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# COMMUNICATIONS RECEIVERS' MANUAL 

by<br>"RADIOTRICIAN"



BERNARDS (PUBLISHERS) LTD.
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## Chapter 1

## General considerations

The Communications Receiver bas, by reason of the many commercial types now advertised, become a familiar feature to most readers of amatetr and professional radio literalure, but the high price of such a receiver makes it, for most amateurs and short-wave listeners, quite out of reach. As the name implies, the communications type of receiver is primarily designed to provide the listening side of a complete radio station, especially in the amateur station, so that the set has controls intended to work in conjunction with a transmitter, but in the main such a receiver is a highly efficient instrument of great use and value to any experimenter working on the higher frequency bands.

The ordinary " all wave " receiver is not ideal for short-wave work, and, of course, is almost useless for the frequencies above approximately 20 mcs. --that is for wavelengths helow about 15 metres, for although a V.H.F converter can be fitted to such a set, the results will never be so satisfactory as those obtained with a receiver epecially designed for such work. In some cases a communications receiver does not work at frequencies above 30 mos., but in this case a converter preceding the set will give excellent results since the main receiver is capable of working with so much greater efficiency

The main outline of a communications receiver will contain features such as the following: An input circuit providing for both dipole and single wire aerial feeds into a pre-selector stage, giving R.F. amplification and thas extra selectivity, with a high image ratio. The frequency-changer following such a stage may consist of a single valve in the usual way, or may have a mixer valve fed with local oscillations from a separate oscillator The use of a separate oscillator allows the injection of local oscillations to he adjusted to the optimum, whilst the overall gain of such a frequency converter can be greater than that obtained from a triode hexode, a triode pentode or a pentagrid.

The I.F. amplifier following the frequency converter is often the real heart of the communications receiver. Whereas the ordinary broadcast receiver has a single I.F. stage, the I.F. amplifier in the communications receiver generally consists of at least two stages, and in commercial models a series of pass-bands is provided so that the overall selectivity of the set is readily changed to suit the signal or conditions-for example, to receive a broadcast or programme signal the pass-band of the receiver will be broadened in order that the sound quality shall not suffer, but for reception of signals in the amateur bands, where the highest selectivity is required, and where some degree of tone value may be sacrificed, the pass-band is then reduced to give a very narrow degree of selectivity.

In the hest I.F. amplifiers is incorporated a " crystal sate." A quartz crystal, similar to those used to stabilise crystal oscillators, except that it is cut to resonate at the intermediate frequency, is used as a tuned circuit
with a very high efficiency or $Q$, giving a very narrow pass band, so thit in cases where stations on adjacenf frequencies are suffering mutus! hataremence which carnot be prevented even with the I.F. at its most selection oftting, switching in this " crystal gate" will generaliy ator: the wouicd station to be tuned free of interference, so great is fhe extia selectivity obtained

In the I.F. amplifier, in many cases, aire incorronated " S " or " R " meters, analogous to the Magic Eye used as a tuning indicator in broadeast receivers from one point of view for, like the Magic liye, the " S " meter gives an indication of field strength. The meter in general use is a moving coil current measurfng instrument, calibrated in decibets or " S " points and connected either in series with the high tension supply to a number of R.F. or I.F. amplifying stages with A.V.C. control, or in a bridge network between anode and screens of R.F. and I.F. amplifying stages. Reports of station quality and reception strength are made by tise R.S.T. code, where the symbols Kl to $\mathrm{R} \overline{5}$, are used to give indications of readability, the symbols S1 to S 9 are used to give indications of signal strength and the symbols T1 to TG are used to give indications of the purity of the tone. These symbols are used more especially in C.W.-i.e., in telegraphy... work, and in telephony have been replaced to some extent by the QSA and the QRK codes. The symbols QSAl to QSA5 indicate degrees of signal strength whilst the symbels QRK1 to QRIK5 indicate degrees of reacaisiity, Frobably the symbols $\$ 1$ to S 9 are the most used, however, for reporting ignal strength, and it is this series of " $S$ " points which appears on the dial of the " S " meter.

Whilst the majority of " $S$ " meters have the points separated by a 6 decibel reading, there appears to be no real standardisation of the S 9 reading-an S 9 indication being given in some cases by a 50 microvolt signal at the receiver's input sockets and in other cases by a 100 microvolt input, but even so differing conditions and even differing frequency bands will render the calibration untrue. It would appear to the author that rather too mach reliance is placed on the " $S$ " meter by many amateurs, but in a later chapter certain suggestions are made for the more valuable use of the instrument.

The detector in the communications receiver may he considered as being part of a group of stages rather than as a single valve, for associated with the detecting or demodufating diode circuit are the Beat Frequency Oscillator and the Noise Limiter. Both are necessary if the receiver is to fulfil all the usual functions.

The B.F.O. is a small self-contained stage built romd a triode, in the maiority of cases, and is simply an oscillating circuit porking on a frequency lose to the I.F. of the receiver. It is used for C.W. reception, although in certain specialised tests or adjustments it may be used when telephony is being received.

The B.F.O. is necessary to allew plain C.W. reception on a superbet. The aerial is receiving an unmodulated train of wascs, and thus while the characters of the code will be passed through the frequency converter and the I.F. stages of the receiver in the ustal manner, thin demodulator nill have no audio signals to pass on to the output stage, so that at best there will be merely a succession of clicks in the headphoncs or loudspeaker,
whist a weak C.W. station will give no ablible rebults at all. The effect may
 tunc sigals, but the stme vestit may be obtinad at tie receiver witi much less trothle.

By switching in the B.F.O., wotking at, say, 1.000 cycles away trom the internediate frequency, umolutated sisuns aniving as l.F. dots and lashes at the demodulator wifl be heterodyned by the oscillations generated hy the B.F.O. and, moreover, the heterodyne will be audidte since it is a 1, boo cycles note. Thus, the B.F.O. and J.F stages, warking in conjunction into the demodurating stage, sive atudio signais on C.W. with the adoed atiantage that the tone or mote may be aijusted to suit bile ear simply by tuning the B.F.O. and thus vareng the heterodyne freathery. 'the tuning contiol may be preset or may tie bought out to a panel control, whist a switch controls the B. $\mathrm{B} . \mathrm{O}$. as a unit. The osci! iations from tre B. P.O. are fed directily to the demodulator through a very smail capacitance.

The detector or demethiator is most usually the conventional diode or double diode, with fuil A.V.C. arrangeraente, although otic: circuits are sometimes used, especially in amateur-buit apparatus. The infinite impedance Detector, using a triode with cathode follower comnections, is very useful as a detector, but with tis or any other special ciraits, smpate stages are then necessary to give A.V.C. vollages, whilst it is possible for such high efficlency in the lest I.F. tuned circuit to he obtained that the chanecs of feeaback and instability are increased.

The Noise Limiter, like the B.F.O., is a self-contained unit, and may be switched in or out of circuif as required. Several circuits are available, the most common being a double diode biased in such a manner that audio is passed without interference. Sudden peaks of noise, however, rising above audio level, are chiped to the level set by the biasing, and in the case of ignition and similar noises it is found that clipping the noise to the level of the audio signa! in the headphones or loudspeaker enabies the signal to be copied without trotiole.

The audio amplifying stage or stages of the receiver may be made to provide facilities for the tyre of work it is desired to carry out. In the first place, both headphone and loudspeaker output sockets should be provided, so that ine demoditator should be foliowed by a triode to feed the headFhones and also the power output stage for the loudspeaker. Again, some amateur operators are interested in recording their contacts so that a cutting head stage may be incorporated in the receiver, with its associated balancing networks, and then a microphone pre-amplifier is, in some cases, also enciosed in the receiver cabinet with further provision for record playback. These refinements are not usually requiced, however.

The outline of the communications receiver, therefore, may be shown in block diagram as in Fig. 1, where the various steges are well marked. It is now necessary to revie\%; some special points in greater detail.

In the first place, the construction of a communications receiver must be most carefully carried out, not only from the electrical but also from the mechanical viewpoint, for complete rigidity and stability are necessary. Again, the multiplicity of R.F. and I.F. stages necessitates very connjete shielding to prevent feedback, and with this end in view it is usual to run


Fig. 1. The Communications Kicceivet in Block Diagram.
the H.T. line at a kower potential than in a broadcast receiver. A 250 -volt line is all that is required, so that a $250-0-250$ volt H.T. secondary transformer may be used in the power pack.

Since frequency drift in the receiver would result in the misalignment of the R.F. and oscillator tuning, the power pack is often kept separate from the receiver and given a chassis and screentus cover of its own, and to avoid enlarging the receiver cabinet it is also wise to house the loudspeaker separately. It is possible to incorporate temperature compensating condensers in the oscillator circuit, and to run the oscillator from a supply line which is held at constant potential by a regulator, but these precautions need not be taken unless a high degree of accuracy is required.

In a home-constructed receiver probably the most difficult part of the design and construction is that connected with the tuning arrangements. Tracking between the R.F. and oscillator tuning obviously must be excellent, yet at the same time as great a coverage as possible is necessary and tuning onust not be cramped. It therefore becomes difficutt to use commerciallymade coils since these are chiefly designed to work in eonjunction with a $\mathbf{5 0 0} \mathrm{mmfd}$, tuning condenser, whereas a 50 mmfd , to a $\mathbf{1 5 0} \mathrm{mmfd}$, capacitance is a more suitable maximum capacity. By using bome-made coils a smaller tuning condenser can be builit into the receiver, but in this case the ganging of the coils for correct tracking must be performed experimentally o obtain good reception over the bands. One method of overcoming the difficulty is to use separate tuning condensers for R.F. and oscillator circuits, but again this is suitable only on the highest frequency bands, and sacrifice of single-knob tuning control (apart from a bandspreading device) is a sacrifice of both convenience and simplicity.

There is also the choice between band-switching and coil-changing to be considered. Where a small receiver is desirable a set of plug-in coils assists considerably in reducing chassis size, whilst at the same time a complicated switching system and slielding arrangement is obviated, but for a comprehensive circuit band-switching is preferable. All these problems, however, re finally dealt with in a later chapter.

It has already been said that the l.F. amplifier is the heart of the receiver,
rejection is the real point at issue, and a note upon images may be helpful at this point.

An image is caused by lack of selectivity in the first tuned circuits of a receiver, and thus image reception becomes more and more in evidence as the signal frequency rises. Consider a zonverter or mixer stage working into an I.F. amplifier where the I.F. is 450 kcs . If a signal to be received has a frequency of 1 mc ., the oscillator, warking as is usual on the ligio side of the signal, will feed into the mixer a 1.45 mcs . sigmal, so that the final result will be the 450 kcs . heterodyne.

At the same time, however, a sigual from a station on 1.9 mes. will also beat with the oscillator on 1.45 mes. to produce a signal at the I.F. of 450 kcs ; or, from a second point of view, the original station at 1 mc . will be heard first, when the oscillator is working on 1.45 mcs , and, secondly, when the oscillator is tuned to 0.550 mcs . or 550 kcs .

The possibility exists, therefore, with any superhet, of tuning in each receivable station at two points on the dial.

At the frequency of the station given as an example, 1 mc., the reception of an image is virtually impossible, however, for the selectivity of even a single tuned circuit is sufficient to prevent a 1 mc . station from feeuing through to the mixer when the first tuned circuit is set at 100 kcs . as fi will be when the oscillator is working at 550 kcs ., but the percentage difference educes rapidly as station frequency rises. For example, matntaining the I,F. at 450 kcs., a station on 10 mes. will give an image when the first tuned circuit is set at 9.1 mcs., the oscillator then being set at 9.55 mcs , and whilst admittedly the tuned circuit which would pass a 10 mos. signal when the circuit itself was set at 9.1 mcs. would be rather poor, the effect becomes passible, and then pronounced before the 10 -metre amateur band on 30 mcs . is reached. Here the image reception of a 30 mcs . signal can fake place when the first tumed circuit is set at 29.1 mics., and there will be sufficient transference in this case to give a strong image. (These figures are given assuming that the oscilator is stilj working at a higher freguency than the first R.F. or signal frequency. Often, however, the oscillator works at a lower frequency for reception of 10 -metre signals-ihis consideration does not, of course, affect image reception, which is still possible.)

An ohviouts solution to this trouble with image reception is to increase the I.F. of the receiver. I.F. transformers working on a frequency of 1.6 mcs. are obtainable, and will help considerably in reducing image recention, whilst for a superhet to be used exclusively on the higher frequencies or the very high frequencies, an I.F. of 5,10 or even 15 mcs. is quite common. Increasing the I.F., bowever, is only possible by sacrificing the coverage of the receiver, for if signals in the medium-wave broadcast band are also to be received, say, on 750 kcs ., the $1 . \mathrm{F}$. cannot, for obvious reasons, be much greater than the usual 450 kcs . or so.

A second solution to the problem of image reception is to use an I.F. of 450 kcs . or a similar frequency and to improve the selectivity of the " front end" of the receiver as far as possible. This is the purpose of the R.F. amplifying stage, which improves selectivity as well as sensittvity, and a regenerative R.F. stage gives even greater image rejection. For the V.H.F.'s. the most convenient metliod of reception is to use a converter
feeding into the main receiver, when the 5 -metre band and signals at even higher frequencies can be received.

By the use of a converter the superhet is changed to doutle I.F. working, for the converter's osillator works al a frequency separated from the sitnal by 5 or 10 mcs . a tuned transformer connects the converter to the receiver's input terminals, the receiver also heing tuned to 5 or 10 mes,, which thas becomes tine first I.F. The frequency converter in the nain receiver then further converts this first I.F. to the receiver I.F. of 450 kes . or so, which becomes the second I.F.

With the choice of the intermediate frequency setticd, the controls of the I.F. amplifier may be considered. To obtain variable selectivity, tro methods at least are available, one being the use of variable selectivity transformers and the other to make one stage of the I.F. amplifier rerenerative, the selectivity varying with the degree of regencration allowed. Since regeneration may be controlled by simple means-a variable resistance in the cathode circuit of the valve involved, for example-selectivity contro! is readily available without the expense of special transformers. The crystal gate, with its particular circuit and requirements, is dealt with in Chapter 4.

When the I.F. amplifier feeds into a conventional diode detector and A.V.C. stage, it is generally found that one or two disadvantages are attendant on the circuit. The B.F.O., for example, cannot be used when the A.V.C. line is operating, for the local oscillator then feeds into the A.V.C. circuit and thus affects the biasing of the A.V.C. controlled stages. At the same time, the " S " meter is generally switched out of circuit when the A.V.C. line is switched out of action. These effects can he remedied if a rather more elaborate detector and A.V.C. circuit is arranged. For example, by using one side of a double triode as a detector of the Infinite Impedance type, taking due precautions over the I.k. feed if necessary, the other side of the double triode may be used with great success as the B.F.O. and, at the same time, the B.F.O.Detector coupling problem is solved, for with both valves in the same envelope the coupling is provided within the valve. Also, it is then possible to tap the A.V.C. rectifier into the I.F. amplifier ahead of the detector, with the result that the B.F.O. may be used with the A.V.C. either off or on, just as is required. Again, the " $S$ " meter may be connected, not to the I.F. or R.F. stages of the set, but to a valve controlled by the A.V.C. line and set apart for meter operation, this valve being connected to the A.V.C. line whether it is switched in to control the receiver or not, the " S " meter then giving its indications at all times. This meter-controlling valve may be combined with the A.V.C. rectifer in the form of a double diode triode or a double diode pentode, thus making the circuit less extensive than might at first appear.

It will be seen, then, that the communications receiver may take many forms, and the circuit details and the more important of these features will be further examined in the following pages. One particular function of the receiver must first be noted, however, together with the special arrangements and circuits used-the use of the receiver with the amateur transmitter.

## Chapter 2

## THE RECEIVER AND THE TRANSMITTER

Where the communications receiver is used alone, the "Standby " switch is probably never touched, but to the transmitting amateur it is possibly one of the most-used controls. The Standby switch cuts the H.T. supply from eitber the whole or the R.F.-I.F. portions of the receiver, whilst leaving the valve-heaters on so that the set is ready to commence work again as soon as the switch is thrown. It is obvious that the transmitter and receiver cannot work in the same band together unless several precautions are taken, and, so far as 'phone operation is concerned, the chief precaution is to open the Standby switch as soon as the replying station has finished a call. The transmitter's Standby switch is then closed, so that at no time does the set receive a signal from the transmitter of its own station.

Even so, the input circuit of the receiver is still open to receive applied ower from the transmitter, and in a high power system, with receiver and transmitter tuned to the same or adjacent frequencies, it is still quite possibie for a high current to flow in the input or first tuned receiver circuit, a current sufficiently high to cause damage.

Where the receiver is connected to the same aerial as the transmitter, it aill obviously be necessary to arrange for the aerial to be switched from the receiver to the transmitter when a transmission is to take place, and if, as is usual, relay switching is used for this purpose, it is a simple matter to arrange a further relay contact to short out or ground the receiver's input sockets. When a separate aerial is used for the receiver, however, so that no aerial-switching is necessary, the receiver's inpat sockets should still be earthed or short-circuited, and in some stations an adaption of the "press-to-talk" method of switching is used, a press-button on or beside the microphone operating relays which, when the button is depressed and held down throaghout the conversation or call, switch off the receiver, render its input circuit inoperative and then apply power to the transmilter's anodes for the transmission.

It is advised, however, that the same aerial be used for both transmission and reception, especially when a beam or directed aerial is in use, for it is useless to make an effort to direct transmitted power over a considerable distance if the receiver is not equally well served. The aerial switching relays can then perform alt the necessary operations by a simple extension of the Standby switch, so far as the receiver H.T, line is concerned, with a contact reserved for the receiver's input circuit, and the relays should be so arranged that switching on the transmitter automatically protects the receiver.

An exceplion to the use of one aerial for both transmitter and receiver must be made, of course, in Duplex working where two stations, generally local, have transmitter and receiver working together, the call being more in the nature of a telephone conversation, since both operators are able to work at the samse time, giving question and answer without interruption. In this type of work it is generally arranged that one transmitter shall be separated in frequency from the other by practically the width of the 'phone batid, so that in each location the receiver is tuned to a frequency widely different from that of the transmitter. Then the receiving and transmitting
aerials should be as well separated as possible, and, since the distance covered is usually not great, the transmitter input power is reduced as far as possible.

Again, a special arrangement is required for break-in working. Ereak-in working will probably becone even more popular now that the British amatear is required to work C.W. for the first year of his licence, and has much to recommend its adoption. By working with break-in, C.W. operation gains character much as personality is given to a contact on phone by Duplex working. for one station can break in on the signals from its contacting station, question and answer can be passed back and forth, repeats of ancopied or bad characters can be requested at the moment of occurrence and, perhaps more important stitl, each station has a check at all times of QRM or interference on his own frequency, since even if the stations are working at different frequencies such information can be passed from one station to the other without delay.

The requirements of break-in C.W. operation are that the receiver is controlled by the transmitter at each depression of the key. Whilst the key at the transmitter is down, forming a dot or dash, the receiver at that station must be dead, but immediately the key is up, even between characters, the receiver must be in operation. This means that the second transmitter may interrupt the first by merely holding down his own key, since then he will be heard as a note or tone in the receiver at the first transmitter with every break in the transmission at that station, which then ceases to send, or sends a code eroup to signify readiness to receive. Separate aerials are usually used for transmission and reception.

At each station, therefore, the key controls a relay circuit, the actual circuits being arranged to the favourite scheme of the operator but capable of keying the transmitter, earthing one aerial and controlling the receiver. The relays, moreover, must be quick and quiet in operation.

At the sante time, however, a monitor is required in order that the operator may check his own keying in his headphones, and the receiver at his station may be left sufficiently operative to give him the sound of his own transimitted signal. Probably the simplest method of achieving this result is to switch in extra biasing into the R.F. stage of the receiver which, aithough its input circuit is shorted and there is no aerial connected to it, will still be able to receive signals from the transmitter at its own station. The blasing switched in to the receiver's first stage should have a manual control, so that the operator can set the volume of his own signal in balance with that of the contacting station.

The use of a high biasing potential on the R.F. and sometimes also on the I.F. stages of the receiver is not confined to break-in C.W. operation, for it can be used also on straight C.W. or telephony transmission to enable tee receiver to act as the station monitor or as the method of rendering the receiver inoperative. The Standby switch, for example, instead of breaking the main H.T. line to the receiver, may connest the A.V.C. line from the R.F. and I.F. stages to $\mathbf{- 3 0}$ or $-\mathbf{4 0}$ volts of bias, obtained from batteries or from a small biasing unit in the power pack.

Some methods of aerial-switching and transmitter-receiver control can now be considered in greater detail.

## Acrial-Suzutching

The contro swith which transfers the aerial feeders from the recener to the lrambitice and vice rease may be manual or reyy-merated, and when oiber chatsan to be closed at the same time reny oneration is adusabse. Sne control initon or sultch can then control serent rebtys, for in a inis power system the actial feeders slould have their own separate relay and contacis mounted oft of harm's way. Specialy designed aerial relays are obababte commercially.

Orfe ingerions methed of aerialswitchirg shatd be noted, however, Which calls for transfentae of ferders from one set of connections to another. Its use th raijy comined fo the higher freagney systems, where

 lov impetance at ant and of the linc, with a high imperance at the other. Such a bioe an theretac be switched toto the main aerial feeder in a manner that preschta a patinat shotechenit to the receiver, and devices based on this prime ise acre wibly used in certain radar gear. It is also possible to use gastalied tutes-hest or argon tomes or gas triodes-as the shorting bar acros: an aerialmathing stub when the tranmiter is cosoled to the aerial tixoush main is devie. The gas-f!led tohe will glow wher the tranmitter is swithen on, this shoritis, the siub and mathing in the tiansmission line to the aerial, hat when the tramitter is switched of the tube is extingathed the shat-inctit beomes athy imedance and a futher quarterwave line from the ends of the matching sht't to the receiver will then transfer aerial power to the receiver's input circuit. These systems, however, are rnconvmional. and manual or relay aerial-swithing is far more common

The transmilier is compled to the aerial via an aerial tuning unit, and the swithine may or may not inchude this unit. The feefers may be switched from the aerial turing urit to the receiver, a separats atrial tuning unit may be ased at the receiter or the aerial tuning unit may be connected to the feeders permaneatly and the unit itself switched from fransmitter to receiver. The systom to the ese derends on the requixaments of the gear in rebtion to the atial, het lane signjest method is to enmpy a suitch which charses tive feeders from the transmitter's aerial tuner straight to the recelver, as shoun in Fig. 2.

If manoing between the feeders and the recelver's input circuit is repures, it can be obtaned by using a anit as shown in fig. 3. The final adinemat of such a unit must be made experimentaly to suit the receiver, the rief foint heing that the lines from unit to receiver must alway be tarped to the main coil in balance--that is, the two taps must always be an equal number of turns on either side of the centre of the main coil.

Components List for the Receiver Aerial-Matching Unit, Fig. 3.
100 mmfd variable. Raymart VC100X.
L1,
12 turns 18 S.W.G. spaced on $1 \frac{1}{2}{ }^{\prime \prime}$ diam. tormer, winding gapped at centre for L2.
3 turns 18 S.W.G. hetween halves of L1.
L2,
Small chassis and tuning knob. Clips.
(To cover 14 mc . band.)


Fig. 2. Aerjal Switching Reday syskomi.

When the switching is performed by a relay, other relays conirolied by the same switch or press-button being used for switching on the transmitter power, shorting the receiver input, etc., some consideration must he given to the consumption of the relay coils and the source of activating pewer. One commercial acrial relay (made by Londex, Lid., who can offer varinus. makes and types of relays) requires 3 v.a. for the coil. Different makes of relay, however, will have widely varying demands on the energising source, so that where several relays are to work as a tean they must be chosen


Ffo. 3. Keceiver-Aerial Matching Unit.
to have similar coil ratings. Low resistance relays may be driven from a sid or twelve volt accumulator battery, the coils being connected in series or parallel to give a suitable total resistance, but the battery may be replaced by a simple power pack giving, say, 100 volts D.C. if high resistance; low current coil relays are used. In either case the relays should be D.C. operated to give positive action without any chance of chattering of the contacts which might occur with A.C. energisation. A.C. relays are, of course, obtainable, but the D.C. type are to be preferred.

It is by no means beyond the limits of the home workshop to adapt old relays to new uses, the best source of old relays being a car-breaker's yard, which should always be able to supply old car cut-outs.

The complete system for C.W. break-in operation shown in Fig. 4 shows how a single D.P.D.T. relay can be used for simultaneous operation of both transmitter and receiver, and will serve as an example from which other systems may be derived. Naturally there is no aerial-switching from one piece of gear to the other in this system for, as in Duplex 'phone, a separate receiving aerial is used. This aerial must be earthed, however, along with the aerial input socket on the receiver, whilst at the same time a high bias is applied to the first R.F. stage of the receiver, the bias being controlled by a potentiometer in order that the transmitter at the receiver's station can still be heard. Note that the relay contacts should be so adjusted that the receiver is off, with its aerial earthed, a fraction of a second before the transmitter is keyed, and that the transmitter is switched off just before the receiver comes back into operation.

It will be seen that the key is in the relay coil circuit, so that a high resistance relay will give a low keying current with less sparking at the key contacts, but a key filter is shown in circuit. The relay contacts which " key" the transmitter sfould be connected in circuit at a suitable point to give good working, in the negative supply lead to the crystal oscillator, for example.


15

Components List for Relay System, Fig. 4.
K,
key.
R.F. Chokes, as Eddystone 1022.
$0.0[\mathrm{mfd} .500 \mathrm{v} . \mathrm{w}$. Non-inductive.
0.5 megohm. Volume control.

R1,
Rr ,
Receiver's volume control.
Ry,

The new volume control, operative only on the transmitter at the receiving end, may be mounted externally to the receiver. This break-in system will work when the two stations in contact are on different or the same frequencies.

The provision of a high bias line in the receiver, to which is connected the Standby switch, is a matter of receiver design and thus appears in more detail in later pages.

## Chaprer 3

## PRACTICAI, RECEIVING CIRCUITS

It is the purpose of this chapter to show some of the sfages and circuits used in a communications receiver, not only that their method of working might be better understood but that the amateur with a small receiver may be able to incorporate one or more of these stages, thus improving bis gear with the minimuin of trouble and expense. An R.F. amphifying stage might be inserted beiveen aerial and receiver, for example, thus acting as a preselector with individual tuning, or a stage in tite I.F. amplifier might be made regenerative to give a degree of I.F. selectivity control and extra gain.

## The R.F. Stage

The R.F. stage of a commutnications receiver is required to carry out a number of tasks. It is reguired to amplify the signal at its original frequency, to tune as sharply as possible in order that image rejection shall be high and the selectivity of the reciver as a whole shall be enhanced, it confains, as a stage, the frist gain control of the receiver and it must work at all the frequencies for 4 fich the receiver is intended.

The amplification oblarued from an R.F. stage varies with irequency, the gain falling as the frequency rises, and at very bigh frequencies not only does the efficiency of the ferst tuned circuit fall, but the loading presented to this circuit by the vaive increases rapidly. The valve to be used in the R.F. stage mus! therefore be chosen to suit one particular set of require-ments-Acorns, however, in their pentode ranges, give prohably the best all-round results, but it should be remembered that at least three cha:acteristics are under compariso on when an R.F. value is to be chosen. These three characteristics are the Signal-to Noise ratio, Selectivity and Gain.
$\rightarrow$ Tbe valye types which might be used in an R.F. stage can be classed very broadly as R.F. Pentodes, $\mathrm{T}_{\mathrm{t}}$ levision Pentodes and Acorn Pentodes. Where selectivity is not so importat it, the Television Pentodes give high gain with
quiet working, but where selectivity is the first requirement an Acorn should be used. The selectivity of a Television Pentode stage can be improved by making the stage regenerative, however, the renegeration being controlled by the usual manual gain control in the valve cathode circuit,

In Fig. 5 is shown a regenerative R.F. stage. Feedback between the two tuned circuits provides the regeneration coupling, and the two circuits should be screened from each other in order that feedback shall remain under control. The pre-selector is not used under conditions of actual oscillation of course, but the cathode control is advanced towards the oscillating point for greater gain and selectivity, whilst an initial control over the feedback is exercised through the anode tap on to the anode coil

The pre-selector shown in Fig. 5 is more suitable for use with an existing receiver than for incorporation in a communications circuit, however. if for no other reason than that an untuned anode stage is preferable to enable the R.F.-Mixer stage coupling to be arranged easily, but a simple R.F. stage such as is shown in Fig. 6 can still be made regenerative by arranging the wiring in such a manner that a small degree of feedback from anode to grid circuits is obtained. Such wiring arrangements must be made experimentally in order that the correct feedback is applied, and the notes on the regenera tive I.F. stage may prove helpful in this respect.


Fig. 5. A Regenerative R.F. Stage

## Components List for the Regenerative Pre-Selector, Fig. 5.

C1, C4, $\quad 40$ mmfd. tuners, ganged. Raymart VC40X.
$\mathrm{C} 2, \mathrm{C} 3, \quad 0.01 \mathrm{mfd} .350$ v.w. Non-inductive.
R1,
150 ohms, $\frac{1}{2}$ watt.
R2, $\quad 5,000$ ohms, variable.
R3, (For 4 wolt operation) 33,000 ohms, 1 watt,
R3, (For 6 volt operation) 62,000 ohms, 1 watt.
V1, $\quad$ SP4I for 4 wolt operation.
1852 for 6 volt operation.
1 International or Mazda octal chassis mounting valveholder.
Small chassis, with valve and coil shields.
2 coil-holders, Eddystone 964.
Coupler for Cl, C5, Eddystone 529.
Slow-motion drive.
Knob for R2.
Note.-To obtain bandspread tuning, use in place of Cl and also in place of C4 a $3-30 \mathrm{mmfd}$, trimmer, adjusted for bandset, and tune with 15 mmfd. tuners, Raymart VC15X, ganged.

## Colls, for amateur band coverage.

L1. 3.5 mcs. 10 turns 22 S.W.G. enam. close-wound below L.2.

| 7 | $"$ | 5 | $"$ | $"$ | $"$ | $"$ | $"$ | $"$, |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 14 | $"$ | 3 | $"$ | $"$ | $"$ | $"$ | $"$ | $"$ |
| 28 | $"$ | 2 | $"$ | $"$ | $"$ | $"$ | ,$"$ | $"$, |



| 7 | $"$ | 24 | ,$"$ | 20 | $"$ | $"$ | $"$, | $"$ | $"$ | , |
| ---: | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 14 | 11 | 12 | $"$ | $"$. | $"$ | $"$ | $"$ | $"$ | $"$ | $"$ |
| $1 "$. |  |  |  |  |  |  |  |  |  |  |

L3, L4, as L"', L2. Tap"L3, as testing points for "further trials," at 8 turns up for 3.5 mes., 6 turns up for 7 mes., 3 turns up for 14 mcs , and $1 \frac{1}{2}$ turns up for 28 mcs .

All coils on 12"1 diameter forms, as Eddystone 537.
Components List for R.F. Stage, Fig. 6.
C1, $\quad 40 \mathrm{mmfd}$. Bandset. Raymart VC40X.
C2, $\quad 15 \mathrm{mmfd}$. Bandspread. Raymart VC15x.
C3, C4, C5, $\quad 0.01 \mathrm{mfd} .350$ v.w. Non-inductive.
R1, (For 4 volt operation) 33,000 ohms, 1 watt.
R1, (For 6 volt operation) 62,000 ohms, 1 watt.
R2, $\quad 150$ ohms, $\frac{1}{2}$ watt.
R3, $\quad 5,000$ ohms variable.
V1, $\quad$ SP41 for 4 volt operation.
1852 for 6 woft operation.
1 Mazda or International octal chassis mounting valveholder.
L1, I,2, Aerial input and first timing coils. As coils for Fig. 5 or as coils already fitted to receiver. C1, C2, may atso be substituted by condenser gang in receiver.

L3, primary of R.F. transformer, coupling into second stage or mixer.


Fig. ©. A: R.f. Stage.
Obtain regeneration by small stray capacity, CS, shown dotted in Fig. G, or by running leads to $\mathrm{C} 1, \mathrm{C} 2$, near to tuned circuit leads of following stage, thus obtaining a small feedback in correct phase.

## The Frequency Converter

If the receiver is to be kept small and inexpensive, it may be permissible to dispense with the R.F. stage and to feed directly into the frequency converter stage, provided that some metbod is used to improve the image rejection of the input stage. Here again, however, the frequency converter, or mixer, can be made regenerative by the use of a conventional grid-anode coupled coil system, and the amateon requiring a small receiver with good selectivity would do well to test such a mixer against a straightforward circuit. The regeneration control is a variable resistance across the anode coil and is used, naturally, so that at no time does the mixer actually ascillate. It is difficult to avoid a slight de-tuning effect on the first tuned circuit as the regeneration control is used, but the advantages consequent on the circuit outweigh the slight disadvantages.

Moreover, in a receiver sufficiently simple to use no R.F. stage, the ascillator and input tuning may quite satisfactorily be separately controlled, with tracking naintained not by trimming and padding methods but through the tuning, tracking thus being under controf at all times. In such a receiver a slight tuning shift in the input tuned circuit will be of no consequence, and a regenerative mixer, using a triode-heprode, is shown in Fig. 7. A pentagrid converter may be used in the same manner, although when using a valve of this type it is advisable to inject the local frequebcy from a second oscillator, whose circuit may be the conventional triode osciliator, this type of frequency converter proving more satisfactory on the high fresuencies.

Components List for the Regenerative Frequency Converter Stage, Fig. 7.

| C1, C4, | 60 mmfd . tuners. Raymart VC60X. |
| :--- | :--- |
| C2, C3, C5, | 0.01 mfd .350 v.w. Non-inductive. |
| C6, | 8 mfd .350 v.w. Electrolytic. |
| C7, | 0.1 mfd .350 v.w. Non-inductive. |
| C8, | 0.0001 mfd. Mica. |
| R1, | 10,000 ohms, variable. |
| R2, | 220 ohms, $\frac{1}{2}$ watt. |
| R3, | 47,000 ohms, $\frac{1}{2}$ watt. |
| R4, | 15,000 ohms, 1 watt. |
| R.F.C., | R.F. Choke, Eddystone 1010 or similar. |
| V1, | ACTH1 for 4 volt operation. |
|  | $6 K 8$ for 6 volt operation. |

1 Mazda or International octal chassis mounting valveholder.
Slow-motion drive for C4.
Knobs for C1, R1.
Coils, for amateur band coverage.
L1. 3.5 mes. 10 turns 22 S.W.G. enam, close-wound, above L3.
L2. ", " 12 ", " ," below L3.

| L2. | " | " | 12 | ", | " | " | ", | $1 \frac{1}{2} "$ long. |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| L3. | $"$ | $"$ | 45 | $"$ | $"$ | $"$ | $"$ | $"$, |


L5. $\quad \ddot{7} \quad$ mcs. $\quad 15$ turns 22 S.W.G. enäm. close-wound, above L. 3 .
L1. 7 mes. 6 turns 22 S.W.G. enam. close-wound, above $\quad, \quad, \quad, \quad$ below L3.



1. 14 mis. 5 turns 22 S.W.G. enam. close-wound, above L3.



L5. 28 miss. 4 turns 22 S.W.G. enäm. close-wound, above L3.
$\begin{array}{lllll}\text { L1. } 28 & \text { mes. } 4 \text { turns } 22 & \text { S.W.G. enam. close-wound, above L3. } \\ \text { L2. } & , " & 2 & , \quad, & ,\end{array}$

A. "coil sets wound on $1 \frac{1}{2}$ " forms, as Eddystone 537. Separation between coils approx. $\frac{1}{4}$ " (between I.1, L2, L3 on one form, and between L4, L5 on second form).

The I.F. Amplifier
When an intermediate frequency of approximately 450 kcs . is chosen, two I.F. stages will give as much gain as can be handled and, providing that ron-cored I.F. transformers are used, selectivity will be good and image rejection at a high ratio until the 14 mcs . band is reached. An R.F. amplifying stage between the converter and the aerial will, however, keep the


Fig. 7. A Regenerative Frequency Converter
mage rejection satisfactory up to about 20 mcs., whilst on the $28-30 \mathrm{mcs}$. mateur band reliance must be placed on the extra rejection obiained by regeneration in the R.F. stage.

Variable selectivity in the I.F. amplifier is achieved, as has already been seen, either by the use of special I.F. transformers with variable couplings between their primaries and secondaries, such couplings being controlled either mechanically or electrically, or by making the I.F. stage regenerative, the resen
Since variable-mu valves are almost always used for I.F. stages, in order
Since variable-mu valves are atrolled from the A.V.C. Jine, this type of egeneration control gives very good results, although it must be realised that the percentage of regeneration over the stage varies with the signal being recelved, so that selectivity is rather less on a strong signal than on a weak one.

Only one sfage of the I.F. amplifier is piven variable selectivity by regeneration, the first stage, that following the frequency converter, usualify being the controlled stage.

It is, perhaps, simpler to introduce regeneration into an I.F. amplifier working on 450 kcs . than into a stage with a higher intermediate frequency of, say, $1,600 \mathrm{kcs}$.-and, at the same time, maintain stability over the whole amplifier.

If a crystal circuit is to be used in the I.F. stage, several different degrees of selectivity can be obtained, but in this case it is wise to use
variable selectivity transformers rather than a regenerative I.F. amplifer. The Crystal Gate, however, is fully dealt with in Chapter 4, and the remarks concerning I.F. amplifers at this point refer to reveivers where no crystal is used.

The shatper selectivity curve of a regenerative I.F. stage has a pronounced effect on C.W. reception, when using the B.F.O. A broad I.F. curve vorking against the B.F.O., with the signal tuned ceniratty on to the I.F. curve and the B.F.O. set to give, say, a 1,000 cycles beat note, will allow the signal to be heard in a varying range of pitch, whilst an interfering signal, breaking through the first tuned circoits and producing a second signal in the I.F. ampifier a few kcs. off resonance, will produce a second beat note which may be at the same audio frequency as the desired signal. To prevent this type of interference, the I.F. curve is sharpened to give Single-Signal reception. Whilst true Single-Signal reception is really obtained by the wse of a crystal gate, a very good approximation to this working condition can be achicved by introducing feedback into the I,F. stage.

The sharper curve given to the I.F. response allows the desired signal to be heard beating against the B.F.O. at only one point, so that the change of pilch with tuning is not observed. At the satue time, unwanted signals which may break through the first tuned circuits will be rejected by the I.F. amplifier, and the result is that whereas, formerly, a signal could be heard on either side of zero beat, with single-signal reception the signal will be heard on only one side of the zero beat point, the response on the other side being so far down as to make the signal either very weak or inaadible.

Introducing regeneration into the I.F. amplifier is a very simple matter since once again all that is required is a small capacity between the grid and

anode circuits. In a really stable stage a small trimmer condenser can be used, with the top or moving plate freed from the adjusting screw and bent up at a sharp angle from the bottom plate so that the final capacity of the arrangement is very small, but it is also possible to obtain the effect by running a wire from the grid circuit close to the anode circuit, clipping the wire down to size until regeneration is at the correct degree.

If a singie-ended valve is used, such as an EF50, the small capacity can be arranged between the grid and anode sockets at the valveholder, but when, as is more usually the case, a top cap grid valve is used, the capacity can be arranged between the secondary of the input I,F. transformer and the primary of the output I.F. transformer.

It is wise to reduce the gain of a regenerative I.F. stage by running the valve at a higher bias. By this means, selectivity is increased and the chances of overloading the stage reduced, whilst at the same time there is greater regeneration control.

A regenerative I.F. stage is shown in Fig. 8, and it will be seen that it follows closely ordinary practice. It will be seen that the introduction of regeneration makes no difference to A.V.C. control on the stage.

## Components List for a Regenerative I.F. Stage, Fig. 8. <br> 0.01 mfd .350 v.w. Non-inductive.

C1,
$\mathrm{C} 2, \mathrm{C}, \mathrm{C} 4$,

## R1,

For 4 volt operation:-

| R2, | 10,000 ohms, | $\frac{1}{2}$ watt. |
| :--- | :--- | :--- |
| R3, | $68,000 \quad$ ", | $\frac{1}{2}$ |
| R4, | 330 | $\prime \prime$ |
| R5, | 25,000 ohms variable, |  |
| R6, | 2,200 ohms, | $\frac{1}{2}$ watt. |

For 6 volt operation:-

| R2, | 33,000 ohms, $\frac{1}{2}$ watt. |
| :--- | :--- |
| R3, | $22,000 \quad, \quad \frac{1}{2}$ " |
| R4, | 330 |
| R5, | $\mathbf{2 5 , 0 0 0}$ ohms variable. |
| R6, |  |

## R6, 2,200 ohms, $\frac{1}{2}$ watt.

I.F.T.1, 2, 465 kcs. Iron cored transformers.

V1, VP41 for 4 volt operation,
6SK7 for 6 volt operation.
1 Mazda or International octal chassis mounting valveholder.
The feedback capacity, CF, is not included in the parts list.

## The Detector and A.V.C.

The diode detector or demodulator needs no explanation since it is such a widely-used circuit, but the alternative detector most suited by its characteristics for use in a communications receiver, the infinite impedance detector, is shown in Fig. 9.

The detector does not impose a load on the tuned circuit to which it is connected, so that selectivity in the final tuned circult can be kept high, this condition depending on the fact that the load resistance of the circuit across which the attio voltages are devefoped is in the cathode lead, giving high negative feedback. The anode current is very low, rising with signals, so


Fsig. 9. The Infinite Inpeclance Detector.
that in fo circumstances can the grid become positive with respect to the cathode, with the result that grid current cannot flow.

The high negative feedback gives excellent quality, and whilst no amplification is obtained from the vaive, as is the case with other "cathode follower " circuits, this detector is well worth using when the receiver is to he used for programme work as well as for amateur contacts.

A filter network should be included in the anode supply line to prevent any chance of hum appearing in the output from the detector.

A separate valve must be used for the supply of A.V.C. voltages, but this is often an advantage in the communications receiver, for the separate A.V.C. valve can then he tapped into the I.F. amplifier at a point where the response curve is broader than the final response at the detechor end. This method of A.V.C. feed is sometimes employed for one diode of a double diode, but here care must be taken when a crystal gate is introduced into the I.F. amplifier, for if one diode is tapped into circuit before the crystal and the second, employed as a detector, follows the filter, a small capacitance between the diodes of the double diode valve will be connected across the crystal gate with some slight loss in its efficiency.

An infinite impedance detector gives excellent results when following a crystal gate.

Components I, ist for the Infinite Impedance Detector, Fig. 9.
$\begin{array}{ll}\mathrm{C} 1, & 0.0002 \mathrm{mfd} . \text { Mica, } \\ \mathrm{C} 2, & 0.1 \mathrm{mfd} .350 \text { v.w. }\end{array}$
C3, $\quad 0.1 \mathrm{mfd} .350$ v.w. Non-inductive.
C3, $\quad 0.5 \mathrm{mfd} .350$ v.w.
R1, $\quad 22,000$ ohms, $\frac{1}{2}$ watt,
R2, $\quad 150,000$ ohms, $\frac{1}{2}$ watt.
R3. $\quad 0.25 \mathrm{meg}$. Volume control.
V1, MHL4, 224 v., etc., for 4 voit operation.
$6 \mathrm{C} 5,6 \mathrm{~J} 5$, etc., for 6 volt operation.
1 British 5-pin or International octal classis mounting valveholder.

When a separate valve is used for A.V.C. it may be either a diode, limited to the one operation of supplying the control voltage to the receiver's A.V.C. line, or may be a double diode triode or pentode, the main section of the valve being fed from the A.V.C. voltage at a!! times and having the " $S$ " meter in its anode circuit, the " $S$ " meter thus being freed from the usual fimitation of working only when the receiver has the A.V.C. suitched on. If it is desired to use a diode as a simple A.V.C. supply, a purely conventional circuit is used, but when the full advantages of A.V.C. and " S " meter are to be taken, the circult of Fig. 10 is capable of giving excellent results.

It will be seen that the anode current of the pentode section passes through the " S " meter so that a shunt resistance, R7, must be provided. Where a meter is used in this fashion it reads " backwards "-that is, for " $S$ " zero the pointer is set to full-scale position, the reading decreasing with increasing signal strength, since increasing signal strength places a more negative bias on the grid of the meter pentode, thus causing the anode current to fall.

In commercial receivers the meter used is arranged to have the no-current zero position at the right-hand side of the scale instead of at the conventional left-hand side, but a simpler solution for the amateur constructor is to mount the instrument upside down, so that with the current switched off the pointer is at the right-hand side of the dial. With the current adjusted to give full-scale deflection, or " S " zero, the pointer will then be at the left-hand side of the scale, increasing signal strength bringing it across scale from left to right in the usual manner. This, of course, means that the instrument used for the " $S$ " meter will require recalibration in order that the inverted scale will read correctly, but this will be necessary in the majority of cases.

The A.V.C. line, in Fig. 10, is shown provided with a switch to give A.V.C. On and Off. If desired, however, this switch can be expanded to


Fig. 10. A.V.C. and 'S'meter Stage.
give A.V.C. Fast, A.V.C. Slow, and A.V.C. Off, the time constant of the resistance-capacitance combination C2, R2, being made variable by providing more than one resistance in the R2 position, such an arrangement being shown in Fig. 11.

A stow A.V.C. action is desirable when the receiver is to be used on programme transmissions, and is also useful for use on C.W. transmissions. A fast A.V.C. action, when code is being received, will tend to give fluctuations of the noise level between the code characters, but a slow action witl " hang over " between the characters so that the A.V.C. is usable in that case with C.W. transmissions. A fast A.V.C. is also useful on rapid fading, however, so that if two positions are prowided as in Fig. 11, the slow position using a 1 megohm resistance, the fast position using a $\frac{1}{2}$ megohm resistance.

The A.V.C. diodes are shown as being fed through a small condenser from the anode of the last I.F. amplifying valve, so that the A.V.C. is taken off before the B.F.O. has effect, but as has already been shown, the diodes may be connected in at a previous stage.

| Components List for the A.V.C.* S " Meter Stage, Fig. 10. |  |
| :---: | :---: |
| C1, | 50 mrnfds. Silver Mica. |
| C2, | 0.25 mfd .350 v.w. Non-inductive. |
| C3, C4, C5, | 0.1 mfd. 350 v.w. Non-inductive. |
| R1, R2, | 1 megohm, $\frac{3}{2}$ watt. |
| R3, | 750,000 ohms, $\frac{1}{2}$ watt. |
| R4, | (For 4 volt operation) 330 ohms, $\frac{1}{2}$ watt. |
| R4, | (For 6 volt operation) 390 ohms, $\frac{1}{2}$ watt. |
| R5, | 68,000 ohms, $\frac{1}{2}$ watt. |
| R6, | 4,700 ohms, $\frac{1}{2}$ watt. |
| R7, | 100 ohms, variable, wire-wound. |
| M, | 1 mA. Meter. |
| S1, | S.P.D.T. A.V.C. On-Off. |
| V1, | DDPen for 4 volt operation. |
|  | 6B8G for 6, volt operation. |
| 1 British 7-pin or International octal chassis mounting valveholder |  |
| R2a, | 1 megohm, $\frac{3}{2}$ watt. |
| R2b, | 470,000 ohms, $\frac{1}{2}$ watt. |
| S1, | S.P. 3-way. |

## A.V.C. Controlled Stages

No matter by what method the A.V.C. voltage is obtained, there still arises the question of the number of stages to which A.V.C. shall be applied, and which stages shall be chosen for control.

Here, again, the matter is largely one for individual choice, and if the " $S$ " meter is fed from the A.V.C. line direct via a pentode, in the manner


Fig. it. A variable A.V.C. arrangement.
just shown, considerable latitude in the choice of the stages for control is possible. If the receiver is to be used for programme work on a local station as well as for distant contacts and listening, the local station wilf call for a fairly high number of controlled stages to prevent overloading, but if there are no strong signals at the receiver location, then control of two stages only in the receiver will be satisfactory.

In the first place it is wise to leave the R.F. stage uncontrolled, in order that it may work " full-out " and since this stage has the first manual control in its catiode circuit, it should be possible to prevent overloading of the input stage by the use of this control alone. The R.F. stage, therefore, will be left free of control, which may be applied to the frequency converter as the first value in the controlled chain.

If control is also applied to the first I.F. stage, leaving the second stage clear, these two valves, converter and first I.F., should then exercise sufficient control over the rest of the receiver for all ordinary purposes.

When the receiver is to be used alongside a transmitier, however, the situation is different, and in this case not only should the R.F. stage have A.V.C., but it should also be possible to switch in a high bias line, supplying a negative bias from a subsidiary pack or battery. By using a high bias in this manner the station receiver may be used as the 'phone moritor or C.W. monitor even with the input shorted to earth, since in the majority of cases sufficient R.F. will break through when the transmitter is at the same or a near frequency. Making the high bias adjustable will give a manual volume control on the station transmitter monitoring, and the set, instead of idling when switched to Standby, or Transmit, will still be performing a useful task.

The controlled chain of valves in this case may well be the R.F. stage, and both I.F. starges, leaving the frequency-changer clear, the high bias, of course, being applied only to the R,F. stage, the signal from the station transmitier thus being attenuated in this stage alone, the rest of the receiver working normally. The arrangement of a high bias tine will be shown in Chapter 6, and a suitable pack in Chapter 7.

## The " $S$ " Meter

Whilst there are many advantages in connecting the " $\mathbf{S}$ " meter to its own Individual valve, this is not economical when the A.V.C. voltages are supplied from a diode of the double djode detector-A.V.C. value, and the meter in this case will be connected into the I.F. section so that it is operated by the changing anode current of the A.V.C. controlled valves.

The simplest connection is to feed the whole I.F. amplifier with current from the main H.T. line through the " S " meter, or, if a low current meter is used, one valve is fed through the meter.

The " $S$ " meter is shunted by a wire-nound variable resistance of, say, 1,000 ohms. The meter is then set to the zero position by allowing the I.F. amplifier to work at full output with no signal applied to the set, the variable shunt across the instrument then being adjusted to give a full-scale deflection. When signals are passed through the receiver, the A.V.C. line switched into action, the rising bias with a rising signal strength reduces the anode current through the meter so that the pointer deflection is reduced. Here, again, there is the disadvantage that unless a right-hand zero instrument can be obtained the meter must be mounted upside down, the scale being recalibrated to suit the new conditions.

In Fig. 12 is shown a bridge circuit in which the " S " meter works in a straightforward manner, since the pointer deflection increases with signal increase.


Fig. 12. Bridge Circuit ' $S$ ' meter.

The bridge action occurs between the current flow in the anode circuit, which is liable to change with signal strength, and the current fow in a voltage-divider through which are supplied the screens of the I.F. valves. Since it is necessary for the current through the screen arm of the bridge to be very similar in value to the maximum current through the anode arm, the voltage-divider must be adjusted to give such a current, taking into account both the current through the valve screens and that flowing through the divider itself.

To set the " S " meter when this bridge circuit is used, the I.F. amplifier is set for full output with no signal applied to the receiver, the meter being set to zero by R1. The pointer indication will then rise when signals are allowed to pass.

Components List for the " $S$ " Meter Circuit, Fig. 12.
R1, $\quad \mathbf{1 , 0 0 0}$ ohms, variable, wire-wound.
R2, $\quad 330$ ohms, $\frac{1}{2}$ watt.
R3,
270 ohms, $\frac{1}{2}$ watt.
C1, C2,
$0.1 \mathrm{mfd} .350 \mathrm{v} . \mathrm{w}$. Non-inductive.
Note.-The values of R4 and R5 depend, as has already been shown, on the current flowing to the screens of the J.F. valves, and upon the maximum anode current through R1. To take a concrete example, the maximum current for a 6 K 7 used as a controlled I.F, valve in the anode circuit is approximately 10.5 mAs . Thus, 10.5 mAs . must flow through R1-R2 and R4. Supposing that a pair of 6K7's are used in the I.F. amplifier, the screens will require a total of approxinately 5 mAs . at 100 volts. Thus, for a pair of 6K7's, suitable values would be:-

| R4, | 15,000 ohms, 2 watt. |
| :--- | :--- |
| R5, | 22,000 ohms, 1 watt. |
| M, | $0-1 \mathrm{~mA}$. meter. |

The calibration of the " S " meter is also, unfortunately, a matter of individual choice. " $\mathbf{5 9}$ " has yet to be given a definite value, although in certain commercial receivers " S 9 " indicates either a 50 or 100 microvolt input to the aerial sockets. Presuming that " s 9 " indicates an input of $\mathbf{1 0 0}$ microvolts, however, it must not be supposed that the receiver is therefore standardised, for the connecting of a pre-selector or v.h.f. converter between the aerial and the receiver will throw the " $s$ " meter completely out of calibration since there will now be the gain of the new unit to take into account, whilst in actual fact the " $S$ " meter gives a true reading only at the frequency, and with the input conditions, that obtained at the time of calibration.

Moreover the noise level of the receiver will affect the " $\mathbf{S}$ " meter when no signal is being received, so that it would probably be more accurate to give signal strength as points above " S1 " rather than above " So." Again, the " $S$ " meter gives an indication which may be affected not only by the manual gain control of the R.F. stage but also by any gain control or controlled regeneration control fitted to the I.F. amplifier. Thas, for comparison between stations the " s " meter is not of real value, although its readings are often quoted-the real value of an " $S$ " meter is to judge the effect of adjustments made at the distant transmitter, or to show the

Lsin obtained from the use of a different tramsmitting acrial, or to show the effect on a distant station of fading or similar variable conditions. For station reporing, also, the true way to use the " S " meter is to take a noise reading on the station channel with the station off, and a second reading with the station on, thus obtaining a reading which is the difference between the station level and the noise level, the report being given as number of decibels or " S " points above noise. The " S " meter is also of great use for checking the radiation patterns of aerials-rotating aerials, used at the transmitter, the " S " meter readings being noted whilst the transmitting aerial is turned through a whole revolution, the readings being plotted against rotation. Such tests should, of course, be made between transmitters and receivers located close one to the other, since such tests conducted over a distance give meaningless results due to fading which cannot be checked.

The nine points on an " S " meter are generally separated by 6-decibed spacings; that is, between each " $S$ " point and the next there are six decibel points. Since six decibels corresponds to a doubling of voltage, this means that each successive " $S$ " point indicates, or should indicate, that the signal voffage at the aerial terminals has been doubled.

The " $S$ " meter may be calibrated, therefore, by the use of a signal generator with a cafibrated microvalt output scate, " S 9 " being set at a known level and the points calibrated down in terms of decibels, each point indicating double the input of that required to give the point below it.

If a signal generator with calibrated output is not available, probably the most satisfactory calibration will be given by printing points on the scale showing the same degree of rise as that already suggested, the calibration being made against a good moving coil instrument. The " S " meter will then be an indicator with an unknown reference level.

A third method of catibration is to style the half-full-scale-deflection point of the meter " X ," with points above and below this calibrated as $2 \mathrm{X}, 3 \mathrm{X}, 4 \mathrm{X}$, etc., and $\frac{3}{\frac{3}{3}} \mathrm{X}, \frac{1}{2} \mathrm{X}, \frac{1}{4} \mathrm{X}$, etc., so that the scale, although once again calibrated to an tinknown reference point, can give readings against $\mathbf{X}$ of standard gains or lozses. This is done by bringing the " $\mathbf{S}$ " meter deflection to $X$ on any received station by the use of the R.F. or l.F. manual gain control, fading or station adjustments then showing on the meter.

## The Noisg Limiter

Of the various noises which may be received along with the desired signal, the most troublesome is impulse nolse, such as is caused by the ignition system of cars. A circuit which would remove the noise entirely whilst passing the station signal would be extremely difficult to devise, but it is found that when noise is troublesome its amplitude is invariably much greater than the signal amplitude, so that limiting the noise amplitude down to the signal amplitude effects a simple and very effective cure.

Several noise limiting circuits are available to the constructor, some working on the audio amplifying stages and some in the detector stage, but the simplest limiter, with adjustable and controlled action, is the seriesdlode clrcuit.

A diode is biased from a voltage-divider circuit belween the positive and negative fi,T. lines in such a fashion that a signal of high amptitude, presented to the valve, renders the diode non-conducting for the duration of the signal, signals of smaller amplitude being passed without causing this action. The diode thus "chops" peaks of noise which, being of short duration thus cause " holes" in the audio signal which are barely noticeable, so that signals can be read through ignition and similar impulse interierence.

The liased diode is placed between the detector and the audio gain control, and may be used with either diode detectors or detectors such as the infinite impedance type. The two circuits to be used are shown in Figs. 13a and 33b.

If necessary or desirable, the noise limiter can be switched out of action by a D.P.D.T, switch, one position of the switch placing the limiter in circuit, the other position switching out the limiter and passing the signal straight to the audio gain control.
$A$ siight drop in audio output is consequent upon the use of a limiter, but this can be masked with the audio gain control.

The level at which the chopping action takes place is set by the bias applied to the diode through the control potentiometer R5 in Figs. 13a and $13 b$, and this is adjusted on a signal until distortion commences. The control is then backed off slightly to ciear the signal of distortion, and will then limit noise with a higher amplitude than that of the signal. The limiting control must, of course, be readjusted for signals of varying strength although the levelling action of A.V.C. is of help in this instance.


Fig. 13A. Diode Noise Limiter with Diode Detector.


Fig. 13b. Dirrfe Noise Iimiter with Inlinite Impedance Detector.


When using a double diode, the anodes and cathodes may be strapped in pairs to give a single diode.

## Chapter 4

## THE CRYSTAL FILTER

The crystal gate, as the crystal filter is popularly called, may be included in the I.F. amplifier of the oommunications receiver to give an I.F. response curve shaped either as a single peak, this peak being steep-sided and narrow, indicating sharp selectivity and rapid fall-off of response to either side of the central frequency, or by the use of a pair of crystals, as a double-peaked bandpass response with sharp cut-off sides and a region on either side of the pass-band of zero response.

The crystal or crystals used in such a filter are cut from quartz, as is the ordinary oscillating crystal used for frequency stabilisation, the crystal-
cut being so made that the filter crystal resonates at or very near the I.F, used in the receiver. A crystal so cut acts as a tuned ci:enii of very high Q or efficiency, this tuned circuit efficiency being vory nuch nigher than can be acitieved by the use of an I.F. transformer, the sclectivily also being improved to a value which coudd only be obtained by a multipicity of I.F. stages were no crystai to be usei.

Not only is the freater selectivity of the I.F. ampliiter useful in giving a "single signal" effect, or in assisting the rejection of sigatis a few kcs. off the rasonance point, but the sharp response curve also inaproves the signal-tomone ratio as far as the I.F. stages are concerned, since noise level is cut with the cuttins of the pass frequencies.

The cris? filter is used as a coupling between siages in the I.F. amphiner, the selectivity introduced by the coupling being variable and under control when the single crystal is used. The tem crystal "gate" really refers to single crystal working.

There are differing advantages and disadvantages obtained by the use of pithe: single or double crystal working, bui it is feit that the single coysial fitter witt be most suitable for the majority of amateurs, especially when tise recever is being bome-constricted. The dowble filter, giving as it woes a narrow banel-pass action, is excellent for C.W. work, but is not open to suct sitale variahle selectivity adjustment as is the gate, whilst The crystal eapense is doabled. For telephony, a pair of crystals separated by a fev kes. most be used, and for C.W. a pair of crystals separated only by 300 on 500 cyctes is used, so that the crystal expense rises by reason of botis the extis crystal and the accuracy of the cut required. Whilst Ituiless is simpier when the band-pass arrangenent is adopted, since the I.F. respanse carte $\mathrm{i} s$ a flat top instead of the single crystal peak, the variable selectivity oblained by the use of the simpler gate circuit minimises tuning troubles and is more suited for non-specialist working.

The bastc essentiats for crystal gate operation are simple and the action quise easy to macesimal. A crystal acts as a tuned circuit of extremely tigh tofeny at it: resonant point (the eguivalent electrical circuit being a series-tuneti rather than a parallel-tuned circuit), the impedance of this tuned circuit being very low at the resonant point but rising very rapidly on elther side of resonance to practically infinity. A crystal, acting as a conbliag between two I.F. amplifiers and cut to resonate at the intermediate frequency -. say, 455 kcs. $\cdots$ will thes provide very good coupling characteristics at the I.F., but will reject signals a few kcs. off the central frequency.

A crystal, however, cannot be tsed alone. In the first place, it must be supported in a crystal-holder, and the plates of this component act as a small capacitance which will pass to some degree the frequencies which the crystal is rejecting, whilst at the same tinie the crystal will have an impedance which requires matching not oniy to the stage feeding into it but also to the stage following the filter. At the same time, it is necessary to arrange a small degree of feedback, in a circuit similar to a neutralising circuit, to offset the disturbing capacitance of the crystal-hoder's plates, this small feed being 90 degrees out of phase with the feed through the stray capacitance.

Accordingly, to supply all these requirements, the crystal circuit is fed from a speciai I.F. transformer with a centre tap to earth, this centre tap being either an actual connection at the centre of the coil or supplied as at electrical centre tap by a pair of condensers acrosis the secondary of the transformer, their juaction being earthed to the chassis.

This arrangement is shown in Fig. 14, where the secondary of the first transformer is actually centre-tapped.

The effectiveness and efficiency of the crystal gate depends to a very large degree upon the following impedance which, in Fig. 14, is suppied by the following transformer and valve. As the impedance $Z$ of this circuit rises, so will the signal voltage developed across the impedance rise, but this has the effect of reducing the apparent Q of the crystai circuit and thus of reducing the selectivity.

By varying the impedance of the circuit following the crystal, it is therefore possible to obtain the variable selectivity effect which is so desirable for use on different types of signals. In this respect the crystal sute is supersor to the couble crystal band-pass filter. The input circuit, hovever, can have the same effect on the selectivity, and in practice it is usual to connect the variable selectivity control into the crystal input circuit, detuning of the input circuit by a condenser giving higher selectivity.

It will be seen that special transformers are necessary for use with a crystal filter, and in Fig. 14 the second tuned circuit, which is acting as an auto-transformer, must be tapped to match the crystal impedance. This state of affairs is further complicated by the fact that two types of crystal are in use, the Y-cut crystal as used in American receivers, having a low impedance, and the X-cut crystal, more often used in British receivers, having a high impedance. By the use of an X-cut crystal, however, and by using a circuit


Fig. 14. The Crystal Crate Circili No. 1.

Ith bigia ingtit itaredance to follow the second timed ciacuit, the toppitg on I.: can be dispensed with and the crystal filter connected to the top end of the tunet circuit.

C2 in Fis. 11 is the wrible condenser used to hatance ont the stray apeity of the reystatiodier, and is termed the "phasing" condenser. Given the phasing combenar is set to balance the circuit, the response rate of the filter is symmetrical, but if the phasing condenser is varied to a surat diegree on either side of the balancing value, the symmetry of the asponse weve is lost and a point of zero signal voltoge ocurs on either tie high or Iow siev of resonance, this point of zero signai apgodimy or recofing fom the cemal frowency as the phasing cowienser is varied in
 since the zero respones poirf can be adjused to fati on an interforist signal, The reponse at the opposite side of the remonse curye rises, however, so
 ost interference fron a secons, but in geneal the benefits given by the zoro fiscal point are vary well worth ubile.

The seicetivity, cuan at the minimum posilion, giver ly the fiter circuit of Fig. 14 is sufficiertiy higi to make tuning on a telemphy iranmission so sharp that considerable sideband cutting ensues, am so a switch actoss the erystal hiay be provited to cut the filter out of acion.

Fig. 14 may be changed from the crystal gate to the band-pass crotal titer circtit by contectins a second crystal acress the phazing condewser Co, this second crystal beinst saparated in frequency from the firse crysiai by the banduidh frecuency it is desired to pass. Ce may then require some becrease in value to deal with the new balance point.

In Fig. 35 is slown a crystal gate with a rider range of selectioty control. the control itset also being simpler since a variate resistace is escd on the outert side of the filter. An input transfozmer matened to tioe crystal imgedace is used, whilst phasing is now carried out by beans of a diferential condeiser. The input coi! 12 is centre topped electricatly rather thas physically $t y$ the use of a pair of condensers.

The output tuned circuit must have a high $Q$, and the salectivit; contion, R 1 , may be variable citier smonthly or in steps, a set of resisiances counected to switch beime ised the theter case. La and C mast, of warae, be capable of tuming to the I.F. in ise.

The main difficu'ty attached to the incorporation of a crystal gate in a homeconstructed receiver hies, therefore, in the proviton of a suitable input transfomer for the filter, for if a crystal is obtainet $3:$ a 3 sivente component its characieristics must be known before a trenstormar thatehed to the redance can be bought or made. Morenver, the transformer characterisies moned upon the fiter chant used. In lig. 14 the transfomer remina a figh inductance grimary with a secondary tighty colphed io it, whitht l. $\%$
 frecit is used to follow the flter.
 for some crestals, wilist a high $Q$ titied circuit must follow tita fiter.

The fitter will, of couse, pork viti a mismatcise tramifomer and see high selectivity, but the loss of gain over the filter will be vary serious. Even


Frc. 15. The Crystal Gate Citcuit No. 2.
with correct matching there is a loss, real or apparent, in the gain over the filter-the higiner selectivity will, at best, catse an apparent drop in gain by reducips backerond noise and signal sidebands-but when two I.F. stajes are provided, there wiil be gain in hand to compensate for this loss.

The wisest plan, therefore, would appear to be the buying of a complete crystal filter unit for incorporation in the receiver, when it would be known that the I.F. transfomers were properly matcled to the crystal, or the transformers and crystai may be obtained as matched components, and the unit built up with its associated condensers, but the experimenter may care to test various transfermers against his crystal in an endeavour to obtain a fifter at the lowest cost withoul loss of efficiency.

In this case it is advised that tests be made using the circuit of Fig. 15. The input transiomer may be made experimentally from an old I.F. transformer of the correct frequency- 465 kcs. is advised-the secondary winding being stripped of half its turns. The centre tap being electrical, further experiment can be carried out on this winding until the most favourable results are obtained with the crystal to be used,

The phasing condenser can be made by mounting two midget turing condensers together, their spindles being coupled via a coupling unit so tlat with one condenser at full mesh the second condenser is at zero mesh, or minimum capacitance.

The high $Q$ circuit of L.3-C4 may be one side of an efficient I.F. transformer, or a pretuned I.F, rejectur coil of the iron-cored variety might be tried in the position.

The type of crystal obtained will govern the circuit constants to a high

The position of the crystal gate in the I.F. amplifier depards to some extent on the following circuit, aid in this connection the inknice impedance detebier makes an exceitent following stage to the filter. Ife gate is of en shown imandialely following the frecuency-changer, but since the fitter requires a fairiy high input signal for its most efficient opeation, it is wise to allow for some I.F. amp:ification prior to the fitter. Tte $Q$ of the tunea circuit I 3.Ch in Fig. 15 will be assisted by an infinite inpedance detector, and so, when such a detecting ologe is used, the obvious piace for the fifter is fotwen the I.F amplifer and the detector. Where tiode detection is usod, howaver, the filter may the used as the coupling betweon the two I.F. stages.

## Components Lisf for the Crystal Gate, Fig. I4.

1.1, 12,

High inductance -. close coupled I.F. transformer, C.T. secondar:-
I.3, I.F. coil, tapped down to suit arystal.

C1, $\quad 100 \mathrm{mmfd}$. variable. Selectivity control.
ce, $\quad 15 \mathrm{mmfd}$ variable. Phasing control.
$\mathrm{CB}, \quad 60$ montd. variable trimmer.
Ci, I.F. tuning trimmer.
Crystal,
465 kes.
s,
Crystal shorting switch. (Low capacity type, with short leads to crystal.)
Nol i.---To eyeriment with this circuit, use a high impedance or K - tut crystil and dispense wita the lapping on L3 by using an infaile impedance detedor as the following stage. Adapt L.L, L2, by using an I.F. transiomer Hith wis mountel on a central dowel, moving the secondary coil ciose to II and mountias, on the other side of $L 1$ and at the same distance, a sciond secendary coif idenical with that already fitted, oftained trom a second shaitar transímmer. These two secondarics are then comected in serics, thus providing a high indactance contre-fapped vinding.

Test l.l both with a trimmer condenser in parallel and without.
Components List for the Crystal Gafe, Fig. 15.
L1, L2, Tuned primary - low impedance secondary I.F. trans-
J.3,

C1, C2,
C3,
C. 4 ,

R1,
Crystal,
S , tormer.
High Q I.F. coil.
0.0001 mfa , Mica.

10 mind. Differential. (See text.)
I.F. furing trimmer.

5,000 ohms vatiabie. Selecifity control.
465 kes.
Crystat shorting switch. (Low capacitance type with short leads to crystal.)
In either circuit tite whole fiter is cut out of action by the switch across the crystal, leaving the I.F. amplifier working at its normal selectivity.

## C112FFER 3

## THE BEAT FRFQLENCY USCHAATOR

The 13.F.O. is a simple oscillating circuit woritus on a frequancy cose Io the intermediate frequency of the recsiver, a fraction of its output being fol to the I.F. amplifier or, prefersbly, the debector. This socally generated frequency then heterodynes any signai passed to the detector from the I.F. momifier so that signals which are not modulated, such as C.W. bansmissions, are given an audio content, tire heterodyne frequency being in the awhe range. The coil used, together with a small trimmer type tuning condenser, as the oscillating tuned circuit is usually tapped near the earthed end in order that a Hartley oschiator circuit arrangement can be used, such a circutit being both economial in comporients and very stable.

Either a pentode or triode valve may be used as an oscillator, the choice of types being wiry wide, and typical circuits and components values are given in the Figs. 16 and 17 with their associated components tists.


Foc. 16 . AB.F.O. and impedance Detector.

In Fig. 16 the B.E.O. is shown is one-half of a doable triode valve, the second part of the value acting as an infinite impedance detetor. This form of construction is excellent in that the coupling from the B.F.O. to the detecior fekes place within the valve itself, via stray capacitics, so that ro further coupling is recuird. Linfortunately, this tye of circuit can be tised only with Amerian vaives of the 6F8 type or similar, sime there are no 4 -volt double triodes suitable for the purpose.

The infinite impedance detector in this circuit is shown as heing of slightly different design from that described in Chapter 3, since fitering in the cathode circuit is essisied by the choke, R.F.C., which, of course, should be effective at the intermediate frequeniy.

Separate triodes can, of course, be used with the same component values: to give equivalent operation, a small coupligg condenser then being used between the grids of koth valves as Cc of Fig. 17. Thee condenser Ce has a very small value of capacitance, and may be made either by removing the adjusting screw of a 30 mmfd, trimmer and bending the top piate at an angle to the boltom plate, thus providing the small capacitance repured or by wrapping a lead from the grid of the B.F.O. round the grid latd of the detector for the anode lead of the deiector if a diode detector is used), both leads being insulated.

Components fist for the Combined Impedance Detector and B.F.O., Fig. 16.

| R1, | 22,000 ohms, | $\frac{1}{2}$ | wati |
| :--- | :--- | :--- | :--- |
| R2, | 150,000 | " | $\frac{1}{2}$ |
| R3, | $10,000 \quad "$ | $\frac{1}{2}$ | $"$, |
| R5, | $47,000 \quad$, | $\frac{1}{2}$ | ", |

R5,
C1, C5,
C2, C3,
C4,
B.E.O. coil,
R.F.C.,

S1,
V],

## 6F8

internationat octal chassis mounting valveholder.
Note.-.-Severai 4 -voit valves may use the same B.F.O. circuit, for a separate detector-B.F.O. arrangement. The AC2HL or 354 V oscillate well, in MIILA or 224 V being used as the Infinite Impedance detector.

Components List for the Pentode B.F.O., Fig. 17.

## C1, C3,

0.0001 mfd . Mica.

| C1, | 150 mmfd . variable trimmer. |
| :---: | :---: |
| C2, | 150 mmfd . variable trimmer. |
| C4, | 0.1 mfd. 350 v.w. Non-inductive. |
| C5, | 0.5 mfd .350 v.w. " |
| R1, | 68,000 oluns, $\frac{1}{2}$ walt. |
| R2, | 15,000 ", 1 - |
| R3, | 10,000 ", 1 , |
| B.F.O. coil, | Wearite B-FO or similar. |



Fic. 17. A Pentode B.i.O. Circuit.

## S1, S.P.S.T. B.F.O. On-Off switch. <br> V1, VP41, etc., for 4 volt operation. GK7, etc., for 6 wolt operation.

1 Mazda or International octal chassis mounting valveholder.
Note.-Cc, small coupling condenser to detector. See text.
To acjust the D.F.O. the receiver should be tuned to a C.W. signal of moderate strength, the B.F.O. being switched off whilst the signal is tuned sharply, the tunimg being on the carrier hiss. The B.F.O. is then switched on and funed to give a suitable beat note with the signal code, the receiver funing loeing left untoucied whilst the B.F.O. funing is carried out.

The B.F.O. is then set for all C.W. signals.
In circuits where the B.F.O. feeds into a diode detector and A.V.C. stage the A.V.C. line should be switched off for C.W. reception. Where the A.V.C. valve is fed from the I.F. amplifier before the introduction of the B.F.O. carrier, however, the A.V.C. line may be left on for C.W. reception providing that a "slow" A.V.C. action is obtainable.

## Chapter 6

## PRACTICAL RECEIVERS

Within the following pages are shown the circuit diagrams, with components lists, of a series of practical communicatons receivers. The circuits include both simple and more complicaled designs, the simpler circuits being included on the strength of the fact that even though they are less versatile than their companion receivers they are still of great value as true "com-
numications" receivers in that they wifl anoply fill the role of listening-post at either the transmitting station or short-wave receiving station.

Whilst the simpler circuits may have two-control tuning-i.e., separate tuning of the osciliator and aerial-tuned circuits-to enable the coils to be home-made and tracking to be adjusted without the use of trimming and padding, the more complicated receivers require to have ganged turing if all the benefits of the more compreliensive circuits are to be realised.

The writer's experimental work has shown that for full coverage of, say, 5 or 10 to 2,600 metres, the work involved in building and especially in adjusting and tracking home-made coils is too fine and time-consuming for the bome workshop. The value of home-made coils must lie in their simplicity, and so two systems of receiver-tuning are shown. For receivers intended to cover the amateur bands only, home-wound coils are shown, with their winding details, and separate aerial and oscillator tuning is employed. The coils are wound and the tuming capacitances are chosen in such a manner that each coil covers the band for which it is specified, the inter-amateur band frequencies not being covered. By this means, those requiring amateur reception are catered for, the circuits being both selective and easy to tune.

To cover the whole frequency range, however, farger condensers must be used to avoid a great multiplicity of coils, and accordingly commerciallymade coil sets are specified. Since these coils are intended to be tuned by ganged condensers of 0.0005 mfd . capacity or similar, bandspreading provision is made so that at any frequency the main tuning gives way to fine tunians whenever necessary. In this way all frequencies are received and at the same time the crowded bands are "opened out" to a very considerable extent.

A communications receiver of any type must be constructed with great care, since the number of stages working at radio and intermediate frequencies increases the possibility of feedback, especially where such stages are made regenerative. The receiver tayout should follow in logical steps, the R.F. stages bsing grouped to one side of the tuning condenser assembly or assemblies, each stage opposite its own section of the condenser, with the I.F. anplifier following the mixer stage in line, the transformers being mounted between the valves wherever possible, since the transformer screening then assists the valve screening. It is wise to provide external valve screens for all the R.F. and I.F. stages, but if this is thought unnecessary the receiver may be tested without extra valve screening, the screens being added later if there should be any trace of instability.

The circuits shown all include extensive decoupling for each stage.
All the receivers should be built on aluminium chassis. A copper chassis might be even more switable, alihough the extra efficiency so gained is insufficient to give any noticeable result, but steel or iron chassis should be avoided since losses with such material at the higher frequencies are high.

Chassis layout, and especiaily panel layout, must be clean and symmetrical. Where both main tuning and bandspread tuning is used, both sets of condensers should have a good slow-motion drive, and it is advised that drives of the panel dial variety with cards for individual calibration mounted in an escutcheon shoukd be used. Two methods of calibration are possible. For the general listener, the bandspread dial need not be calibrated,
for the bandspread condensers should be set to half capacity and all exploration work carried out on the main tuing condenser control. The bandspead condeiners are then avaiable for expansion of the main tuned frequency, the main dial being caiibrated in terms of frequency or wavelenglh.

The andateur tranmitter, hovever, might weit use the reverse of this technique, calibrating the main tuning dial to show band fimits with the bandspread condenser at half mesh, the bandspread tuning dial itself being calibraied in terms of each band.

Only in the smaller receivers should the power pack be included in the receiver cabinet, although when S.C./D.C. arrangements are shown this type of power supply may also be included with the receiver, since tive chassis space taken up is small and the power supply can be grouped well to one end of the chassis, provided that ample ventilation is provided. In general, however, even with a smail and simpler receiver, the lieat generated by the power unit should be kept from the set to minimise the chance of frequency drift with temperature.

For battery operation, vilirator power supplies must be tised, and bere the builder is advised to obtain the vibrator power pack commercially, such a pack as the Masteradio "Silent Surge" type, speciaily designed for communications and similar work, proving highly stitable. In the next chapter, however, the circuit of a vibrator power pack is shown.

It will be noted that in the majority of diagrams two H.T. lines are shown, one running at the anode line voltage of 250 volis, the other at the screen voltage of 150 volts. The provision of two lines, one for screen operation, saves a considerable outlay on screen dropping resistances, as well as making screen decoupling simple.

The receivers are shown with straight I.F. amplifiers-that is, no crystal gate is shown. It is feit that the majority of constructors will be content with the selectivity obtained from the use of a regenerative I.F. stage alone, and that if a crystal gate is to be included in the circuit the details in Chapter 5 will enable the work to be carried out without trouble.

## Receiver Alignment

The alignment of the communications receiver must be carried out with great care, and a signal generator is essential. Procedure is as follows:-

Switch on both receiver and generator, and allow them to reach operating temperature-a time of ten minutes at least should be allowed.

Whenever possible, the receiver should be connected into an output meter, either of the Magic Eye type or the " Outpat Meter" sockets of a good circuit analyser. The first alignment is, of course, on the I.F. amplifer, so that the " S " meter of the receiver, if fitted, may be used as the output meter, the A.V.C. line in this case bsing left switched on. The usual practice, however, is to align the set with the A.V.C. tine switched off, since the alignment should be made with the receiver running at maximum gain, so that in the case of a separately-fed " S " meter, such as that shown in Fig. 10, the A.V.C. line may be off, so far as the receiver is concerned, wiilst the meter will sill operate, with enfanced sensitivity.

The B.F.O. shoutd be switched of for all alignments, whilst the crystal gate, if fitted, should be switched out of circuit. Clip the easth lead of the
signal generator to the receiver chassis and take the signai lead from the generator to the grid of the last I.F. amplifier and set the generator to the recuired I.F. -465 kcs . for the circuits shown. 'Trim the last I.F. transformer to give maximum output, reducing the generator signal as the circuit comes into tune. With this transformer set, re-connect the signal lead from the generator to the grid of the first I.F. stage, and trim the next-to-last I.F. iransformer for maximum output in the same manner. (Further I.F. stages following the frequency converter should be trimmed in turn, working beck always to the frequency converter; this applies to a commercial receiver tusing several I.F. stages.)

To align the first I.F. transformer, connect the signal lead from the genemtor to the signal grid of the frequency converter, disconnecting the tuned circtit allied with the frequency converter should the signal passed to the I.F. amplifier appear very weak. This will be cansed by a high-frequency circsit acting almost as a short circuit to the considerably lower frequency oulput of the generator. The output from the generator must be kept at a low leval when feeding into this stage, however, since the 1.F. amplifier is now tuned and witl be giving a high gain to the signal, so that overloading must be prevented.

If a crysial gate is incorporated in the I.F. amplifier, the afignment should be carsied out up to the frequency converter stage as already described, the I.F. as set by the signal generator being as near as possible to the exact crystal frequency. The crystal gate is then switched into circuit, and the signal generator varied very slowly to a slight degree on either side of the set frequency. A rise in output from the I.F. amplifier as the generator frequency is slowly varied indicates that the crystal peak has been found, and the generator should be left at the frequency causing the output rise, ant connected into the frequency converter, whilst the I.F. amplifier is given a final adjustment to bring it to resonance with the crystal.

It is best to use an unmodulated output from the signal generator for aligring the I.F. amplifier when a crystal gate is in use, using the " S " meter indications on the generator carrier. If no " S " meter is fitted, the B.F.O. may be switched on and adjusted to give an audio signal at the output sockets of the receiver, alignment being carried out by bringing this audjo signal up to maximum output.

The I.F. amplifier is now set, and should be left as it stands whilst the remainder of the receiver is aligned.

The procedure for aligning the R.F. circuits will vary with the type of receiver, for in the simpler separately-tuned aerial and oscillator type of set, where no R.F. stage is employed, no further aligning will be required, although the signal generator can be used very effectively to calibrate the two tuning dials.

The osciflator dial is the main tuner, in such a receiver, and signals should be tuned with this dial, the aerial tuner being kept roughly in step until the required signal is heard when the tuning can be finely adjusted. It will be sufficient, therefore, to calibrate the oscillator tuning dial in fairly close frequencies with broad frequency indications only on the aerial dial.

For a receiver employing ganged tuning, however, the oscillator circuits must be set for tracking, the adjustments being made on each frequency range by the following method:-

Set the handspread condenser, if used, to mid-capacity and Jeave. Switch to the first freauency range, and reduce the oscillator trimmers to minimum capacity, leaving other trimmers and paders at half-capacity. Tune the main tuning condenser to the high freguency-low wavelength end of the band, elther to a calibrated spot on the dial, or, if the dial is to be calibrated, a a point just above minimum capacity. Set the signal gencrator to the same frequency-this vill require to be discovered by experiment if the exact coverage of the coils is unknown-and connect the signal lead from te generator together with the earthing clip to the aerial input sockets, or aerial and earth sockets, of the receiver. Trim the oscillator trimmer towards maximum capacity until the signal is heard or indicates on the output meter.

With the higl frequency adjustment temporarily set, mark or note the dial reading of both receiver and generator, and then tune to the low fre-guency-figh wavelength end of the band either to a frequency indicated on he receiver dial, or with an uncalibrated dial, to a frequency near the low Srequency limits of the coils in use. Sci the generator to the same frequency and adjust the padding condenser for maximum output at that frequency. Return to the original high frequency where the trinmer was adjusted. The adjustment will probably have varied, due to the changing of the padder capacity, and the trimmer must be reacijasted for maximum ontput, this rocess of adjusting trimmer and padder and readiusting being carried out until the two adjustments are in final balance. Six or eight readjustments are not too many.

This process must be carried out on each frequency band.
With the oscillator aligned, it remains to trim the R.F. stage, if included in the set, together with the frequency converter input circuit. The trimmers connected with these stages must be trimmed for maximum output at the high frequency end of each range, the whole range being tested, by means of the signal generator, at convenient points to ensure that no points of bad alignment or weak signals exist.

With the receiver aligned on all frequency ranges, it may be tested for correct opeation and stability. A fiss, varying with the tuning of the oscilator stage, indicaies that the oscillator is squegging, possibly because of too high a grid leak value or anode voltage, whilst instability causing oscillaion in the I.F. amplifier is immediately shown when the B.F.O. is switched on, since a continuous squeal or howl is caused, the note varying with the luning of the B.F.O. A regenerative I.F. stage should not, of course, have feedback sufficient to give this effect, and the feedback capacity between grid and anode should be reduced until the stage is regenerative without bursting into oscillation.
" Motorbeating " is almost certainly due to the oscillator's fluctuating in requency with shogt variations of anode voltage, the chance of this defect occurring being highes! witio high selectivity in the I.F. amplifier. Switching out the A.V.C. line will prebably stop the trouble, proving that the oscillator node voltage is fluctuating and that the stage is varying its output frequency sympathy. Only a poorly-designed oscillator would cause this trouble, which may be cured either by re-design of the oscillating circuit or a stabilising device on the oscillator H.T. supply line.
" Birdies," a heterodyne whistle or beat on a signal, are sometimes caused
by feedback into the I.F. amplifier via the A.V.C. diode, or by feedback of signal harmonics from the detector into the R.F. or frequency converter, or may be another sign of squegging in the oscillator, Generally the cure is better circuit arrangement or heavier screening.

It must be remembered, also, that a heterodyne note can be produced by a carrier close to that of the signal under reception, the crystal gate being the only solution to this nuisance.

Components List for a Simple 4-volt Receiver, Fig. 18.

C1, C9,
C2, C4, C6, C7, C10.
C11, C15, C21,
C 3 ,
C5, C12, C13,
C17, C18, C19,
C8,
C14, C22,
C16,
C20,
R1,
R2, R8, R15,
R3, R6,
R4,
R5,
R7,
R9, R16,
R10.
R11,
R12,
R13,
R14,
R17,

60 mmid. Tuners. Raymart MC60X.
0.1 mfd. 350 v.w. Non-inductive.
0.01 mfd .350 v.w. Non-inductive.
0.0001 mfd . Mica.

40 mmfd. Bandspread tuner, Raymart VC40X.
25 mid. 25 v.w. Electrolytic.
8 mfd. 350 v.w.
30 minfd. variable trimmer.
2,200 ohms.
47,000
220
10,000 "
1,000 ,,
5,000 variable, I.F. gain.
220,000 ohms.
680
33,000 ",
68,000 ,,
1 meg. variable. Audio gain.
22,000 ohms.
180
465 kcs . Iron-cored I.F.T.'s.
I.F.T.1, 2

J,
Headphone jack.
R.F.C.,

Short-wave choke
Output transformer, 5 watt, to match to 5,200 ohms load.
Arrange Cr for regeneration over V2, and Cc for coupling between V3 and V4.

| S1, | S.P.S.T. B.F.O. On-Off switch. |
| :--- | :--- |
| L5, | Wearite B-FO. |
| V1, | ACTH1. |
| V2, | VP41. |
| V3, | ACHLDD. |
| V4, | AC2HL. |
| V5, | Pen 45. |

2 Britisl 7-pin chassis mounting valveholders.


1 British 5-pin chassis mounting valveholder.
Chassis, aluminium, $10^{\prime \prime} \times{ }^{\prime \prime} \times 2 \frac{1}{2}^{\prime \prime}$.
1 Tuning Drive.
Coil Data.
1.75 mcs .

L1, 15 turns 26 S.W.G. enam. close-wound, $\frac{10}{4 \prime}$ above L2.
L2, 70 ,, ,,
L3, $\mathbf{1 5}$ ", " 24 ", ", ",
L4, 42 , ", ," ," Tap-Top of coil.
3.5 mes.-

L1, 9 ", ", ", $\frac{1}{2}^{\prime \prime}$ above L2.
L2, 35
L3, 10 " " " " " $\quad$ "
L4, $25 \quad$ " ", " " ", ", Tap-18 turns up.
7 mcs.-
L1, 5 , " ", $\quad, \quad$ " above L2.
L2, $20 \quad$ " $18 \quad$ " $\quad 18 \quad$ ", $24 \quad$ " below L4.
L4, 14 " 18 ", $\quad$ to $1^{\prime \prime}$ long. Tap-6 turns up.
14 mcs .
L1, 5 , 24 , , close-wound, $\frac{1}{\frac{1}{\prime \prime}}$ above L2.
L2, 10 ", 18 ," to 1 " long.
L3, 4 ", 24 ", close-wound, $\frac{1}{2}$ " below L4.
L4, 7 " 18 " to $1^{\prime \prime}$ long. Tap-- $2 \frac{1}{2}$ turns up.
28 mcs .
L1, 4 " $24 \quad, \quad$ close-wound, $1^{\prime \prime}$ above L2.
L2, $4, \quad 18, ", \quad$ to $1^{\prime \prime}$ long.
L3, 3 " 24 ," close-wound, $\frac{11}{4}$ below L4.
L4, $3 \frac{1}{2} ", 18 ", \quad "$ to $1 "$ long. Tap- $1 \frac{1}{2}$ turns up.
Coils L1, L2, and L3, L4, all wound on $1^{\frac{1}{2}}{ }^{\prime \prime}$ diameter formers.
Provide 2 coilform holders.
Components List for a Simple 6-volt Receiver, Fig. 19.
L1, L2, L3, L/4, sections of commercial tuning pack, such as A.I.S Type 30A, etc. Note, padding condensers, and trimmer values are not shown, since these are included in commercial packs.

C1, C8,
C2, C9,
0.0005 mfd . ganged tuner.

C3, C4, C10, C11,
C12, C13, C14, C15,
C18, C19, C20,
C5,
C6, C7,
C16, C17,
C21, C23,
C22,

60 mmfd . ganged bandspread tuner, with
Raymart MC60X tuners and couplers.
0.1 mid. 350 v.w. Non-inductive.
0.0002 mfd . Mica.
0.01 mfd. 350 v.w. Non-inductive.
0.0001 mfd . Mica.

25 mfd .25 v.w. Electrolytic.
8 mfd. 350 v.w


48

R1,
R2, R9,
R3, R7, R11,
R4,
R5,
R6, R10,
R8,
R12, R15,
R13,
R14,
R16,
R17,
R18,
R19,

10,000 ohms.
2,200
$220 \quad "$
47,000 ",
15,000 ,,
1,000 ,,
5,000 ohms variable, I.F. gain.
100,000 ohms.
470,000 ,,
22,000
3,300
1 meg. Audio gain.
220,000 ohms.
430
$\frac{1}{2}$ watt ratings.)
S1, 2, 3, 4,
S5,
J,
I.F.T.1, 2, 3,

T1,
V1,
V2, V3,
V4,
V5,
Wavechange switches, ganged.
D.P.S.T. Standby switch.

Headphone jack.
465 kcs . iron cored I.F.T.'s.
Output transformer, 5 watt, to match 7,000 ohms load.
6 K 8.
6SK7.
6SQ7.
6F6.
5 International octal chassis mounting valveholders.
Chassis, aluminium, $10^{\prime \prime} \times 8^{\prime \prime} \times 2 \frac{1}{2}^{\prime \prime}$.
2 Tuning Drives.
Arrange for regenerative capacity over V2.
No B.F.O. is included in the circuit, but may be added if required.
Components List for an Advanced 4-volt Receiver, Fig. 20.
L1, L2, L3, L4, L5, L6, sections of commercial tuning pack, such as the M. Wilson 6 Waveband Coil Kit, 5-2,000 metres.

Note.--Padding condensers and trimmer values are not shown, since these are included in commercial packs.
C1, C6, C13,
C2, C7, C14,
0.0005 mfd . ganged tuner.
60 mmfd . ganged bandspread tuner, with
Raymart MC60X tuners and couplers.

C3, C4, C5, C8,
C10, C15, C16,
C17, C18, C19,
C20, C22, C26,
C28, C29, C30,
C9, C11,
C12,
C21,
C23,
C24, C25,
0.1 mfd .350 v.w. Non-inductive. 0.0002 mfd . Mica.
$0,0005 \mathrm{mfd}$. Mica.
50 mmfd. Silver Mica.
$0.25 \mathrm{mfd} .350 \mathrm{v} . \mathrm{w}$. Non-inductive.
0.0001 mfd . Mica.


| C27, C32, | 25 mfd .25 v.w. Electrolytic. |
| :---: | :---: |
| C31, | 8 mfd .350 v.w. ," |
| R1, R10, | 1,000 ohms. |
| R2, R17, | 220 , |
| R3. | 5,000 ohms variable, R.F. gain. |
| R4, R8, | 10,000 ohms. |
| R5, Ril, R15, | 330 |
| R6, R24, | 22,000 ", |
| R7, R9, R13, | 1 meg. |
| R12, | 10,000 ohms, variable, I.F. gain. |
| R14, | 470 ohms. |
| R16, | 1,000 ohms, variable, " S " meter zero set. |
| R18, | 6,200 ohms |
| R19, R30, | 39,000 ", |
| R20, R21, | 680,000 ", |
| R22, | 100,000 ", |
| R23, | 470,000 ", |
| R25, R28, | 47,000 ", |
| R26, | 680 , |
| R27, | 1 meg. variable. Audio gain. |
| R29, R32, | 220,000 ohms. |
| R31, | 10,000 ohms variable. Noise limiter set. |
| R33, | 180 ohms. |

I.F.T.1, 2, 3,

M,
J,
R.F.C.1,

S1-6,
S7,
S8,
T1,
V1,
V2,
V3, V4,
V5,
V6,
V7,
Pen. 45.
1 British 7-pin chassis mounting valveholder.
5 Mazda octal
1 D1 holder.
No B.F.O. is included in the circuit, but may be added if required
Chassis, aluminium, $16^{\prime \prime} \times 8^{\prime \prime} \times 2 \frac{12^{\prime \prime}}{}$.
2 Tuning Drives.
Arrange regenerative capacities across V1 and V3.


Frg. 22. Using the High Bias Line.

10 International octal chassis mounting valveholders.
T1, Output transformer, 5 watts, to match 8,000 ohms load.
Chassis, aluminium, $16^{\prime \prime} \times 8^{\prime \prime} \times 2 \frac{12^{\prime \prime}}{}$.
2 Tuning Drives.
Arrange regenerative capacities across V1 and V4.
Components List for the High Bias Line Control of the R.F. Stage, Fig. 22.

L1, First tuned circuit, R.F. stage.
CI,
C2, C3,
C4,
R1,
R2,
R3,
R4,
R5,
S1,
S2,
V1,
Note.-The first I.F. stage may also be switched into the High Bias control, as shown, if a higher degree of control is required.

Components List for a 5-metre Converter for 4 or 6 volt operation, Fig. 23.
L1, 2 turns 20 S.W.G. enam. $\frac{1^{\prime \prime}}{2}$ diam., $\frac{7^{\prime \prime}}{4}$ above L2.
L2, 6 ", 16 , $\frac{1}{2}{ }^{\prime \prime}$ ", to $\frac{3}{4}{ }^{\prime \prime}$ long. L3, $10, \quad 16 \quad \ddot{\prime} \quad, \quad \frac{1}{2} ", \quad$ to $1 \frac{1}{4} "$ long.
L4, L5, Wearite PHF5, tuned to 10 mcs .

| C1, C6, | 15 mmfd . tuners, Rayma |
| :---: | :---: |
| C2, C3, | 0.01 mfd . 350 v.w. Non |
| C4, | 0.0001 mfd . Mica. |
| C5, C7, | 3.30 mmfd , variable tri |
| r 4-volt operation :- |  |
| R1, | 10,000 ohms, 1 watt. |
| R2, | 33,000 |
| R3, | 47,000 |
| R4, | 330 |

For 6-volt operation :-

R1,
R2,
R3,
R4,
(Resistors, $\frac{1}{2}$ watt ratings, unless otherwise specified.)


Fig. 23. A 5 metre Converter for 4 or 6 volt Oparation.
R.F.C.,

V1,
1 British 7 -pin chassis mounting valveholder, or
1 International octal chassis mounting valveholder.
Slow-motion drive for C6, main tuning, knob drive for C1.
Chassis, $7 \frac{1}{2}{ }^{\prime \prime} \times 3 \frac{1}{2}{ }^{\prime \prime} \times 2^{\prime \prime}$.

## Chapter 7

## POWER SUPPLIES

The power supply for a communications receiver should be stable, capable of excellent regulation and, although not required to supply a high voltage, must be able to supply a fairly heavy current without any heating.

A good transformer is necessary to ensure proper regulation and a heavy heater winding will be required to supply all the valve heaters, especially if 4 -volt valves are in use. The power pack, and therefore the whole equipment, should be protected by fuses both in the primary to mains wiring and also in the receiver supply line. The power leads to the receiver may terminate in a plug, constructed from an old octal valve base, the leads being soldered into the pins and the base then filled with Chatterton's compound or a good wax. At the receiver, the power supply may be received in an ordinary octal socket mounted at the end of the chassis, or at the rear. The power input point should be at the audio end of the receiver, bus-bar distribution through the receiver being advised.

Smooth working of the power supply is assisted by the bleeder resistance which also allows the low voltage screen feeding line to be taken out, and the adjustable bleeder should be set, with the receiver load connected to the power pack, to give the correct voltage.

A bias pack may be used with any receiver to provide a high bias line to which the R.F. amplifier may be switched for Standby or monitoring the local transmitter, or batteries may be used since the current drain is negligible and layer-built type batteries may be used, thus allowing the biasing department to be condensed to a very small size.

It may seem extravagant to give over a valve and transformer for biasing one stage, but in any case a high bias line is only required by the amateur transmitter. In the circuils showing a high bias line, this may be replaced by a simple Standby switch in the negative or positive H.T. line by the constructor who is interested only in reception. In any case, the separate heater transformer can be dispensed with if 4 -volt valves are used throughout the apparatus, since in that case a spare 4 -volt secondary on the main transformer can be used to supply the rectifier heater, an ordinary 4 -volt rectifier being used with one section out of circuit, or strapped in parallel with the other section.

It will be seen that the bias supply has only half-wave rectification and resistance smoothing, but since only a fraction of the total voltage is used and the current is negligible the smoothing thus obtained is amply sufficient for the purpose.

Although the load of the communications receiver is steady, that is, there are no great current changes as are found in, for example, a Class B amplifier, it is thought advisable to use two-section filtering for the mains supply to give as quiet operation as possible. Where economy is necessary, however, a perfectly straightforward power supply circuit may be used with only a single L.F. choke and two condensers rather than the two chokes and three condensers shown.
A.C. power packs are shown in Figs. 24 and 25, the main difference being in the bias supply arrangements. In Fig. 24 the bias rectifier is supplied from a separate heater transformer; in Fig. 25, a power pack for 4 -vole valves, the bias rectifier is supplied from a heater winding on the maies transformer. In either case the bias voltage supplies may be onitted from the circuit altogether if desired.
, When A.C./D.C. operation is required a rather different set of circumstances arises. The use of ordinary 0.2 amp . heater valves would mean in any case that the heaters of some of the valves would be at high potentials above earth, since the number of stages in a communications receiver is, in general, higher than the number found in other receivers. The potential difference between the heater and earth increases the chance of hum as the potential rises, and thus it is desirable to keep the heater drop over the whole chain at as low a value as possible. The most promising solution would appear to be to use American 6 volt 0.3 amp . valves in all stages except the output stage, where no suitable 0.3 amp . valve is readily obtainable. In this stage, however, a British 0.2 amp . valve may be used, the heater being shunted by a suitable resistance to pass the further 100 mAs . heater current drawn by the rest of the circuit. The value of the resistance is calculated by Ohm's Law, and for one very suitable valve, the Mazda Pen 3520, whose heater operates at 35 volts 0.2 amp ., the resistance across the heater would be

$$
\mathrm{R}=\frac{35}{0.1} \text { ohms }
$$

or $\mathrm{R}=350$ ohms, and the resistance rating would be $35 \times 0.1$ or 3.5 watts. Such a resistance may be made up of standard values, using a 200 ohms and a 150 ohms resistances in series, each being rated at 2 watts.

A barretter is preferable to a wire-wound dropping resistor for applying the correct potential across the heater chain, since the barretter gives a good degree of automatic compensation for changes in line voltage whilst at the same time it requires no setting to value as does the ordinary dropping resistor with an adjustable tap. Should a dropping resistor be used, however, it must be set to the correct value to give a current of 0.3 amps . through the heater chain as measured by a good A.C. or D.C. ammeter to suit the supply.

Alternatively the dropping resistor may be adjusted by measuring the voltage across the whole heater chain, the dropping resistor being adjusted until the correct voltage is shown on a good A.C. or D.C. voltmeter, the type of meter again depending on the supply.

It must be remembered that the adjustments should be made by reducing resistance-i.e., the dropping resistance should be high in value, the resistance being lowered until the valve heaters are correctly loaded. The measurements should be taken a half-minute or one minute after adjustments, since the valve heaters undergo a change of resistance with heat, as does practically any circuit.

No arrangements are shown for a high bias line in the A.C./D.C. power pack of Fig. 26, as there is no convenient way of obtaining it. If a high bias line is required, batteries must be used.

It must also se emembered that gear working from an A.C./D.C. surply is alive to the mathand the piag shoud be connected into the socket in such a way thai the chassis of the power pack and the chassis of the receiver are both comected to the earthed mains line. In some cases it may be found that the mositive line of the mains D.C. supply is earthed so that it is virtually impossible to connect the chassis of the gear to the earthed line. in this case, every precaution must be taken when using the gear, esprecially if it is desired to work with headphones, and the whole operating position, including the apparates itself, should be insulated by the use of rubber mats.

In every A.C./D.C. operaied receiver, not only the earthing connection to the chassis, if used, should be isolated from actual connection with the chassis by an 0.01 mid. 500 v.w. condenser, but the aerial also should be isolated in the same namner.

The rating of the batreiter or dropping resistance is of course determined by the number of vaives used, together with their common current consumption and the supply voltage. For example, a circuit using 6 volt 0.3 amp. valves in an R.F. stage, a frequency converter, two I.F. stages, a celector and B.F.O. combined, an A.V.C. and " $S$ " nepter stage combined and with an audio amplifier before the output stage wotild have seven 6 -volt vanes with their heters connected in series, the total drop thus being 6.3 volts $\times 7$ or 44.1 volts at 0.3 amp . Then the output stage, using as recommended a Pen 3520 shunted by a 350 ohm resistance, would introduce a further drop of 35 volts at 0.3 amp ., so that the total heater load would be 79.1 or 79 volts, 0.3 amp . The barretter or dropping resistance must therefore be capable of handing the heater current of 0.3 amp .

Besides the voltage across the valve heater chain, however, the rectier also requires feeding. The $25 \vee 5$ and 2525 types of rectifer are in good supply at the time of writing, and are capabie of supplying up to 80 mAs ., which is sumeent for all but the largest receivers, these rectifiers being suitable since they also reguire 0.3 amp . through the beater. The $35 R E$, at present in very short supply, can give up to 120 mAs ., and also requires a heater current of 0.3 amp., whilst the heater voltage is, as inclicated by the code name, 35 volts. Presume, however, that a 2575 rectifer is to be used. The heater volfage of this valve must also be added to the voltage drop across the receiver heaters, so that the total heater voltage required is 79 plus 25 voits, or 104 voits.

With the usual mains voltage of 230 voits, this means that the barretter will have to drop 220-104 volts, or 126 volts. The barretter is chosen so that this figure falls as near as possible to the centre of the working range-for example, the Phillips Miniwatt type of regulator is rated at 0.3 armp., 100-240 volts for the type number 1941, so that this barretier would be perfectly suitable.

The constructor who wishes to work the receiver from a Vibrator power pack may either purchase a commercial model of pack, such as the Masteradio "Silent Sugge," already mentioned, or construct his own pack using bought components.

Very careful screening and filtering must be provided, for a vibrator pack will radiate R.F. interference taiess every precaution is taken. The


Fig. 24. A.C.' Power Pack for 6-volt valves.


Fig. 25. A.C. Pow-r Pack for 4 -volt valves.
battery leads must he fitted with a heavy current choke in order that "hash" is not introduced into the receiver via the valve heaters, whilst the output line must be fitered for both R.F. and L.F.

Either synchronous vibrator or valve rectification may be used, and if vaive rectification is decided upon it is recommended that the 0Z4 gas rectifier be used, since this valve reģuires no heater supply and thus not only is battery drain reduced but the chance of a brealdown obviated. The $0 Z 4$ rectifier is at present in good supply from Government surplus stores, etc., and can supply up to 75 mAs . at 300 volts D.C. Less than 30 mAs . should not be drawn, since the valve will then work at reduced efficiency or refuse to operate properly at all.

If a current greater than 75 mAs . is required, it is advised that synchronous vibrator rectification be used.

Whilst vibrator transformers can be constructed or adapted from existing mains transformers, greater efficiency and more silent working will be obtained by using a commercial model.

The vibrator power supply must be enclosed in a metal or metal-lined box, the earth connections throughout being made with heavy gauge wire, and good quality components must be used, the working voltage values of the condensers being particularly noted. The wave shape of the currents in both primary and secondary of the vibrator transformer give rise to back E.M.F.'s sufficiently high to break down condensers of low working voitage ratings, and any breakdown or short-circuit in the power pack can cause serious damage to the vibrator.

A fuse in the supply lead to the battery is also essential, since should the vibrator contacts stick a very heavy current would fow through the vibrator and one half of the transformer primary, possibly fusing the transformer and damaging the battery. The usual fuse value used in this position is 10 amps . The switch in the battery lead should be rated at 10 amps , and should be of the Q.M.B. type.

The " hash " choke may be home-wound, using 60 or 70 turns of 16 S.W.G. enamelled copper wire (or heavier) on a 1 " diameter former such as a wooden dowel.

Components List for the A.C. Power Packs, Figs. 24 and 25.

> T1 (Fig. 24),

T2 (Fig. 24),

T1 (Fig. 25),
L.F.C. 1, 2,

C1,
C2, C4, C6,
C3,
C5, C7,
200.250 v. primary.

5 v .2 a . secondary.
$200-250$ v. primary.
250-0-250 v. 200 mAs . secondary.
6 v. 4 a. 5 v. 2 a.
$200-250$ v. primary.
$250-0-250 \mathrm{v} .200 \mathrm{mAs}$. secondary.
4 v. 2 a. 4 v. 2 a. 4 v. 8 a.
20 Hys. 200 mAs. 150 ohms.
0.1 mfd. 850 v.w. Non-inductive.

8 mfd .350 v.w. Electrolytic.
$16 \mathrm{mfd} .350 \mathrm{v} . \mathrm{w}$.
8 mfd . 500 v.w.

R1,
R2,
R3,
F1,
F2,
S1,
V1, V2 (Fig. 24),
V1, V2 (Fig. 25),
2 International or Mazda octal chassis mounting valveholders. Chassis, $9 \frac{1}{2}^{\prime \prime} \times 4 \frac{1}{2}^{\prime \prime} \times 2^{\prime \prime}$, aluminium.

Components List for the A.C./D.C. Power Pack, Fig. 26.
L.F.C. 1, 2,

R1,
R2,
C1,
C2, C4,
C3,
C5,
V1,
B,
International octal chassis mounting valveholder
1 Holder for Barretter used.
F,
S1,
Chassis, $9 \frac{1}{2}^{\prime \prime} \times 4 \frac{1^{\prime \prime}}{} \times 2^{\prime \prime}$, aluminium.

## Components List for the Vibrator Power Packs, Figs. 27 and 28.

T1,
R1, R2,
R3,
R4,
C1,
C2,
C3,
C4,
C5, C7,
C6,
C8,
R.F.C. 1,
R.F.C. 2,
L.F.C.,

F,

1 amp. fuses.
10,000 ohms, 3 watts, with slider
22,000 , 1
10,000 " 1 ,
5 amps. fuses.
200 mAs . fusebulb with holder.
D.P. On-Off Switch.

5Y3G.
5 Y3G
UU6. hassis

20 Hys. 100 mAs .150 ohms.
5,000 ohms, 3 watts, with slider.
22,000 ,, 1 .,
0.1 mfd .350 v.w. Non-inductive.

8 mfd .350 v.w. Electrolytic.
16 mfd .350 v.w.
8 mfd. 500 v.w.
25Y5, 25Z5, 35RE "etc
Barretter to suit heater load.
D.P. On-Off Switch.

Vibrator transformer, Bulgin M.T.5, or similar.
220 ohms, 1 watt.
4,700 ," 1 "
To suit screen current. (See Note.)
0.5 mfd .350 v.w. Non-inductive.
0.0003 mfd . Mica.
0.01 mfd . 1,500 v.w.
0.01 mfd .350 v.w. Non-inductive.

8 mfd .350 v.w. Electrolytic.
16 mfd .350 v.w.
0.1 mfd .350 v.w. Non-inductive.

Hash filter. (See text.)
Screened all-wave choke.
20 Hys. 100 mAs .150 ohms.
10 amp . fuse.


Fig. 26. A.C./D.C. Power Pack.


Fig. 27. Vibrator Pack with Valve Rectification.


66
s1,
B,
D,
V1 (Fig. 27),
Q.M.B. On-Ofi Switch. 6 -volt accumulator battery. Vibrator driving coil.
024.

1 International octal cliassis mounting valveholder for V1.
Chassis and shielding cover.
Note.--The constructor should follow any makers' instructions obtained with the vibrator, particularly as regards buffering circuits. It may be desirable, for instance, either to shunt R1 and R2 with 0.1 mfd. condensers, or to replace the resistances altogether by such condensers.

It is possible to obtain a reversed polarity at the output side, so that no output filter component should be connected up, especially C5, C6 and C7, the electrolytic condensers, until the output polarity has been checked. This, of course, refers to Fig. 27.

A dropping resistance rather than a potential divider is used for the screen supply to avoid further current drain. The resistance R4 should be chosen to give the correct voltage drop at the current passing, using a simple calculation by Ohm's Law. Each circuit diagram in the previous chapter shows the approximate screen current on the 150 -volt line.

This method may also be used, if desired, in the A.C. and A.C./D.C. power packs.

## Chapter 8

## AERIALS FOR COMMUNICATIONS

It is, of course, impossible to give anything like a full account of aeria! theory and practice in a few pages, but some salient points can be noted especially for the use of the receiving amateur. The transmitting amateur will in all probability use the one aerial for transmission and reception except for Duplex and Break-in working, which means that the aerial and its coupling to both transmitter and receiver will be adjusted to the band in use and will thus be working at maximum efficiency at all times.

The transmitting aerial, as has already been noted, is usually the best receiving aerial, but where the communications receiver is to be used alone, in a listening post, then the most useful aerial is that which will receive all amateur bands as well as broadcast and commercial stations with as great efficiency as possible.

The reader who requires further information on aerials and their many types is referred to the Aerial Handbook, No. 56, in Bernards' List.

At high frequencies-that is, for short-wave reception-a tuned aerial can be erected in quite a small space. The best example is perhaps the television aerial, seen in ever greater numbers at tha top of flagstaffs and attached to chimneys. This type of aerial is a vertical half-wave, and often has a reflector so situated that the true aerial is in line with transmitter and reffector, the reflector, naturally, being behind the aerial.

The inaif-wave acrial. as its name suggests, is a half-wavelength long, measured eiectrically rather than mechanically. An acrial suffers from what is known as the "end effect" so that a half-wave aerial is slightly shorter than a measured half-wave, the relationship being given by the formula

$$
L=\frac{462}{f}
$$

where $L$ is the total length of the aerial in feet and $f$ is the operating freguency in megacycies. The formula can also be given as

$$
\mathrm{Li}=\frac{5540}{\mathrm{f}}
$$

where Li is the aerial length in inches.
To take an example, a television acrial for vision reception must work with maximum efficiency at 45 mcs ., so that the aerial length is

$$
\mathrm{Li}=\frac{5540}{45}
$$

or $\mathrm{Li}=123.1$ inches or $10^{\prime} 3^{\prime \prime}$.
The television aerial is mounted vertically since the transmitter aerials are also vertical, and the transmitted waves are therefore said to be vertically polarised. This polarisation holds only over relatively short distances, however, so that for general working on rather lower frequencies the great majority of aerials are horizontal. The increased length of an aerial for lower frequencies also makes horizontal construction simpler, although the new B.B.C. vertical long-wave aerial may be cited as an example of vertical polarisation on the very low frequency band.

By erecting an aerial tuned to the frequency of operation the signal strength is increased at the receiver and, at the transmitter, the aerial accepts all the power which can be passed to it.

For working on the 20 and 40 metre amateur hands the half-wave aerial is still sufficiently short for erection in a fairly small space, but it is practically impossible to erect a tuned aerial for, say, the broadcast transmissions at medium irequencies, and in any case such an aerial would be larger than the licence allows.

For wide frequency coverage, therefore, a compromise must be made. The aerial in any case will be more efficient at the higher frequencies which is where the efficiency is needed, so that the best arrangement is that which will give good working on all the amateur bands, the lower frequencies being left to take their chance.

The direction in which the aerial receives most efficiently also requires consideration. The half-wave aerial, at whatever frequency for which it is built, receives most strongly from a direction at right-angles to the plane of the aerial wire, and is thus known as a broadside radiator or receiver. Reccuton of stations in line or nearly so with the wire will, other things beins oftul, be much weaker than reception from stations in a direction perpendialar to the wire. For this reason, 5 and 10 metre transmitters ofte: arrange their aerials to be rotating, so that the array can be turned bodily to direct the signal to any required compass point.

By erecting an aerial known as a " long wire," however, the "end fire" effect--that is, the strength of transmission or receptica in line or nearly so with the aerial wire itself is greatly improved, whilst the broadside radiation or reception is attenuated. In generai, however, a wire twice the wavelength of the favoured band in length will give good all-round coverage in the British Isles if erected in a due East-West direction.

The formula for the length of a two-wavelength aerial, or for any aerial longer than a half-wave, is

$$
L=\frac{492(n-0.05)}{f} \text { feet }
$$

where $L$ is the length of the aerial wire in feet, $n$ is the number of half-waves in the aerial length, and $f$ is the favoured operating frequency in mes. Thus, as an example, if the favoured band is the 20 metre anateur band, the frequency in this case being taken as 14 mcs., the two-wavelength aerial will contain four half-waves. The formula then becomes

$$
L=\frac{492(3.95)}{14} \text { feet }
$$

or $L=138.8$ feet.
It is still necessary to connect the aerial to the receiver, and the best method to use with a long wire aerial is to cut the aerial at the exact centre. supporting the cut ends by a short insulator of strength sufficient to carry the strain of the aerial. The wire is thus separated into two eoual portions in line one with the other.

All aerials have a radiation resistance, or characteristic resistance presented to a feeder system at their points of maximum current fcurrent antinodes). Resistance of a four half-wave aerial is approximately 110 ohras, though this resistance changes within fairly narrow limits with the height of the aerial and the type of ground at the locality. The feeder requires matching to this aerial resistance and also to the receiver, and so a suitable type of feeder must be chosen and matched to the receiver, for best results, through a circuit such as that shown in Fig. 3, although the feeder may be taken directly to the receiver with a slight loss of efficiency.

The use of a 110 ohms feeder will allow the connection to be made, at the aerial end, directly to any current anti-node (these occur at every odd quarter of a wayelenth along its length, that is, in a two wavelength aerial at points along its length equal to $\frac{3}{3}, \frac{3}{3}, \frac{5}{8}$ and $\frac{7}{8}$ of the total length. The aerial may be cut at any of these points and 110 ohm feeders connected

Such a feeder may be purchased, and the mismatch will not be serious if 80 ohm feeder is used. Several makers can supply such feeder and ordi nary lighting flex presents approximately the correct characteristics, although such a feeder would not weather well.

In a situation where bad interference is experienced, another type of feeder may be reguired, where twin wires are lashed to tramsposition blocks at every 18 " or so, such blocks being obtainable from Messrs. Eddystone or kaymarts. The feeder wires are thus crossed at regular intervals, the effect being to cancel out any signal, including interference, which is picked up by
the feeders themselves. A matching unit should be used between such a feeder and the receiver.

In very noisy localities, with interference from traffic, neon signs, and the like, a short ae:ial may prove better than a properiy-designed long aerial, since the signal-to-noise ratio must be kept high for satisfactory reception. In this case, the aerial can only be decided upon by experiment, and it may prove beneficial to use a complete commercial aerial system such as the " Eliminoise."

## APPENDIX

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