary nature, until experiment which way round the two wires should be connected has been carried out.

Coils.—Three coils are required for the oscillator valve and coupling, and these are plugged into the three plugs and sockets at the back of the baseboard.

The coils required are Nos. 60 and 75, and one having about five complete turns of insulated wire (No. 18-gauge d.c.c.) wound in a circular hank and tied together with small pieces of string or wire. The two ends are connected to a coil mount having the usual plug and socket.

The completed coil is inserted into the right-hand plug and socket mounted on the small panel (looking at the back). Into the middle plug and socket the No. 60 coil is inserted, whilst the No. 75 is plugged into the left-hand holder.

Testing Completed Unit.—This completes the construction of the first unit, all that remains to do being the testing. For experimental purposes a fairly low-reading milliammeter, reading up to about 10 milliamperes, is required. Such an instrument should be connected temporarily between the H.T. terminal supplying the plate of the oscillator valve (the second terminal from the left on the large strip, looking from the back) and the positive tapping on the H.T. battery.

A valve is then inserted in the second valve holder (the oscillator), and the filament current switched on by turning the controlling filament rheostat.

When the coils have been inserted in the sockets, the plate current of the valve indicated by the milliammeter should be noted. The leads to the middle coil holder should then be reversed and the plate current again noted. The higher of the two readings denotes that the connections to the middle coil are the right way round and that the valve is oscillating.

These connections may now be fixed permanently, and, still watching the milliammeter, slowly turn the oscillator variable condenser (on the right of the panel) throughout its full capacity range. If, at any setting, the valve ceases to oscillate, the fact will be denoted by the sudden decrease in the plate-current value.

If this happens, a slightly larger coil should be plugged into the left-hand holder. Try a No. 100 instead of the No. 75.

It is most important that the oscillating valve should oscillate at every setting of the right-hand variable condenser on the panel. It is also important that as small a coil as is compatible with the preceding statement should be used in the left-hand socket.

Suitable Aerial.—A suitable frame aerial to use in conjunction with this unit is made by winding twelve turns of wire on a square frame having sides 2 ft. 6 in. in length. Bare copper wire, No. 16 gauge, should be used, and the two ends brought down to the two outside aerial terminals.

To the middle aerial terminal a piece of flex with a metal clip attached to the free end is connected. The clip is clipped on to the frame aerial winding at the second or third turn from the end of the winding joined to the left-hand aerial terminal (looking from the back).

Thus, between the right-hand and middle terminals there are nine or ten turns of frame winding and two or three turns between the middle and left-hand terminals.

By connecting a pair of phones in the plate circuit of the detector valve—that is, between the extreme left-hand terminal and the positive terminal of the H.T. battery—it should be possible to pick up the local

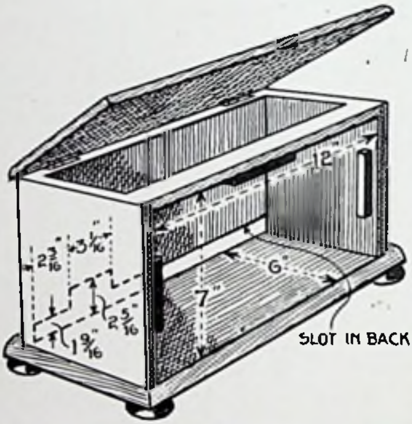


Fig. 42.—Cabinet for Oscillator and Detector Unit

station on the frame, provided the distance is not too great.

During this test the oscillator valve and the two oscillator coils should be removed. Experiments should be carried out in this way to bring the receiver valve into its most sensitive state.

When the unit has been tested in this way and found to work satisfactorily, it can be placed in the cabinet (Fig. 42).

2.—The Intermediate-frequency Amplifying Unit

The intermediate-frequency amplifier and second detector unit, a most important portion of the receiver and one that needs careful design, is shown in Fig. 43. Fig. 44 is the circuit diagram.

Besides the filament rheostats and the potentiometer to check any tendency for the amplifier to oscil-

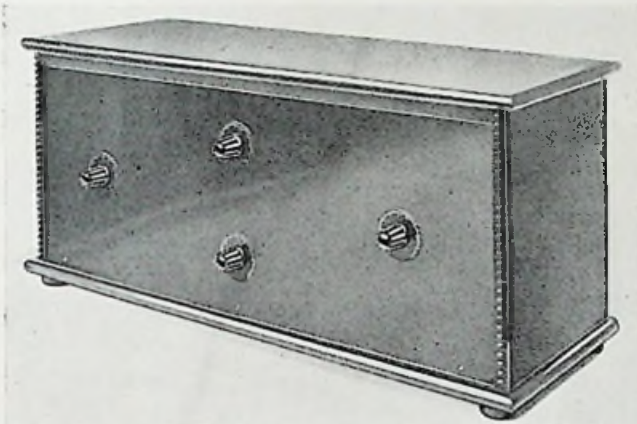


Fig. 43.—The I.F. Amplifying Unit

late, there are no tuning controls, the wavelength of the intervalve coupling units being fixed at a definite value.

The wavelength of these coupling units is a very important factor. It is quite possible, for instance, for a sensitive set, such as this, to pick up some long-wave station in the intermediate-frequency amplifier, and as the wavelength of the latter is fixed it would be impossible to tune the station out.

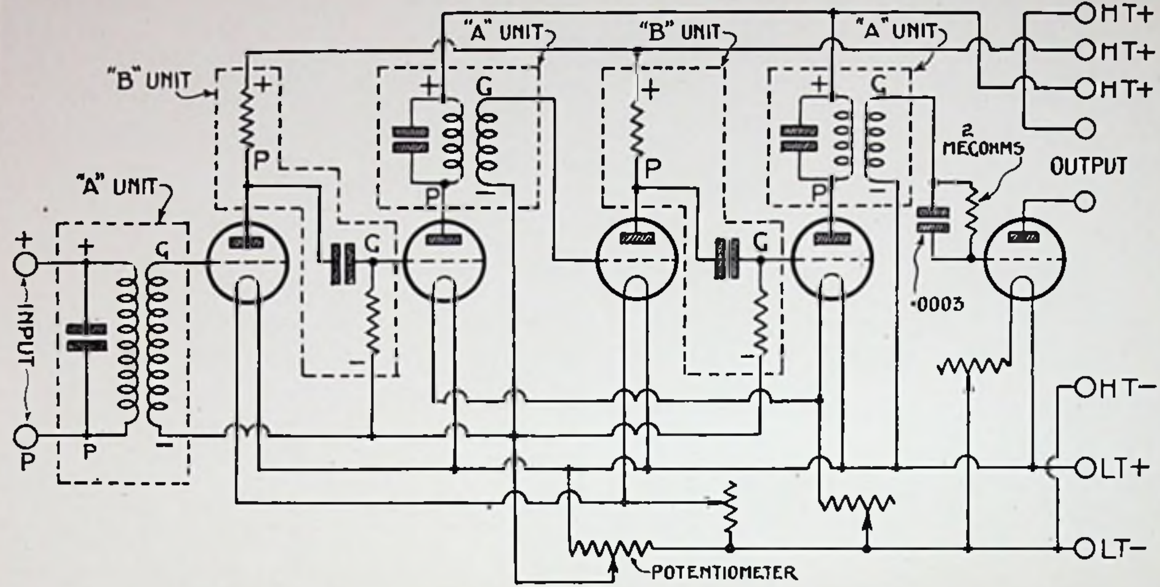


Fig. 44.—Circuit Diagram of the Intermediate-frequency Amplifying Unit

The wavelength of the amplifier, therefore, should have some value other than that of any of the high-power, long-wave transmitting stations.

Moreover, the selectivity of the amplifier must not be too great, nor must the amplification be too low, as both these qualifications are in a sense contradictory. A happy medium must be found.

To obtain the greatest amplification, the valve must work on the portion of the characteristic curve to the left of the zero grid volts line—that is to say, the grid of each valve must have a negative potential.

Valve Stability.—This can only occur if the valve is stable and will not break into oscillation, in which case some form of damping device will be required.

It is always safer, of course, to fit a damping potentiometer, but the amplifier should be so constructed that the slider of the potentiometer is always at the negative end of the resistance winding.

In the amplifier unit described there are five valve-coupling units, three of which consist of long-wave H.F. transformers and the remaining two of resistance-capacity units.

Alternate Units.—The units are so arranged that the first stage of I.F. amplification contains a transformer, the second stage a resistance-capacity unit, the third stage a transformer, the fourth stage a resistance-capacity unit, and the last stage a transformer. The transformer units are thus separated by a resistance-capacity unit.

Each transformer possesses a fixed condenser across the primary winding, and all are wound to the same

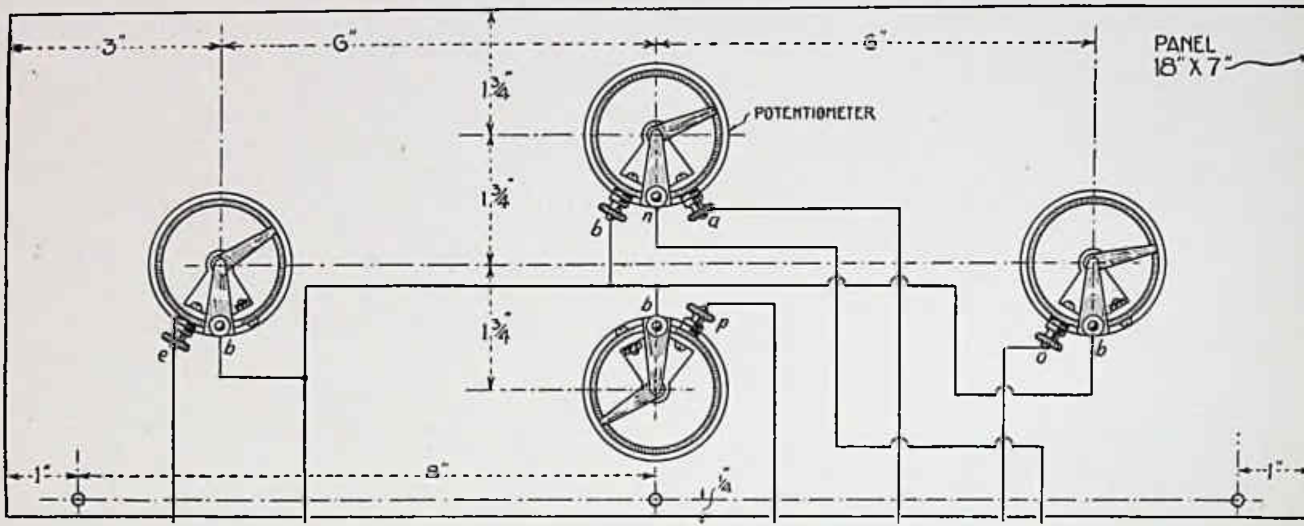


Fig. 45.—Panel Layout and Wiring Diagram of I.F. Amplifying Unit. (See also opposite page)

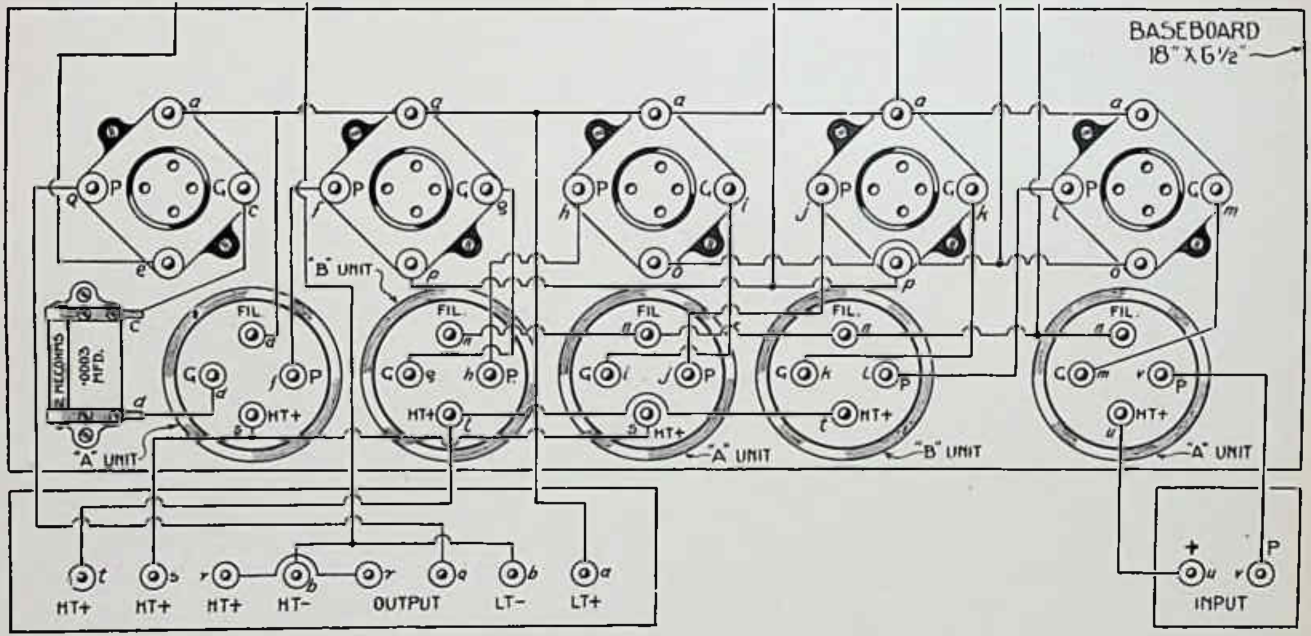


Fig. 45A.—Baseboard Layout and Wiring Diagram of the I.F. Amplifying Unit. (See also preceding page) wavelength. The resistance-capacity units are more or less aperiodic in their response to H.F. oscillations, and they will, therefore, amplify the frequency passed on by the transformers, and will add just sufficient stability to the whole amplifier to allow the valves to give their maximum amplification.

This unit also contains the detector valve, which follows the last stage of intermediate-frequency amplification. The connections of the detector valve are normal, and do not require any explanation.

Components.—The components required for the construction of the second unit are as follows: Ebonite panel, 18 in. by 7in.; terminal strips, 9 in. by $1\frac{3}{4}$ in. and $1\frac{1}{2}$ in. by $1\frac{3}{4}$ in.; 3 magnaformers, type A, and 2 magnaformers, type B (Burne-Jones); 5 anti-microphonic valve holders (Benjamin); 10 engraved terminals (Belling and Lee); 3 filament rheostats (Lissen); potentiometer (Lissen); 3-megohm grid leak and .0002-microfarad condenser (T.C.C.); baseboard, 18-in. by 6 in. by $\frac{3}{8}$ in. thick; cabinet (Unica Cabinet Co.).

One-hole Fixing.—All the components mounted on the panel, including three filament rheostats and one potentiometer, are of the one-hole fixing type, thus rendering the drilling of the panel a very simple matter (*see* Figs. 45 and 45A).

The potentiometer is mounted centrally at the top of the panel and directly below it one of the filament rheostats is fixed. On each side of the panel one of the remaining two rheostats is mounted, so that the whole presents a symmetrical appearance.

Positions of Holes.—The positions of all the holes

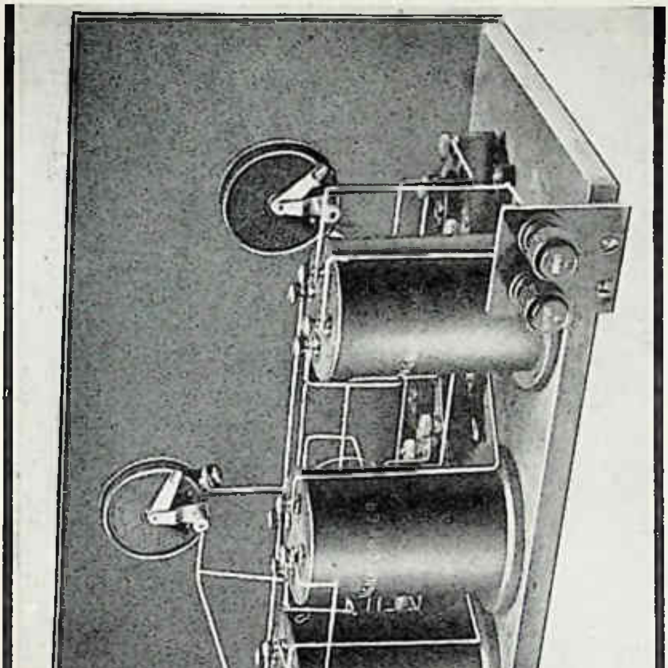


Fig. 46.—Photograph showing Disposition of Components of I.F. Amplifying Unit

to be drilled and their sizes are shown in Fig. 45. It will be noted that three holes, drilled along the bottom of the panel, are required for screwing the panel to the baseboard. The other larger holes are for the rheostats and potentiometer.

After mounting these components the panel is left aside, and attention turned to the baseboard, which consists of a piece of hardwood measuring 18 in. by 6 in. by $\frac{3}{8}$ in. thick.

On the baseboard the valve-coupling units, valve holders, grid condenser, and leak are mounted in the positions shown in Figs. 45, 46, and 46A.

Terminal Strips.—The large ebonite terminal strip carrying the terminals is screwed to the left-hand corner of the back edge of the baseboard by means of two 1-in. brass wood screws, whilst the smaller strip, on which the two input terminals are mounted, is screwed to the right-hand corner.

Full details of the sizes of the terminal strips and the positions and dimensions of the holes to be drilled to take the terminals and for attaching the strips to the baseboard are shown in Fig. 45.

Assembly.—The valve-coupling units are fixed to the baseboard in a row parallel to the panel and close to the back edge of the baseboard, exactly as shown. Note that the A and B types are mounted alternately, one of the A type being mounted on the right-hand side of the baseboard, looking from the back, and next to it the B type is mounted, then the A type again, and so on, ending with another of the B type on the left-hand side of the baseboard.

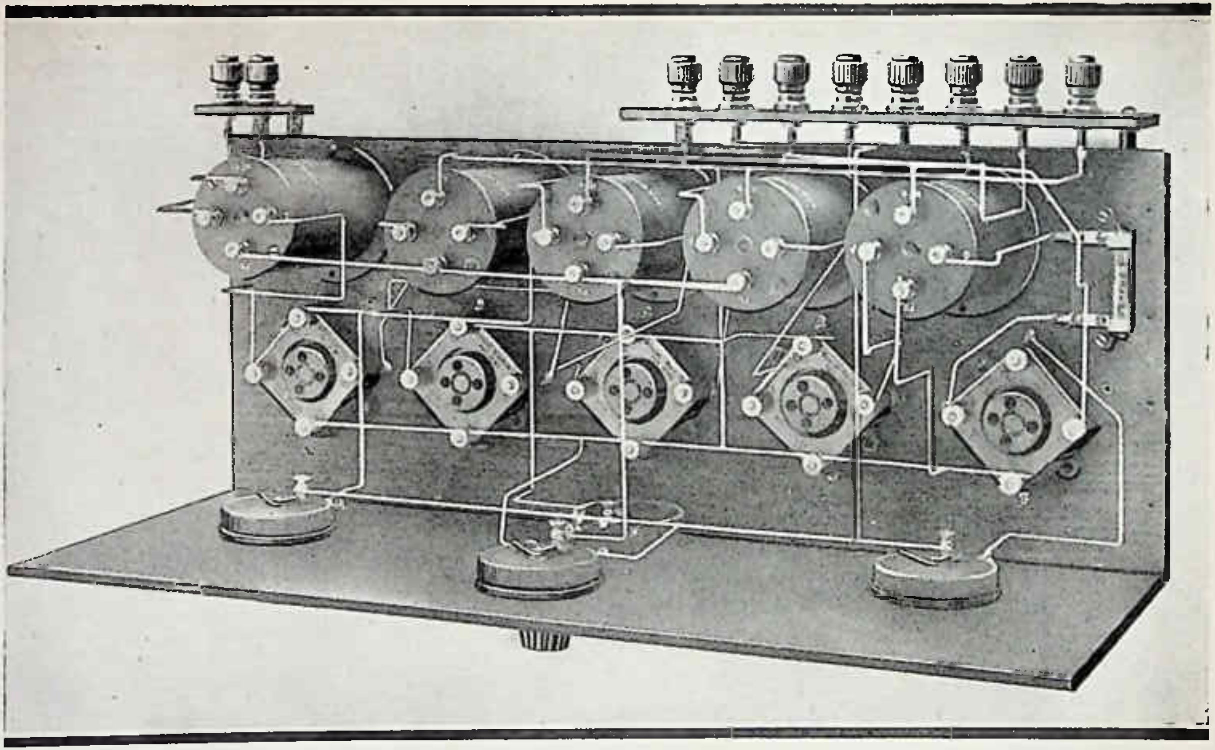


Fig. 48a.—Photograph showing Position of Components on Baseboard

Between the coupling units and the panel the valve holders are mounted, also in a row. The disposition of these components are shown in Figs. 45, 46, and 46A.

After the components have been fixed in their correct positions, the panel and baseboard should be fixed together by means of 1-in. brass wood screws passing through the holes drilled along the bottom edge of the panel, and screwed into the front edge of the baseboard.

Wiring.—Wiring may now be started, and for this to be accomplished quickly and easily, good use should be made of the wiring diagram, which not only shows the way in which each component is connected up, but also affords an indication of the order in which the wiring should be carried out.

The terminals of every component are marked with a small letter of the alphabet, and the wiring should be carried out in the order of the letters. All those terminals marked *a*, for instance, should be wired up first with one wire or as few wires as possible. Then all those marked *b* are connected up next in a similar fashion, after which those marked *c*, and so on, until the wiring is completed.

Final Check.—After a final check of the wiring the amplifier may be placed in its cabinet (Fig. 47). With the exception of the dimensions, the general design of the cabinet should be on similar lines to that housing the first unit.

Slots are cut in the back of the cabinet to allow the terminal strips to project through the back of the cabinet.

Valves.—The next question is one of valves, a very important factor in the efficient working of an intermediate-frequency amplifier. The filament voltage of the valves must be identical to that of the valves used in the first unit.

If 6-volt valves are used in the first unit, then 6-volt

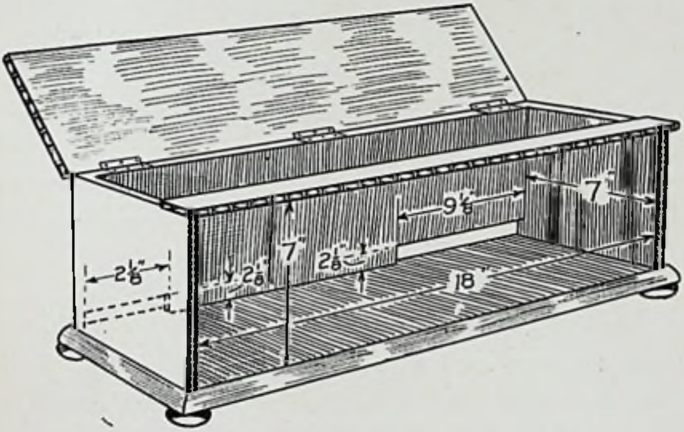


Fig. 47. Cabinet for I.F. Amplifying Unit

valves must be used in the second unit, and the Osram or Marconi DE8 H.F. type are recommended, both for the I.F. stages and for the detector—that is, five DE8 H.F. valves. Other good valves that can be recommended are the Burndept H512 type.

For a 4-volt accumulator the Mullard D H.F. are suggested for the I.F. stages and a D.06 for the detector. The Ediswan valves type AR H.F. for the I.F. stages and a GP4 for the detector make an excellent combination.

For a 2-volt accumulator good results can be obtained from the Cossor point-one red top for the I.F. stages and a plain top for the detector. The Osram DE2 H.F. are also excellent valves.

Operation.—Now we come to the operation of the first and second units. The two output terminals of the first unit are connected up to the two input terminals of the second unit. These connections must not be made haphazardly, but in the correct manner as shown in the circuit diagram (Fig. 44).

A pair of phones is connected to the output terminals of the second unit, and the H.T. and L.T. terminals of both units are joined up to the same H.T. and L.T. batteries. Two distinct sets of H.T. and L.T. batteries are *not* required.

Suggested Voltages.—For a trial apply the following H.T. valves to the plates of the respective valves: First unit—Receiving valve, plate voltage 40; oscillator valve, plate voltage 80. Second unit—Valves with I.F. transformer in plate circuit, plate voltage 100; valves with resistance in plate circuit, plate voltage 120; detector valve, plate voltage 40.

The above figures were obtained from the original set using Osram DE8 H.F. and DE8 L.F. valves. Other types of valves will probably require different voltages.

Turn on all the filament rheostats until the filaments of the valves reach a suitable temperature, and turn the slide of the potentiometer until it is right up to the negative end of the resistance winding.

Reaction Condenser.—Place the reaction condenser on the first unit at zero and slowly turn the two large condenser dials on the first unit until signals are heard. The first station to be tuned in will probably be the local one.

If the I.F. amplifier is oscillating this may be checked by adjusting the potentiometer. If the latter needs to be turned a considerable amount thereby introducing a damping effect, try reducing the H.T. voltage applied to the plates of the I.F. valves.

Every station should be received on two settings of the oscillator dial of the first unit. Incidentally, this is an indication that the oscillator is functioning properly.

Signal Strength.—By adjusting the reaction condenser the signal strength may be greatly increased, but care should be taken that the number of reaction turns in the frame aerial is not so great that the receiving valve refuses to stop oscillating no matter how the reaction condenser is adjusted.

The very minimum number of reaction turns should be used to give a smooth control by means of the condenser.

Constructors should concentrate on obtaining the maximum efficiency of the two units. If dissatisfaction is felt at the working of the units try various alterations, such as the values of grid leaks, oscillator coils, frame aerial windings, etc., until the very best results are obtained.

3.—The Low-frequency Amplifying Unit

This unit consists of a two-valve low-frequency amplifier, the first stage of which is transformer and the second stage resistance-capacity coupled (Fig. 48).

The only control on the panel is a filament rheostat which adjusts the filament current of both amplifying valves. Immediately below this control is a two-point jack into which the loud-speaker is plugged. The filament rheostat forms a convenient volume control.

By using a good make of transformer followed by

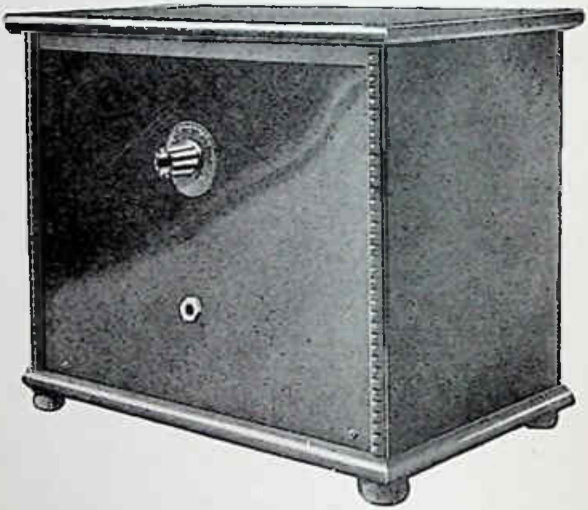


Fig. 48.—Completed L.F. Amplifier Unit

a resistance-capacity unit the best reproduction of speech and music is obtained.

Circuit.—It will be seen from the circuit diagram (Fig. 49) that the two input terminals are connected to the primary terminals of the transformer, and, when wiring up the unit, it should be seen that the plate of the detector valve in the second unit is connected to the terminal of the transformer marked "plate" in this unit.

The secondary terminals of the transformer are connected to the grid of the first amplifying valve and to a common negative grid-bias tapping.

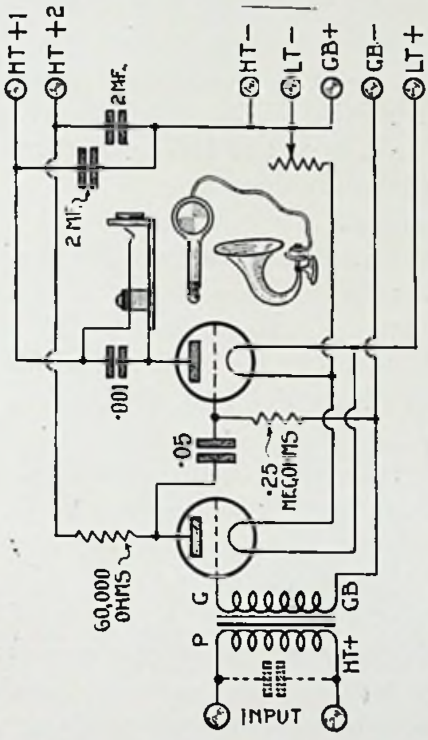


Fig. 49.—Circuit Diagram of the L.F. Amplifier Unit

In the plate circuit of the first valve the wire-wound resistance is inserted, and the coupling condenser between the plate of this valve and the grid of the last valve prevents a high positive potential being applied to the grid while, at the same time, it allows the passage of low-frequency oscillations.

The size of this condenser is not critical, and it is good practice to keep the capacity at as low a value as is consistent with good results. We have used one having a capacity of .05 microfarad.

Two H.T. + tappings are provided, enabling the correct voltage being applied to the plate of each valve. Each H.T. + tapping and H.T. – is shunted with a 2-microfarad fixed condenser.

The grid leak, connected to the grid of the last valve, should have a lower resistance than is usual with H.F. work. To some extent the value depends on the capacity of the coupling condenser, but the actual value is not very critical, and a leak having a resistance of .25 megohm (250,000 ohms) will be found satisfactory.

Components.—The components needed for the amplifier are as follows: Ebonite panel, 9 in. by 7 in.; baseboard, 9 in. by 5½ in. by ½ in., and cabinet (Unica Cabinet Co.); 30-ohm filament rheostat (Lissen); L.F. transformer (Ferranti A.F.3); 2 baseboard-mounting valve holders (Magnum); 60,000-ohm wire-wound anode resistance (Varley); .25-megohm grid leak (Dubilier); 2 2-microfarad fixed condensers (Dubilier); .05-microfarad fixed condenser (Dubilier); 2-point jack and plug (Bowyer-Lowe); .001-microfarad fixed condenser (Dubilier); 9 engraved terminals (Belling and Lee); ebonite terminal strip, 9 in. by 2 in.

Drilling the Panel.—Four holes only are to be drilled through the panel (Fig. 50), one for the filament

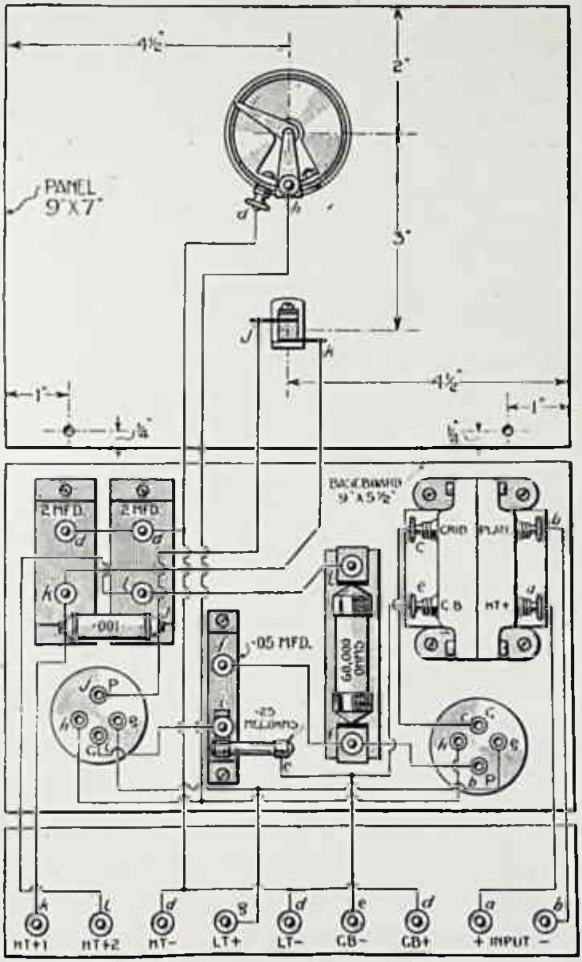


Fig. 50.—Combined Panel Layout and Wiring Diagram of L.F. Amplifier Unit

rheostat, one for the jack, and two for fixing the panel to the baseboard. The dimensions of the holes and their positions are clearly indicated.

Assembly.—On the baseboard the transformer (*see* Fig. 51) is mounted on the right (looking at the back) and the two 2-microfarad fixed condensers on the

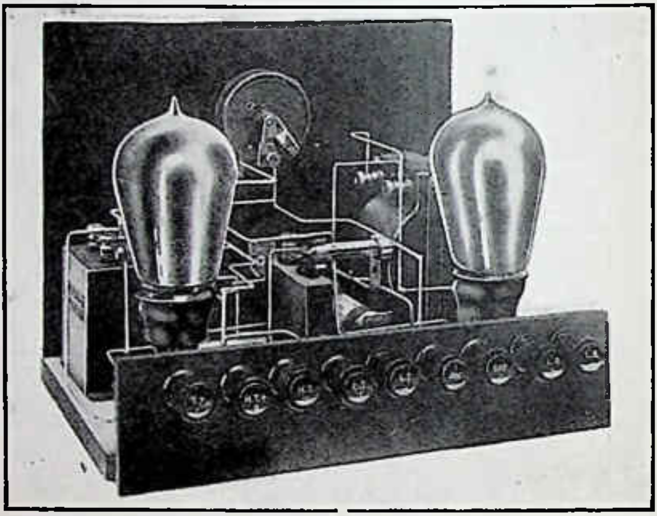


Fig. 51.—Photograph showing Disposition of Components in L.F. Amplifier Unit

left. The two valve holders are mounted directly in front of the transformer and fixed condensers and close to the back edge of the baseboard, while the anode resistance, coupling condenser and grid leak are seen between these components, in the centre of the baseboard.

Terminal Strips.—Along the back edge of the baseboard the terminal strip is mounted, carrying the nine terminals. Reading from left to right these terminals are as follows: H.T. +1 (supplying the last valve), H.T. + 2, H.T. −, L.T.+, L.T. −, grid bias −, grid bias +, input +, input −.

Wiring.—Wiring is quite simple, and should be tackled in conjunction with the wiring diagram (Fig. 50). This diagram is sufficient in itself, and any explanation as to how the wiring is carried out is superfluous.

The grid leak should be fitted into two metal clips and the connecting wires should be soldered to them. If thick-gauge wire is used for connecting purposes, there is no need to fix the grid leak either to the panel or baseboard. The wiring itself is sufficient to hold it in place. In any case, the connecting wires must on no account be soldered direct to the metal clips of the leak itself or the latter may be damaged.

The small .001-microfarad condenser shunted across the loud-speaker jack may also be held in position by the wiring.

When the wiring has been completed the unit should be placed in the cabinet (Fig. 52).

Valves.—The next point is the important one of the choice of valves. For a 6-volt accumulator the constructor can do no better than use the Osram or Marconi DE8 L.F. followed by a DE5A or an LS5A for the last stage.

For a 4-volt accumulator the Mullard PM4 and D.P.425 are recommended, whilst with a 2-volt accumulator the Cossor Stentor valves or the Mullard PM1 L.F. and PM2 will give excellent results.

H.T. Supply.—The H.T. voltage which will be applied to the plates of these valves will depend on the type of valve used, but the constructor is recommended to buy a 120-volt battery tapped in steps of 2 or 3 volts—this will be sufficient to supply all nine valves.

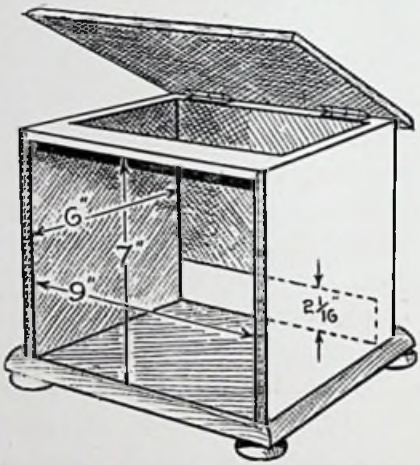


Fig. 52.—Cabinet for Amplifier Unit

An accumulator H.T. battery should, if possible, be used, but if a dry-cell type of battery is obtained one of extra large capacity is practically essential. It will be realised that the total plate current of nine valves may be considerable, adding with certain valves to something over 50 milliamperes (.05 ampere), a current which would put considerable strain on a small dry battery.

Completing the Receiver.—Assuming that the two units previously described are by now in good working order, all that remains to be done is to connect the output terminals of the second unit (containing the I.F. and detector valves) to the input terminals of this unit.

Make sure that the plate of the detector valve of the second unit is connected to the "input – " of the third unit.

Insert the valves, turn the rheostat until the filaments reach a suitable temperature, and tune-in any station on the first unit. Now adjust the tappings on the H.T. battery and the grid-bias battery until the maximum volume is obtained together with a minimum of distortion.

CHAPTER VIII

An Ultradyne Eight-valver

An unlimited receiving range, remarkable volume, distortionless reproduction, compactness, ease of control, and selectivity—these are the features of the superhet described in this chapter. And the cost of making it is approximately £20 (excluding valves and batteries).

A great deal of time and trouble has been expended in producing this really efficient "super-het." It was decided, for instance, that a very convenient and, indeed, the logical method of constructing a set of this type so as to avoid the use of large, expensive ebonite panels housed in long, coffin-shaped cabinets, would be to build the receiver in tiers or "steps," each step comprising a special unit of the receiver.

Sequence of Operation.—The apparatus on the lowest step, for instance, receives the incoming oscillations, and heterodynes them, producing oscillations of a lower frequency; these lower frequency oscillations are amplified and rectified by the apparatus on the second or middle step.

They then pass up to the top step, where the rectified oscillations are amplified by low-frequency amplifiers and pass through the loud-speaker.

Thus the three phases of supersonic-heterodyne

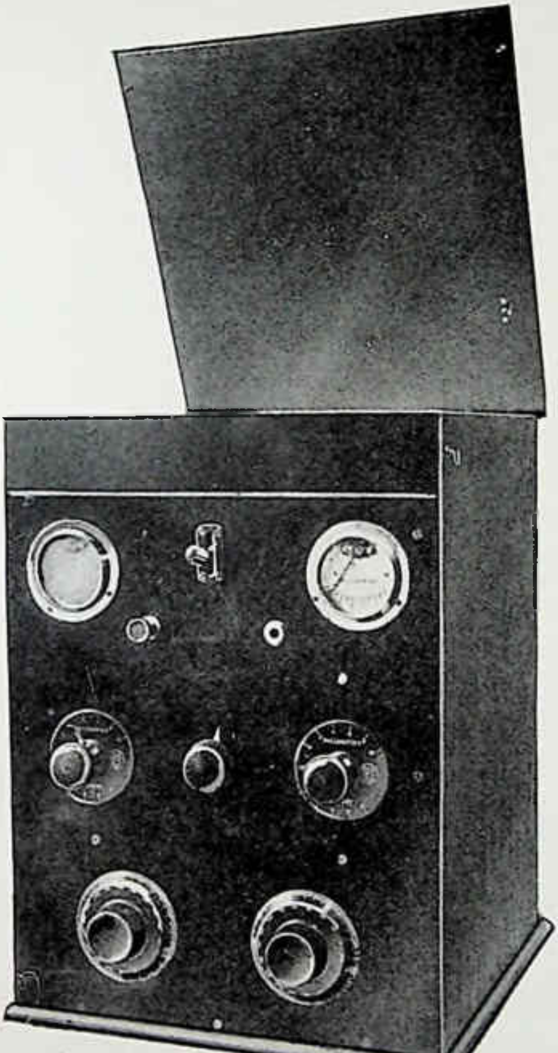


Fig. 53.—The Set Complete

Fig. 54.—Details of Terminal Strip

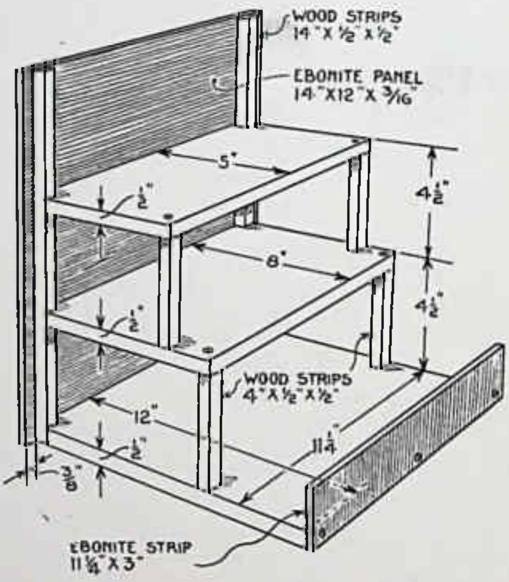


Fig. 55.—Details of the Tiers

reception are carried out on the three steps. This system makes for extreme compactness without loss in efficiency.

The Cabinet.—The set is enclosed in a polished mahogany cabinet, having the dimensions shown in

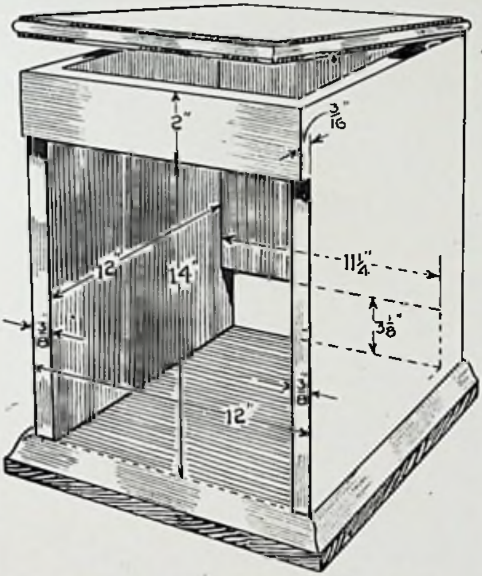


Fig. 56.—The Cabinet

Fig. 56. The panel covers the two side pieces and does not fit in flush. A strip of wood is provided at the top so that plenty of room is allowed for the insertion of the two L.F. valves on the top step. A slot is cut out of the back of the cabinet at the bottom so that the terminal strip (Fig. 54) screwed to the back of the baseboard can project through flush with the back.

Components.— The components required are given in the following list:

Ebonite panel, 12 in. by 14 in. by $\frac{3}{16}$ in. (American Hard Rubber Company); 2 filament rheostats (Radio

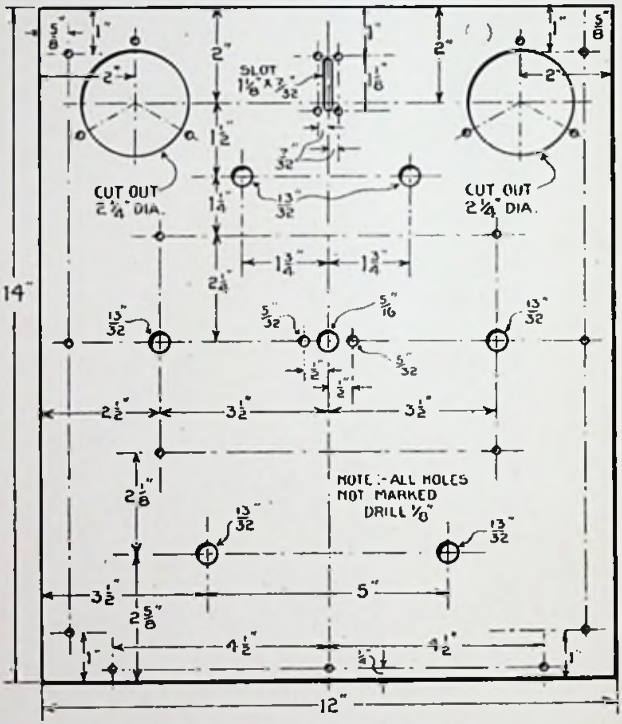


Fig. 57.—Layout of Front Panel

Instrument Duostats); potentiometer (Igranic); 2 L.F. transformers, ratios 2 to 1 and 4 to 1 (B.T.H.); 2 .0005-microfarad variable condensers (Newey); D.P.D.T. lever switch (Burndept); 5-point push-pull switch (Lissen); supersonic heterodyne kit; including oscillator coils, filter, .0005-microfarad fixed condenser and 3 I.F. transformers (Bowyer-Lowe); 8 baseboard-

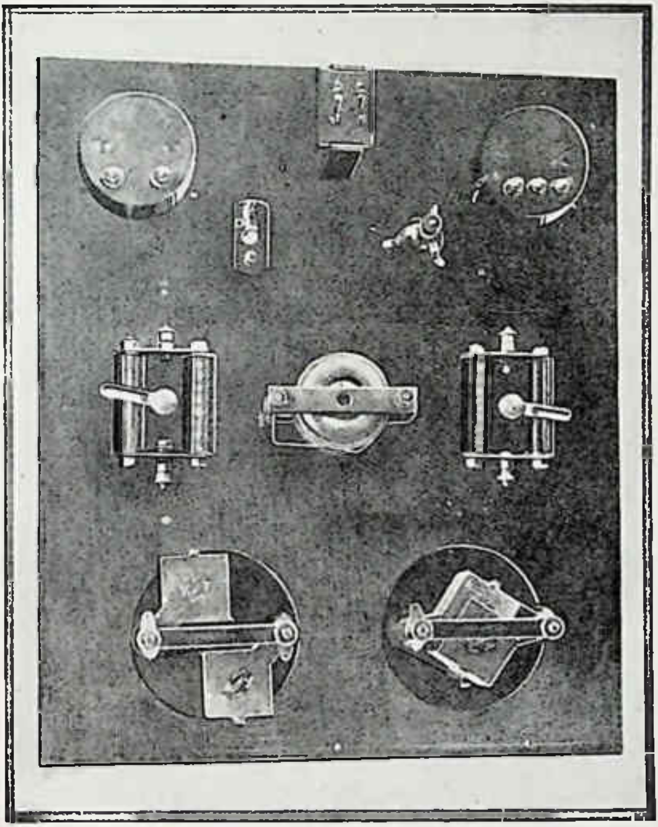


Fig. 58.—Back of Front Panel of the Eight-valve Super-het before Wiring

mounting valve-holders (Peto-Scott); 2 .0003-microfarad grid condensers (Dubilier); 2 grid leaks, 5 megohms and 2 megohms (Dubilier); 2 .006-micro-

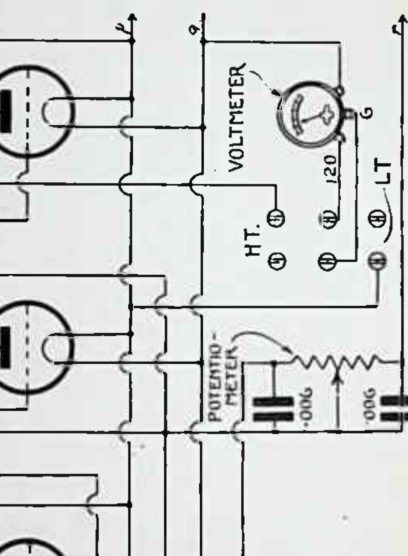


Fig. 59.—Circuit Diagram (see also Next Page)

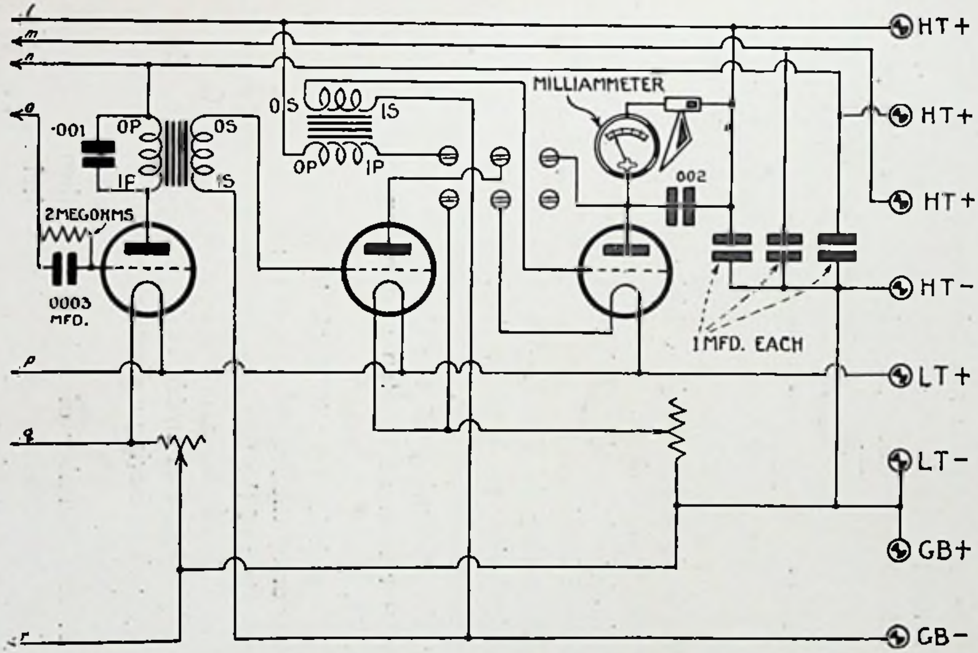


Fig. 59A.—Circuit Diagram (see also Preceding Page) farad fixed condensers (T.C.C.); .001-microfarad fixed condenser (Watmel); .002-microfarad fixed condenser (T.C.C.); 3 1-microfarad fixed condensers (T.C.C.); double-range voltmeter, reading 0 to 6 and 0 to 120 volts (Sifam); milliammeter reading 0-10 milliamperes (Sifam); 8 terminals (Belling Lee); polished mahogany cabinet (Caxton Wood Turnery Company); frame aerial (Success Collapsible type); 3 boards, 12 in. by 11¼ in. by ½ in. thick, 8 in. by 11¼ in. by ½ in. thick, and 5 in. by 11¼ in. by ½ in. thick; piece of wood, ½ in. square section, 5 ft. long; ebonite terminal strip, 11¼ in. by 3 in. by ¼ in. thick (Paragon); plug and jack (General Radio).

Preparing the Panel.—The panel, which is a standard size, needs no cutting, so that drilling may be started immediately. Two large holes are required for the mounting of the flush-type voltmeter and ammeter seen at the top of the panel in Figs. 53 and 58.

These holes may be made by means of a special cutter or by the following method: Mark on the panel the centres of the two holes, and by means of pointed steel dividers draw out the exact sizes. Concentrically with, and inside each of these circles, draw another circle having a diameter less by ⅛ in. than the outer circles.

A large number of holes should then be drilled, having their centres on the inner circle. A $\frac{1}{16}$-in. twist drill should be used, and the holes should be close to each other so that consecutive holes are separated by a very thin piece of ebonite.

By means of a sharp knife, or, better still, a fret-saw blade, the entire centre piece of each outer circle can be cut. The holes, of course, will present a jagged appearance, but this can be remedied by carefully smoothing the points off by filing with a half-round file.

It is better to make the holes a tight fit for the instruments than to have the former so large that the latter can easily fall in or out.

Arranging the Components.—The instruments are then placed in position and the centres of the three holes in each of the flanges of the meters marked through on to the panel. With the exception of the Burndept switch and the Igranic potentiometer the remainder of the components mounted on the panel are of the one-hole fixing type. Mounted on the bottom of the panel are the two variable condensers, of the low-loss type. Both sets of plates move—the entire movement requiring a 360-degree movement of the dial.

On the centre of the panel is mounted the potentiometer, with a filament rheostat on each side, whilst at the top in the centre the Burndept switch is mounted with the voltmeter and ammeter, one on each side.

A little lower down between the potentiometer and the switch the phone jack and the Lissen push-pull switch are mounted on opposite sides of the vertical centre line of the panel. Photographs (Figs. 60 to 63) are given showing how the components are fixed, and the relative position of each to the others.

The Framework.—Attention must be turned next to the construction of the wooden framework on which the components are mounted. Referring back to the list of components it will be seen that three boards are required. These boards are mounted on top of each

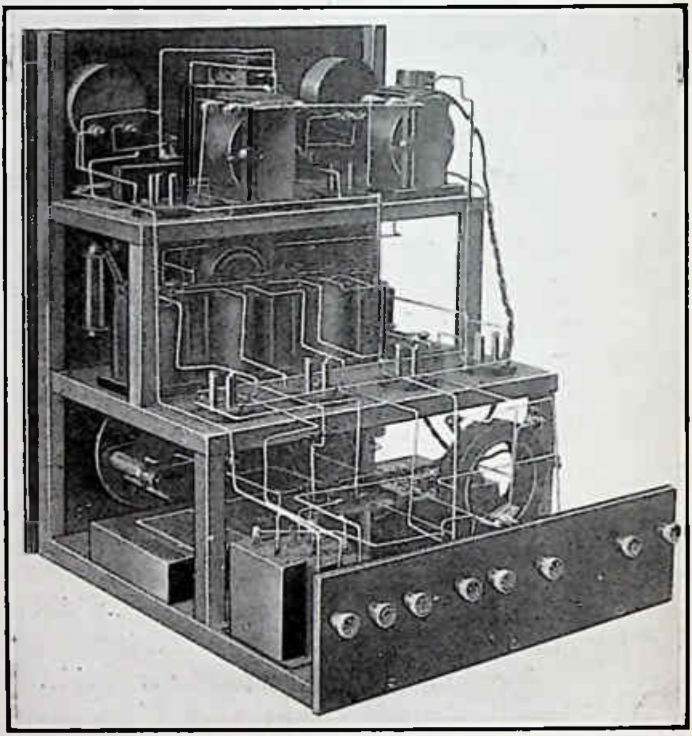


Fig. 60.—Illustration showing Components and Wiring

other—the largest at the bottom and the smallest at the top, thus forming a series of "steps."

At the two adjacent corners on the longer side of each board a rebate is made that measures ½ in. by ½ in. This allows each board to fit close to the panel between the two upright wooden ½-in. square battens. An illustration of the framework is given in Fig. 55.

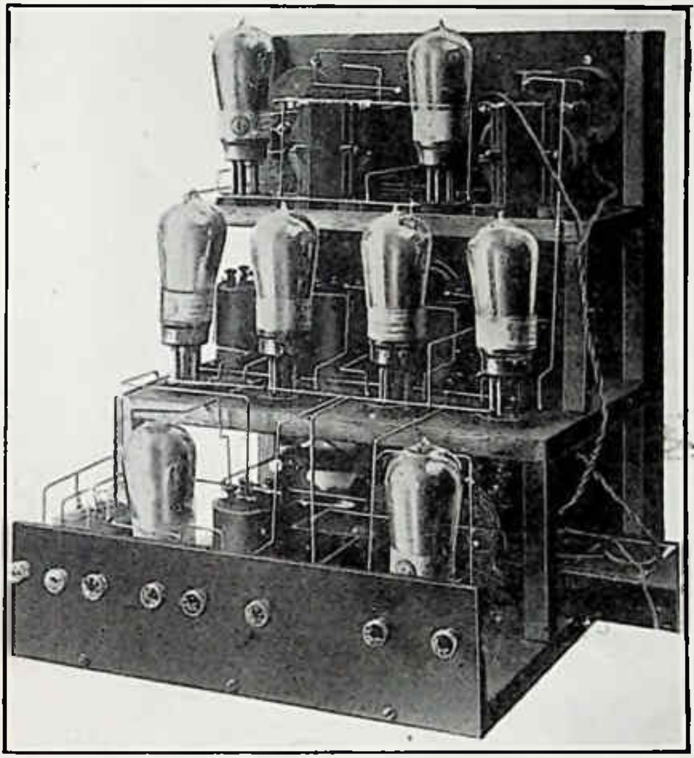


Fig. 61.—The Valves in Position

The best method of constructing the framework and mounting the components is as follows: Screw the panel with its wooden supporting uprights to the lowest and largest board. Next, mount the second board temporarily on to the panel and the two 4-in. wooden supporting uprights.

The First Step.—The oscillator coils, filter, first detector and oscillator valve holders, grid leak and condenser, and the three 1-microfarad fixed condensers, are so arranged on the lowest board that they do not foul the second board.

An indication of the positions of these components is given in Figs. 64 and 65. They should be screwed down by small brass wood screws.

The Terminal Step.—The ebonite terminal strip is then screwed to the back edge of the bottom board.

Before proceeding any further with the construction the second board should be removed and the variable condensers wired to the oscillator coils and frame-aerial terminals respectively, and all the components mounted on the bottom board wired up as far as possible.

The Second Step.—The second board, forming the second step, is next screwed to the panel uprights, the panel, and to the 4-in. wooden supporting pieces, as shown in Fig. 55.

On the second step are mounted four valve holders, the three I.F. transformers, two .006-microfarad fixed condensers, and the second detector valve's grid leak and condenser. The four valve holders are screwed down along the back edge of the second step so that the valves, when inserted in the sockets, do not touch the top step.

If the components on the panel have been mounted according to the panel-drilling diagram (Fig. 57), it will be found that the two filament rheostats and the potentiometer clear the top of the second board.

As in the case of the bottom step, the wiring of the second step should be completed as far as possible before proceeding to the top and last step.

The Third Step.—The top step is fixed in a similar manner to the middle step, the board being supported at the back by two wooden pieces $\frac{3}{4}$ in. square and 4 in. in length, and is screwed to the panel and the panel uprights at the front.

On the top step the two L.F. transformers, two valve holders and a .002-microfarad condenser are mounted. The .001-microfarad condenser connected across the primary of the first L.F. transformer (ratio 4 to 1) is not screwed down, but rests on the top of the transformer and is held in position by the wiring.

In between the L.F. transformers the first low-frequency valve holder is screwed to the panel, whilst the second L.F. valve, which can be brought in or out of circuit by the double-pole switch, is mounted directly behind the milliammeter.

The wiring of the top step may now be completed.

It should be noted that in the entire wiring of the receiver no wires (with the exception of the two grid-bias flexible leads) run without an intermediate connection from the bottom step to the top. Hence the wiring throughout can be neatly done step by step. Seven wires are connected from the bottom step to the second, and three wires, excluding grid-bias connections, from the second to the top step.

Grid-bias Leads.—Grid-bias leads are made with flex of sufficient length to be connected to a grid-bias battery placed out of the way under the second step.

The Voltmeter Connection.—A little difficulty may

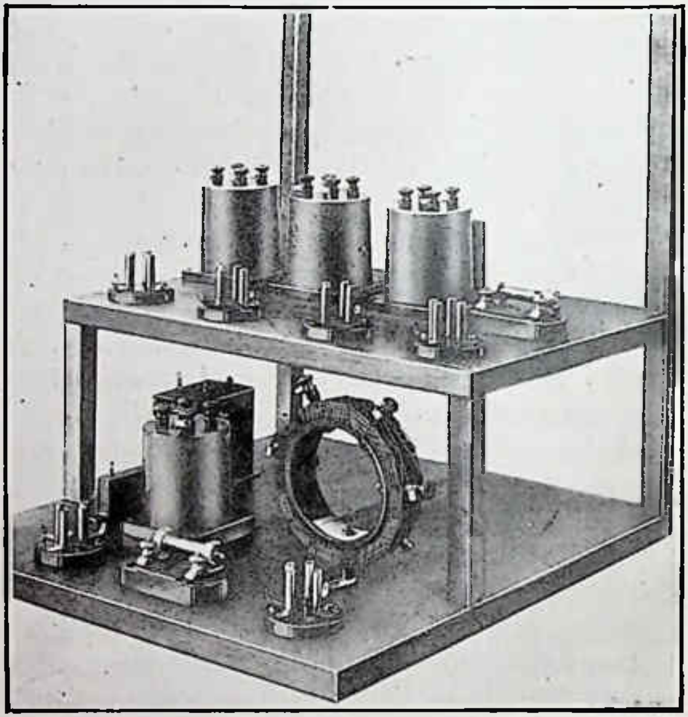


Fig. 62.—First and Second Steps in Position before Wiring

be experienced in wiring up the push-pull switch operating the double-range Sifam voltmeter, which possesses a common negative terminal.

It will be noticed that in the wiring diagram showing this switch the soldering lug,-which is *not* attached to a spring contact, is connected to the middle terminal of the voltmeter. If the actual switch is placed in a similar position to that shown in the diagram and the

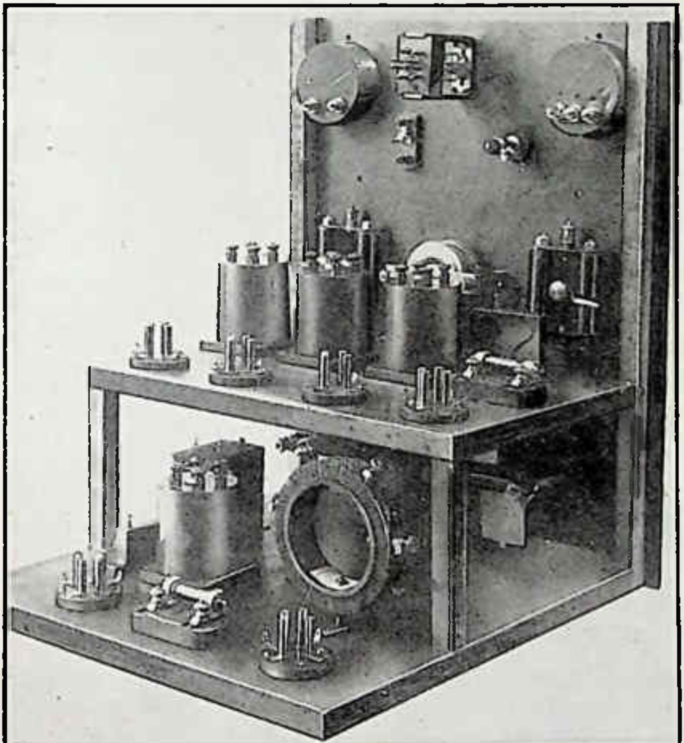


Fig. 63.—First and Second Steps and Front Panel in Position

connections made in the same manner, the difficulty may be easily overcome.

Another point arises in connection with the oscillator coupling. There are four terminals on this coupling marked 1, 2, 3 and 4 (the marks are on the side of the ebonite former).

Polarity and Coupling.—To ensure that the polarity of the coupling is correct and that the proper coil is connected up, the terminal marked 1 is joined to + H.T.; 2 is joined to the plate of the oscillator valve; 3 to the grid of the same valve and also to + of the filter, and 4 is joined to − filament. The oscillator-tuning condenser is connected across 3 and 4.

Preliminary Tests.—Before connecting up the set to the external apparatus for a preliminary trial, it is advisable to test through the H.T. and L.T. connections to ensure there is no possible danger of damaging the valves.

This should be done as follows: Place all the valves in their sockets and connect the accumulator H.T. −, and each of the H.T. + terminals in turn. If the valves light up there is a short-circuit between one of the H.T. + and L.T. +. This must be located and remedied before anything else is done.

Now take all the valves out and connect the accumulator to the L.T. terminals with a flashlamp bulb or a voltmeter *in series*. If any short-circuit exists between L.T. + and L.T. −, the fact will be demonstrated by the lighting up of the bulb or the movement of the voltmeter needle.

Tuning-in.—Having made sure that everything is all right, the set may be connected up to the frame aerial, phones, H.T., L.T., and grid-bias batteries.

Put the Burndept switch lever in the "down" position, thereby cutting out the last stage of L.F.

amplification. Turn the two rheostat knobs until the filament voltmeter registers the voltage recommended by the valve manufacturers.

Now turn the potentiometer knob one way or the other so that the set is just short of the oscillating point. This point is denoted by a slight "hiss" in the phones.

Set the frame-tuning condenser at about 180 degrees, that is, with the plates half interleaved. Slowly rotate the oscillator-condenser dial (the right-hand dial) until signals are heard.

The adjustment of this control is very critical and requires a great deal of care.

Now slowly rotate the frame aerial, when it will be found that signals are stronger with the plane of the frame pointing towards the station that is being received. Leave the frame pointing in this direction and bring the received signals up to maximum strength by careful readjustment of the frame-tuning condenser, the potentiometer, and the oscillator condenser.

It will be noticed that the potentiometer gives a very smooth reaction effect.

Adjusting the H.T.—Next, adjust the wander-plugs on the H.T. battery until best results are obtained. Any slight distortion can be cured by applying a larger negative grid-bias potential to the grid of the L.F. valve. A grid-bias voltage of about 3 or 4½ volts will be found suitable if 100 volts or over are applied to the plates of the L.F. valves. The correct H.T. voltages can only be found by experiment.

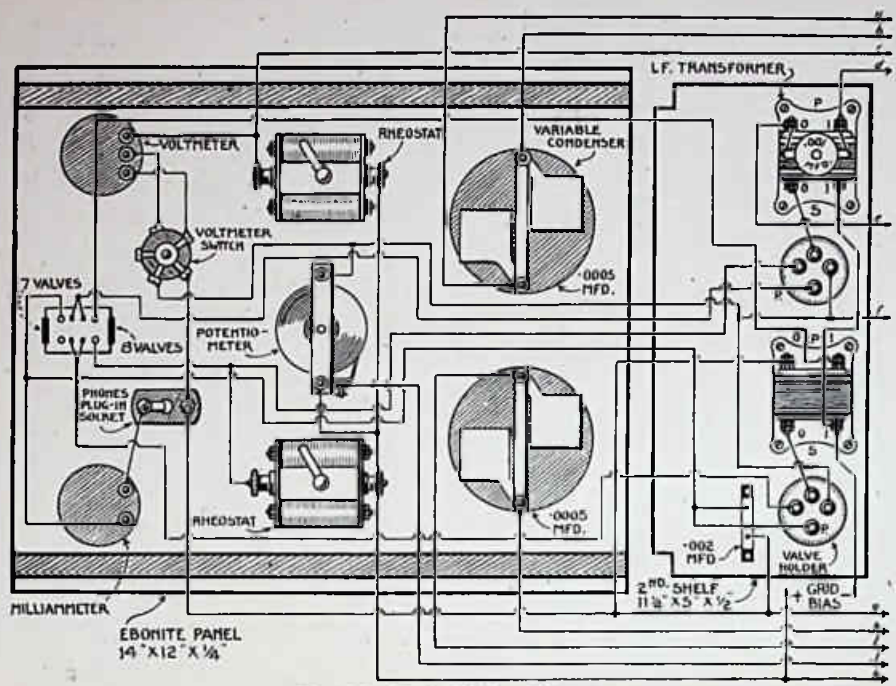


Fig. 64.—Part Wiring Diagram

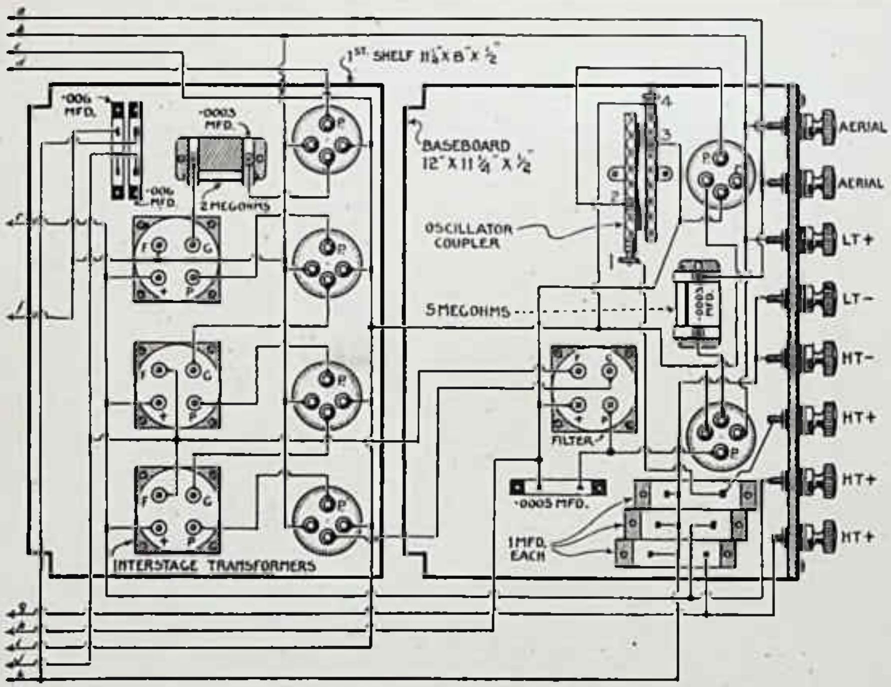


Fig. 65.—Another Part Wiring Diagram

If greater volume is required the last valve may be brought into circuit by placing the Burndept switch lever in the "up" position. It may be necessary to readjust the voltage applied by the grid-bias battery.

Purpose of the Milliammeter.—The milliammeter connected in series with the phones shows the current flowing in the plate circuit of the last valve. The needle of the milliammeter should keep quite steady. If it fluctuates this is an indication that distortion is present, and the grid-bias voltage should be adjusted until the needle becomes steady.

The H.T. voltage on the L.F. valves should not be increased just for the sake of obtaining a very high reading on the milliammeter. A very large plate current does not necessarily mean a large output of volume.

It will be noticed, for instance, that with no negative voltage on the grid of the L.F. valves the milliammeter will give the highest reading, and reproduction will be great in volume but distorted.

With the application of negative grid bias the plate current will be decreased and consequently the milliammeter will register a lower reading. The volume, however, will still remain the same, and reproduction will be much better in tonal quality.

Having adjusted every control until the best results are obtained, it is recommended that a note be taken of the position of each control and the readings given by the voltmeter and milliammeter.

Voltmeter Switch.—By pushing the voltmeter switch in, the voltmeter will register the voltage applied to the filaments of all the valves except the L.F. amplifiers.

With the same switch pulled out the voltmeter shows the value of the H.T. voltage applied to the plates of the L.F. valves.

Casing the Set.—The set may now be placed in its cabinet and the external apparatus connected to the terminal strip projecting through the back. Owing to the special construction of the set it will be found that the valves can be easily inserted or withdrawn from the top.

Results.—Perhaps the most outstanding feature of this receiver is the ease of control. The potentiometer gives an excellent control of oscillation, and, indeed, the whole set has a particularly smooth " feel " about it.

Approximately seven miles from 2 L O Cardiff could be received on the loud-speaker with no trace of London in the background. By the careful adjustment of the potentiometer and the two variable condensers most of the main B.B.C. stations were received on the loud-speaker. Birmingham, Glasgow, Bournemouth, and, of course, London were received with tremendous volume. Of the continental stations, L'Ecole Supérieure, Madrid, Brussels, Oslo, and five German stations were received with beautiful clarity. Several other stations were also logged, but the operator, who was not a linguist, was unable to identify them. Only when exceptional volume was required was it found necessary to use both stages of L.F. amplification.

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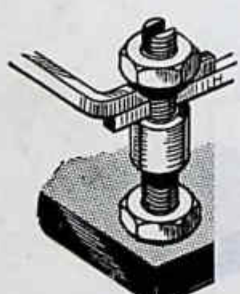

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