Transistor Circuits for the Constructor

No. 4

E. N. BRADLEY

This latest addition to the series contains descriptions of unusual receivers commencing with complete details of a medium and long wave superhet using TRANSFILTER i.f. stages. These modern components need no alignment and confer great selectivity on the sensitive 4-transistor frequency-changer, i.f. and detector strip. These receiving circuits can be followed by various types of output stage—from a simple earpiece to a quality 1-watt amplifier. The original receiver was tested in difficult reception areas from the Lake District to Land's End with excellent results.

There follows a full description of a 3-transistor ALL-WAVE t.r.f. receiver with six wavebands covering a range of 2,000 metres down to 15 metres. World-wide reception has been obtained on the prototype using only a built-in whip aerial and earth connection. The circuit is simple and straightforward enough to be built by any constructor.

The book concludes with two very novel circuits for the experimenter. Both are for v.h.f./f.m. reception, the first using only one transistor, and the second only four transistors.

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CHAPTER 1

A TRANSFILTER PORTABLE SUPERHET

TRANSFILTERS, or ceramic i.f. transformers, are the most recent of the new components which are being developed to work in conjunction with transistors. Described by the manufacturer as "ceramic filters with impedance matching characteristics" they take the place of conventional wirewound i.f. transformers. A transfilter consists of a small disc of ceramic piezoelectric material, one face being completely silvered and carrying a single wire lead connected to the silvering, the other face being silvered in two sections, forming an outer "ring" and an inner "dot". The ring and the dot each carries its own connecting lead. The dot is the input electrode and if a suitable frequency signal is fed to the dot the disc, being piezoelectric, will resonate in sympathy. The mode of resonance is radial and as a result a signal at the same frequency becomes available at the ring electrode. The mechanical and electrical characteristics of the disc are such that the dot has a fairly high input impedance—of the order of 2kΩ and over—and so is suitable for connection to the collector circuit of a transistor i.f. stage. The ring has a fairly low output impedance (about 300 ohms) and therefore matches well into the base circuit of a transistor i.f. stage.

The general appearance of a transfilter disc, with its technical symbol, is shown in Fig. 1. The disc is mounted in a plastic case and the connections brought out to three lugs to give the appearance and dimensions shown in Fig. 2.

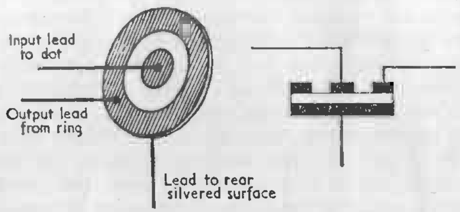

FIG. 1. A TRANSFILTER ELEMENT AND ITS TECHNICAL SYMBOL

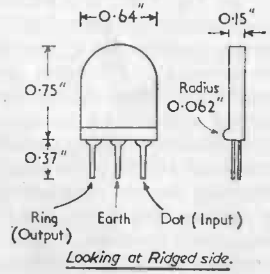

FIG. 2. TRANSFILTER DIMENSIONS AND CONNECTIONS

A transfilter operating at an i.f. of 455kc/s or so is actually resonating at the first overtone of its fundamental frequency which is in the region of 180kc/s; this simplifies manufacture since a fundamental frequency of 455kc/s would require too small a disc for convenience. As a result some precautions are necessary to ensure that no fundamental frequency signals are fed to a ceramic i.f. transformer stage, and signals with frequencies around the second overtone—approximately 700kc/s—must also be filtered out. It is therefore quite usual to couple the first stage in a ceramic i.f. transformer amplifier to the frequency-changer by means of a conventional double-wound i.f. transformer.

A second form of transfilter is available, smaller in size than the ceramic i.f. transformer, and with only two connecting lugs, which replaces emitter by-pass capacitors in transistor i.f. amplifying stages. The characteristics of this type of transfilter are such that it presents a very low impedance—about 15 ohms or less—at the intermediate frequency and a considerably higher impedance at all other frequencies, thus further improving the selectivity of the i.f. circuit. This extra selectivity is not required in the receiver to be described and only the transformer type filters are used.

Transfilters offer several advantages to the constructor, the first of which is, of course, that they require no tuning or adjustment, the i.f. amplifying stages always being in tune. Where a wound transformer is used between the frequency changer and i.f. amplifier, as in the present circuit, this is simply adjusted during receiver alignment for best results and can never be so far off tune as to prevent signals from being heard.

A ceramic i.f. circuit is very stable. High frequency transistors can be employed in common emitter circuits for good gain without any neutralization and, further, the receiver is very selective, owing to the transfilter action, enabling stations adjacent on the tuning scale to be separated with the minimum of interference. Finally, transfilters are inexpensive, costing little more than ordinary i.f. transformers.

The prototype receiver was intended to fit into an existing case and since it was not miniaturized a good quality 1-watt amplifier was used as an output stage. A much smaller output can be used, however, and the circuit could be built into a very small case as a pocket receiver. The circuit of the frequency changer, i.f. amplifier and detector is shown in Fig. 3. Both medium and long-wave ranges are included, and a transistor detector, rather than a diode detector, provides a good level audio output and supplies amplified a.g.c. to the first two i.f. stages. The measure of automatic gain control thus provided makes it unnecesssary to include an overload diode. The sensitivity and selectivity of the receiver make it suitable for use in any reception location.

In Fig. 3 Tr_1 is the frequency-changer, an OC44 being recommended. A commercial oscillator coil and first i.f. transformer are employed but a home-made aerial of simple construction is used to simplify the design and to obviate the trouble, experienced in some circuits, of high frequency instability. This takes the form of oscillation or whistling at the low wave-length end of the medium-wave tuning range and is due mainly to stray capacitance coupling between the aerial and oscillator circuits. In preventing this fault the first essential is to use a ganged tuning capacitor with screening between the two sections; in the present circuit this presents no difficulty since a normal 500pF twin gang tuner is used. Careful selection of values for the bias chain resistors, R_1,R_2 is important but a great deal can be done to improve frequency-changer performance by adjusting the ratios of the aerial primaries and secondaries. The aerial coils are damped by their secondary windings, the damping naturally increasing as the secondaries are made larger. In the present receiver the reduction of signal input to the frequency-changer entailed in the use of large secondary windings appears, on test, to be relatively unimportant, and the aerial coils were designed to feed into a high grade OC44. As a result the frequency-changer circuit should suit practically any r.f. transistor, so far as stability is concerned.

The Repanco i.f. transformer, an XT6, is designed to feed into the emitter of a common base stage but in this circuit, as shown in Fig. 3, it is connected into the base of Tr_2. The output of this transistor is developed across R_5 and applied to the dot of the first transfilter TF_1, whose ring feeds the base of Tr_3. The bias to both Tr_2 and Tr_3 is fed from the collector of the detector transistor, Tr_4, through filtering circuits formed by R_{14}, C_{13}, R_7, C_{10} and R_8. The second transfilter couples Tr_3 into the base of the detector which also serves as the first audio amplifier, the output being taken from the slider of a 5kΩ volume control. Resistor R_{16} with C_{15} and C_{16} forms an i.f. filter and also prevents

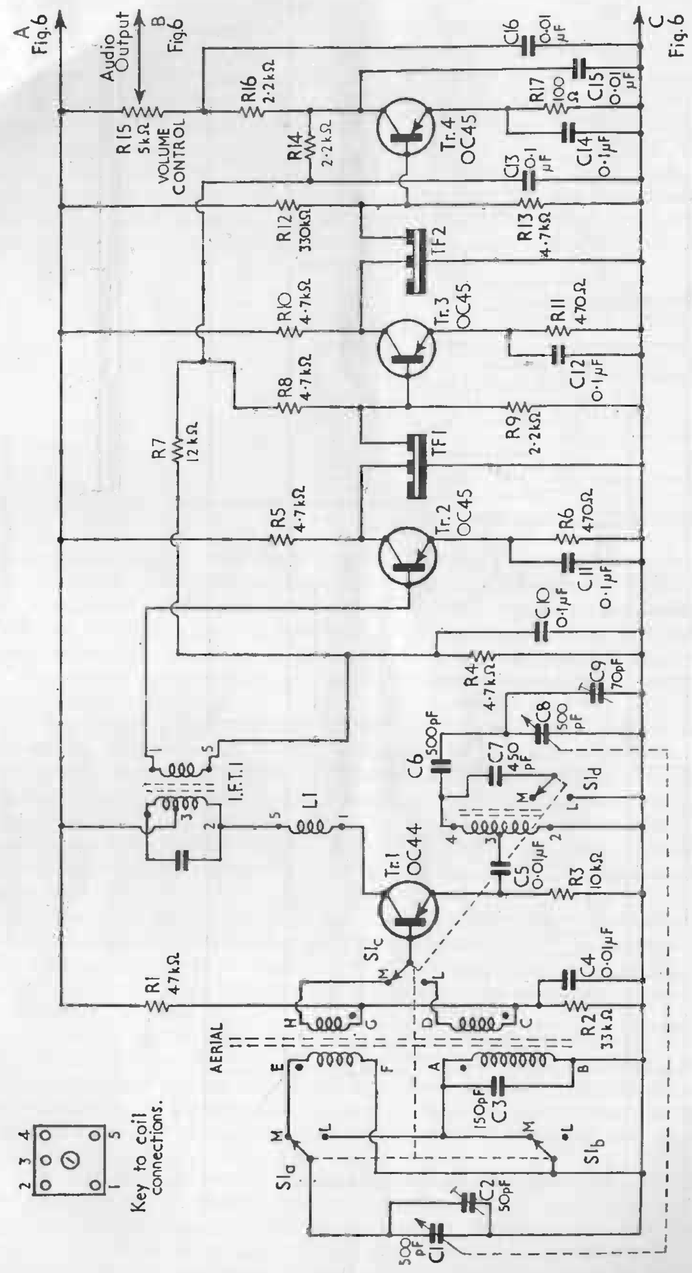

FIG. 3. THE TRANSFILTER PORTABLE SUPERHET; R.F., I.F. AND DETECTOR STAGES

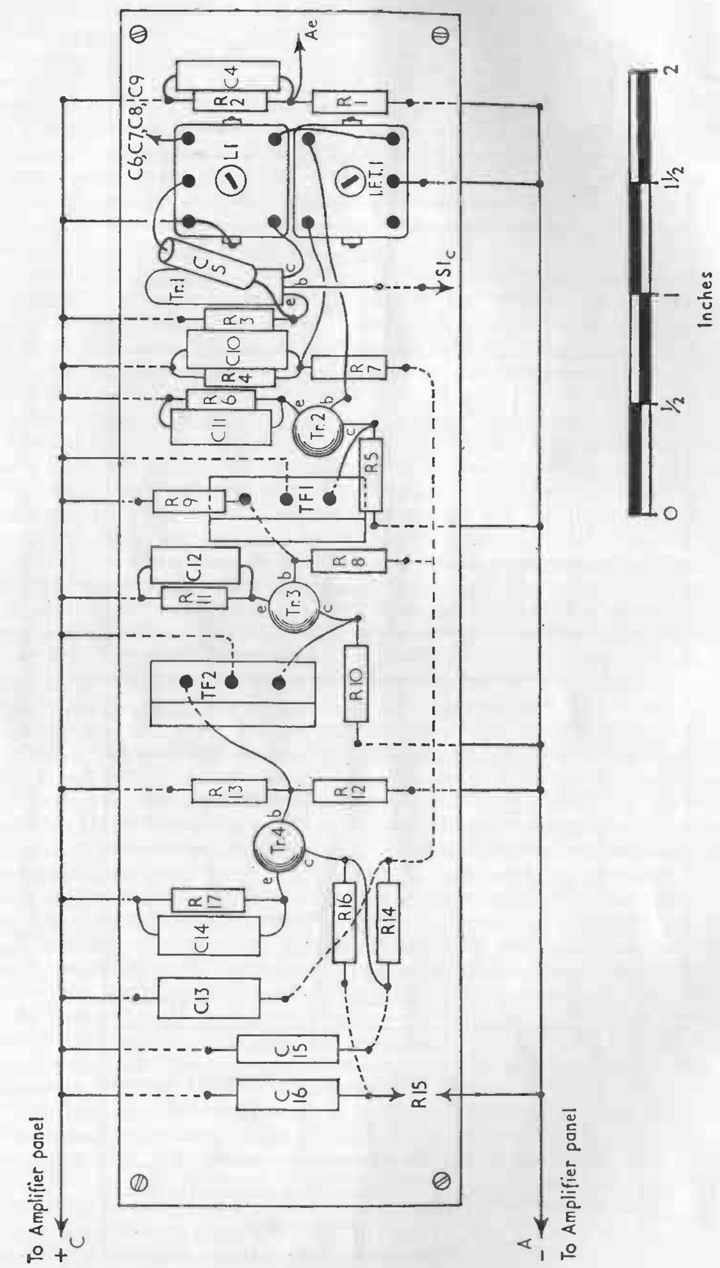

FIG. 4. THE R.F., I.F. AND DETECTOR PANEL

feedback on the long-wave band where the transfilter's fundamental frequency falls within the r.f. tuning range.

The frequency-changer, i.f. and detector circuits were built up on to a separate panel since the output stages were already in existence in the form of a general purpose 1-watt amplifier. The method of construction is shown in Fig. 4, although there is, of course, no need to adhere to this form. The panel is a strip of paxolin $5\frac{1}{4}''$ long, $1\frac{1}{2}''$ wide and $\frac{1}{16}''$ thick. The small components are mounted as though on a printed circuit, the end leads of resistors and capacitors being turned down and passed through small holes drilled at appropriate points. The leads are then soldered together at the back of the panel, a small blob of solder being left on each joint which is sufficient to anchor the parts. The method is shown in section in Fig. 5.

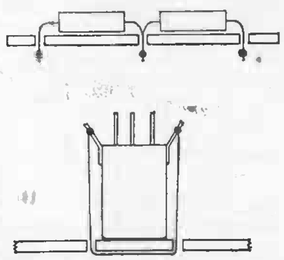

FIG. 5. MOUNTING COMPONENTS ON THE PANEL

The oscillator coil L_1, and the i.f. transformer can be cemented to the panel but additional anchorage was provided in the original receiver by passing a 22 s.w.g. tinned copper wire from one fixing lug down through a hole in the panel, up through a second hole and so to the second fixing lug, the wire being soldered to the lugs. Where two wires or components leads meet a $\frac{1}{16}''$ hole in the panel suffices, a $\frac{1}{8}''$ hole being needed for three or more leads or for the transfilter tags.

A heat-shunt should be used on all short components leads to prevent overheating of component bodies, and should be regarded as essential when soldering-in the transistor leads. A simple but effective shunt can be made in a matter of seconds by sweating two lengths of 14 s.w.g. bare or tinned copper wire to the jaws of a crocodile clip. The two faces of the wires which press together are then filed flat with a fine file and the shunt thus made can be clipped on to any wire, between the joint and the body of the part, to absorb excess heat.

All leads are made from light insulated flex connecting wire, using black and red colours for identification of the negative and positive lines respectively. The main supply leads are shown running alongside the panel in Fig. 4 for convenience—the leads are actually connected from point to point on the underside of the panel.

The 1-watt output stage is shown in Fig. 6. It consists of an OC81D and two OC81s in Class-B, with negative feedback and, as a standard Mullard circuit designed for these transistors, is a useful amplifier with excellent tone and sensitivity. Here again a $5\frac{1}{4}''$ by $1\frac{1}{2}''$ panel of $\frac{1}{16}''$ paxolin carries the circuit, the method of construction being as already described, and as shown in Fig. 7.

A point requiring special attention is the fact that the output transistors are mounted on heat-sinks. When these transistors are purchased two "standard cooling clips" should be obtained at the same time, and used to mount each OC81 on a plate of 22 s.w.g. aluminium, measuring $2\frac{3}{4}'' \times 2''$, one short edge of each plate being turned up for $\frac{1}{4}''$ to serve as a foot by

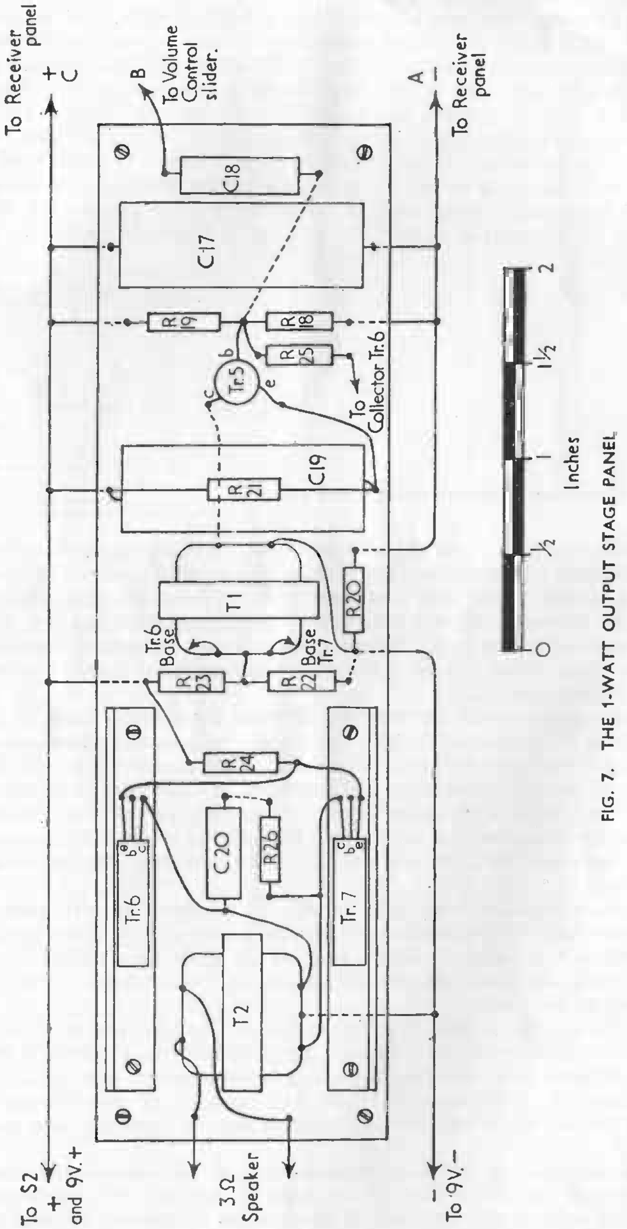

FIG. 7. THE 1-WATT OUTPUT STAGE PANEL

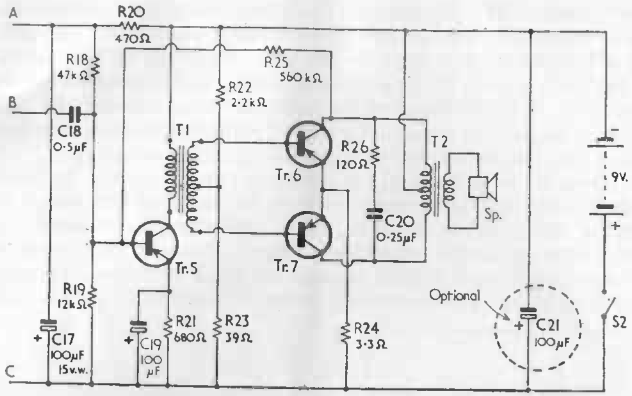

FIG. 6. THE 1-WATT OUTPUT STAGE

which the heat-sink is bolted to the paxolin panel by 8 B.A. nuts and bolts. The heat-sink arrangement is shown in Fig. 8.

In the circuit and layout diagrams the negative feedback resistor R_{25} is shown as being taken to the collector of Tr_6. The actual connection depends

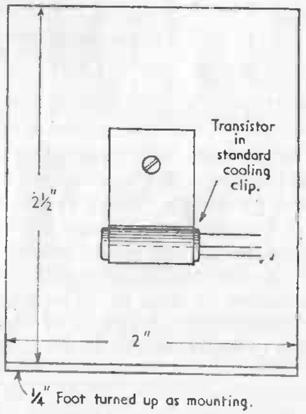

FIG. 8.
THE HEAT-SINK AND TRANSISTOR MOUNTING

on the phase in which T_1 is wired, and if this is inverted the feedback will be positive rather than negative. The connection of R_{25} is therefore decided by trial, the resistor being connected to the collectors of Tr_6 and Tr_7 in turn. The wrong connection is indicated by loud howling, or severe distortion on signals.

The transformers used in the original amplifier are taken from the Radiospares range of miniature transistor components, Types T/T3 and T/T2. If other makes of transformer are used ensure that the correct ratios are obtained: 3·5 : 1+1 for the driver (T_1 in Fig. 6); and 3·1+3·1 : 1 for the output transformer (T_2 in Fig. 6). Radiospares components may be ordered through good dealers.

Capacitor C_{21}, shown as optional in Fig. 6, does not appear in Fig. 7. Under normal working conditions this capacitor is by no means essential, but where the receiver is used only intermittently the slowly ageing battery will show the effects of rising internal resistance, the audio tone deteriorating until finally the receiver breaks into motor-boating oscillation. Capacitor C_{21} provides a by-pass for a battery in this condition, and so can be said to prolong battery life in so far as it permits ageing batteries to be used for a further period. If C_{21} is included the audio amplifier panel could be made slightly longer to provide a mounting space for the component, or it could be mounted in the case beside the VOLUME CONTROL/ON-OFF switch.

Other types of amplifier and output stage can, of course, be used and, indeed, if a really miniature receiver is to be made of the circuit by the experimenter the detector, Tr_4 of Fig. 3, will drive a personal earpiece adequately with no further amplifying stages. One side of the earpiece is taken to the volume control slider through an 0·5μF capacitor, the other side of the earpiece being earthed to the positive battery line as shown in Fig. 9.

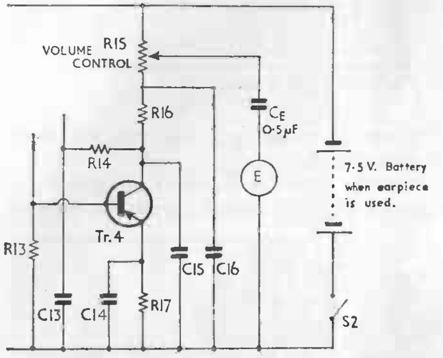

FIG. 9. PERSONAL EARPIECE OUTPUT FROM THE DETECTOR

The dropping and decoupling components, R_{20} and C_{17} of Fig. 6 are then no longer needed, and the receiver can be driven from a 7·5V battery in place of a 9V supply. Good results have been obtained with an Ardente ER 250 earpiece (d.c. resistance 250 ohms, impedance 1kΩ) and a cheap crystal earpiece has also been used satisfactorily.

A very simple low output power stage which will drive a small loudspeaker is shown in Fig. 10. The performance in no way approaches that of the Class-B OC81s amplifier of Fig. 6 since the power may be measured in only tens of milliwatts; but it is sufficient for a personal or bedside receiver. So few

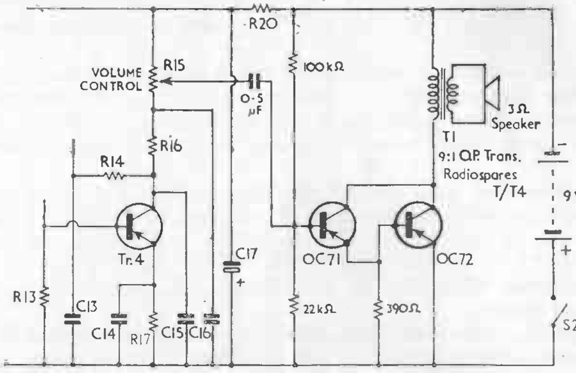

FIG. 10. A SIMPLE LOW POWER OUTPUT STAGE

components are used that the circuit could easily be included on the receiver panel. The stage consists of two transistors coupled in a "super-alpha" pair, the base of the second being connected directly to the emitter of the first, the stage gain of one transistor being multiplied by the gain of the second. The circuit is of value in many applications and is particularly useful in relay operation and similar switching functions.

The Aerial

The aerial details are shown in Fig. 11. The separate medium and long-wave sections are mounted on a ferrite rod 5/16" in diameter and 5½" to 6" long.

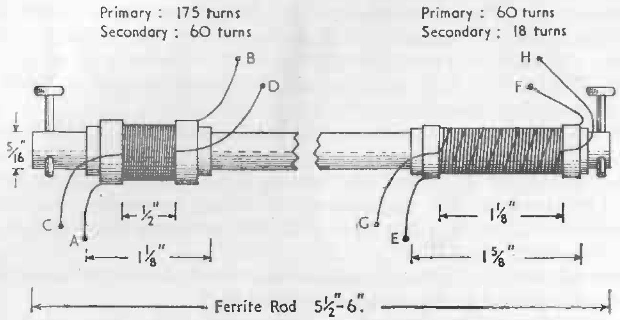

FIG. 11. DIMENSIONS OF THE FERRITE AERIAL (COILS SHOWN DIAGRAMMATICALLY)

In a miniaturized version of the receiver it is probable that a shorter rod would be required, although the rod should be as long as possible for pick-up efficiency. The aerial windings are carried on formers which are a sliding fit on the rod so that the coils can be adjusted to their best reception positions. The formers can be made from stout paper or thin card, that for the medium-wave coil being 1⅝" long and that for the long-wave former 1⅛" long. Two or three turns of the paper are wound round the ferrite rod (and kept slightly slack to permit movement), the ends of the formers then being secured with a turn of Sellotape.

The medium-wave coil is wound with 60 turns of wire in a single layer, turns touching, to occupy about 1⅛" of the former. The wire can be either 30 s.w.g. enamelled (or enamelled wire of about that gauge) or, for slightly greater efficiency, Litz wire. Many constructors will find an old Litz-wound aerial coil in the spares box and wire from this is suitable. Whichever wire is used for the winding, it should be soldered to a flexible connecting lead made from a few inches of light plastic covered connecting wire (all connecting wires in the original were of "miniature" P.V.C. 7/40 wire), care being taken, in the case of Litz wire, to ensure that each strand is bared and tinned in the soldered joint.

The start of the medium-wave winding, E in Fig. 11, is secured by a narrow strip of Sellotape about ¼" from the end of the former, and the turns of wire wound on and counted in a clockwise direction. The last turn is soldered to another flexible connecting lead and also secured by a narrow strip of adhesive tape.

The secondary winding consists of 18 turns of 30 s.w.g. enamelled wire (or a similar gauge) wound spirally over the whole length of the primary, as shown diagrammatically in Fig. 11. Single strand wire is used for the secondary with either single strand or Litz wire primaries. Both ends of the secondary are terminated by flexible connecting wires and secured under turns of Sellotape. Note that the secondary is wound in the same direction as the primary.

The long-wave aerial coils occupy a winding space about ½" long on their former, and on the original aerial were made between cheeks built up from several turns of narrow strips of Sellotape. Both coils are wound using 40 s.w.g. enamelled copper wire (or a similarly small gauge) and as in the medium-wave coils, both are brought out to thin flex leads. The primary winding consists of 175 turns of wire wound in the same way and in the same direction as the medium-wave windings, the turns being built up in reasonably neat layers though meticulous accuracy in laying the turns side-by-side is not at all necessary. The completed winding is covered by a single layer of adhesive tape and the secondary is then wound over the primary in the same direction—the secondary consists of 60 turns of the same wire as used for the primary. The leads to both windings are, of course, secured to the cheeks by strips of tape.

Note that the long-wave primary coil is trimmed by C_3, a 150pF capacitor, permanently connected across the winding, and also that the long-wave coil is short-circuited by S_{1b} when the receiver is switched to the medium-wave band. This prevents the long-wave coil from resonating with its stray capacitances at some frequency within the medium-wave range and so spoiling medium-wave reception.

As already explained, the secondaries on the aerial coils are large compared with normal practice to give adequate damping.

A dot beside a coil termination in diagrams, such as those at *A*, *C*, *E* and *G* in Fig. 3, indicates the start of a winding. The aerial connections and switch wiring are shown in detail in Fig. 12.

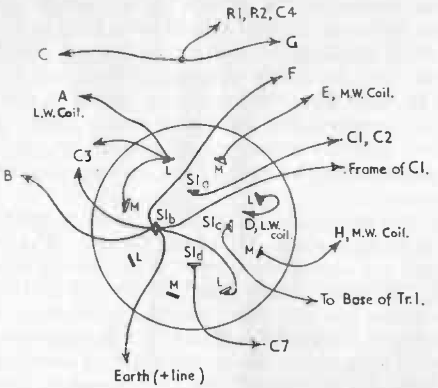

FIG. 12. SWITCH WIRING OF THE TRANSFILTER RECEIVER

The mounting of the aerial rod will depend on the type of case in which the receiver is built up. One method is shown in Figs. 11 and 13, where supports are bent from piano wire and screwed to the inside top of the case, gripping the ferrite rod by the natural springiness of the material (it is as well to strengthen the joint between the rod and supports with a good adhesive or cement). When wire supports are used a closed loop of wire must not be allowed to encircle the ferrite rod since this would act as a "shorted turn" and absorb all the signal; for the same reason the ends of the rod must not be passed through holes in metal plates.

COMPONENTS LIST FOR THE TRANSFILTER PORTABLE SUPERHET WITH 1-WATT OUTPUT STAGE, FIGS. 3 and 6

Aerial	See text for details
C_1, C_8	500pF twin-gang miniature tuner
C_2	50pF postage stamp trimmer
C_3	150pF silver-mica
C_4, C_5, C_{15}, C_{16}	0·01μF midget tubulars
C_6	500pF silver-mica
C_7	450pF silver-mica. See note below
C_9	70pF postage stamp trimmer
C_{10}, C_{11}, C_{12}, C_{13}, C_{14}	0·1μF midget tubulars
C_{17}, C_{19}, (C_{21} optional)	100μF 15 v.w. electrolytic
C_{18}	0·5μF midget tubular or 15 v.w. electrolytic
C_{20}	0·25μF midget tubular
R_1, R_{18}	47kΩ
R_2	33kΩ All fixed resistors ¼ or 1/10 watt
R_3	10kΩ
R_4, R_5, R_8, R_{10}, R_{13}	4·7kΩ
R_6, R_{11}, R_{20}	470 ohms
R_7, R_{19}	12kΩ
R_9, R_{14}, R_{16}	2·2kΩ
R_{12}	330kΩ
R_{15}	5kΩ volume control with s.p. ON-OFF switch
R_{17}	100 ohms
R_{21}	680 ohms
R_{22}	2·2kΩ 5%
R_{23}	39 ohms 5%
R_{24}	3·3 ohms
R_{25}	560kΩ
R_{26}	120 ohms
L_1	Oscillator Coil, Repanco X08
$I.F.T._1$	I.F. Transformer, Repanco XT6
TF_1, TF_2	Transfilters TO-01A. See note below
T_1	Driver Transformer, 3·5 : 1+1, Radiospares T/T3
T_2	Output Transformer, 3·1+3·1 : 1, Radiospares T/T2
Sp.	Loudspeaker, 6" oval or similar, 3 ohms
Tr_1	OC44, Mullard, or equivalent. See note below
Tr_2, Tr_3, Tr_4	OC45, Mullard, or equivalent. See note below
Tr_5	OC81D, Mullard
Tr_6, Tr_7	OC81, Mullard, with standard cooling clips
S_1	4-pole 2-way wavechange switch
S_2	S.p. ON-OFF switch ganged with R_{15}
Battery	Ever Ready PP9 or similar

Sundries: Paxolin panels, battery press-stud-connectors, case, three knobs, plates for heat-sinks, etc.

NOTES

C_7. The value of C_7 is finally found by trial as described in the alignment details which follow, a usual value being about 450pF made up of a 400 and a 50pF in parallel.

TF_1, TF_2. Several different types of transfilter are available, some components being tuned to resonance and some to anti-resonance at the specified intermediate frequencies. (A circuit tuned to anti-resonance is actually adjusted to present its greatest impedance at the quoted frequency). The transfilters currently available are marketed by the Brush Crystal Company and their codings are TO-01 for resonant tuned transfilters and TO-02 for anti-resonant operation. The full codings and frequencies are as follows:

TO-01A	455 ± 2kc/s	TO-02A	457 ± 1kc/s
TO-01B	465 ± 2kc/s	TO-02B	465 ± 1kc/s
TO-01C	500 ± 2kc/s	TO-02C	500 ± 1kc/s
TO-01D	470 ± 2kc/s	TO-02D	470 ± 1kc/s

The original receiver was designed round two TO-01A transfilters but to investigate the performance if different components were used these were replaced by TO-02D transfilters—thus both the intermediate frequency and the basic type of transfilter were altered. After a slight readjustment to the i.f. transformer and the core of the oscillator coil results on listening tests in a poor reception area were just as satisfactory. As a result transfilters of the TO-01A type are specified but the set should operate equally well using TO-01B or D, or TO-02A, B or D types. The 500kc/s units are not recommended because this frequency is rather too high to suit the oscillator coil and i.f. transformer. It will, of course, be realized that the two transfilters must be of the same type. Transfilters are not yet stocked by all retailers but they are advertised regularly in technical magazines. At the time of writing they cost 8*s*. 6*d*. each.

Tr_1. An OC44 is recommended as the frequency-changer but white spot surplus transistors have been tested in this position with good results. It may be necessary to alter the value of R_1 to suit other transistors, or to improve results, but this can be done by trial. If signals are weak bridge R_1 with about 100kΩ to try the effect of more negative bias on the base of the frequency-changer; if an improvement is obtained make a further trial with an 82kΩ or 68kΩ to see if the improvement can be increased. If, on the other hand, the stage is "lively" and breaks into oscillation with the main tuning capacitor at minimum capacitance, R_1 should be increased in value. To save unsoldering the components the same effect can be obtained by reducing the resistance of R_2 which can have a 100kΩ resistor bridged across it for a trial. If some improvement is obtained, again reduce the value of the bridging resistor to 82kΩ or 68kΩ until the stage operates correctly and is stable.

Tr_2, Tr_3, Tr_4. White spot or blue spot surplus transistors can be used in these stages with satisfactory results. As a general rule the components values given will serve for substitute transistors. Red spot transistors have been tried in the Tr_4 position with good results. At the time of writing it is possible to purchase, at greatly reduced prices, "packages" of transistors containing 1 OC44, 2 OC45s, 1 OC81D and a pair of OC81s, intended for more conventional receivers. Such a package can, of course, be used in the existing circuit with the addition of a further OC45 or substitute.

Construction and Alignment

The original receiver was built into a wooden case measuring $8\frac{1}{2}'' \times 6\frac{1}{2}'' \times 3\frac{1}{4}''$, which gave ample space for a reasonably sized loudspeaker and supply battery, the layout being as shown in Fig. 13. The volume control, wave-change switch and tuner were mounted on the wooden front of the case, their spindles protruding through an escutcheon carrying suitable wording for the switch and R_{15} and a tuning scale for C_1,C_8, which is turned directly by a plain pointer knob. When tuning capacitors are mounted in this way, by means of threaded holes in their front frames, care must be taken to use suitable short bolts so that there is no fouling of the moving vanes or short-circuits on to the fixed vanes.

As already described, the ferrite aerial was mounted at the top of the case;

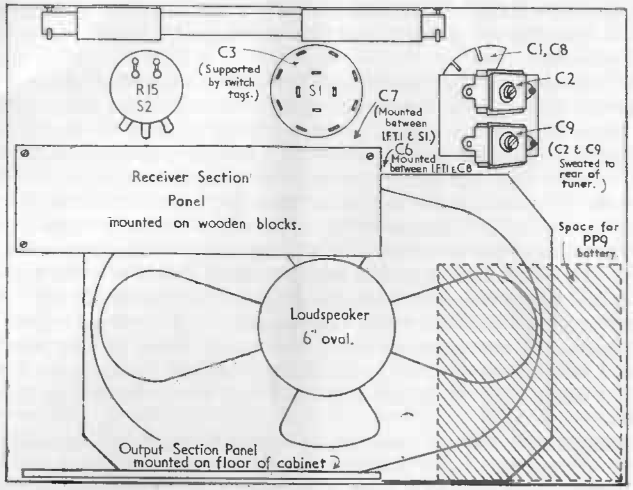

FIG. 13. THE RECEIVER CABINET LAYOUT

the positions of the two paxolin panels carrying the circuits are shown in Fig. 13.

If any considerable changes are made in the receiver layout, especially in miniaturisation, it would be as well to connect up all circuits on the bench for a preliminary test and for alignment before mounting them.

Unless a signal generator is available alignment is best carried out under evening reception conditions when stations can be received all round the medium wave range. With all the wiring completed and checked set C_1,C_8, fully open, C_2 at rather less than half capacitance, C_9 at almost full capacitance and set the core of L_1 about two full turns into the former. (When adjusting the midget cores of the oscillator coil and i.f. transformer be careful to avoid turning them so far into their coils that they bind and jam against the cans). The core of *I.F.T.*$_1$ should be at about the mid position, and the windings on the ferrite aerial rod should be in roughly the positions shown in Fig. 11, the medium-wave winding towards one end and the long-wave winding less advanced towards the other. Switch S_1 to the medium-wave range, turn R_{15} to switch on the set, and adjust for full volume. (It is assumed that where the 1-watt output stage is fitted the correct connection for R_{25} has been made).

Slowly rotate the tuner, C_1,C_8, and endeavour to find a signal. If nothing can be heard reset the tuner to the fully open position, screw C_9 to its full capacitance and then slowly reduce its value. Signals should then be found, but if stations are still not heard try a different setting of C_2. Remember that the aerial is very directional and that the receiver may need turning on its axis to receive even the local station. In a case of real difficulty connect an earth to the battery positive terminal to increase signal pick-up. In view of the fact that the original receiver was aligned on signals in a very poor reception area there should be no difficulty in finding some station near the high-frequency end of the medium wave range.

When a signal is received tune *I.F.T.*$_1$ for best volume. The core slots of the Repanco coils are too small to be turned without damage by even a small screwdriver, but a suitable trimming tool can be made from a short piece of 22 s.w.g. tinned copper wire, one end of which is flattened into a thin blade with a few taps from a light hammer. The wire can then be inserted and cemented into an orange stick and the blade used to trim the cores with no fear of harm.

Now turn the tuner over its range. Probably a number of stations will be heard as the vanes start to mesh, but signals will rapidly die away into silence as the capacitance is increased. Make a slight alteration to the core setting of L_1, turning the core either in or out by a half-turn or so, and again rotate the main tuner from minimum capacitance towards maximum. If the core adjustment of L_1 was made in the correct direction a greater number of stations will be heard before the signals die away; if the adjustment to the core of L_1 was in the wrong direction there will, of course, be fewer signals heard. Make a further correction to L_1 and aim at a setting of the core where stations are heard all the way round the tuning range of the variable capacitor. As these adjustments progress, check the medium-wave aerial winding for position on the ferrite rod by leaving the main tuner set on a station towards the low frequency end of the tuning range and moving the medium-wave winding to and fro along the rod. A point will be found where the station is heard at best volume.

At this point it will be necessary to adjust C_9 because improving results at the low-frequency end of the band will affect results at the high-frequency end. Turn C_9, with the main tuner fully open, until stations are again heard at the high-frequency end of the range, and then adjust C_2 for best volume.

The actual range over which the tuner is operating must now be found and corrected. The final range is of the order of 205 to 550 metres and if the Light Programme on 247 metres can be identified the correct tuning point for this signal is with the tuner vanes about 22° in mesh from the fully-open point. A very convenient way of setting the high-frequency end of the range, however, is to adjust C_9 so that Luxembourg is tuned in with C_1,C_8, practically right open. When this setting of C_9 has been found by trial, adjust C_2 for best volume, then tune to a station at the other end of the range and again correct the position of the medium-wave aerial winding on the rod. Tune back to the Light Programme on 247 metres and make a further correction to C_2 for best volume. Signals should now be heard all round the medium-wave band; if there appear to be any dead spots in the centre of the tuning range it will be necessary to make a further adjustment to L_1 and then to C_9, C_2, and the aerial winding.

If a high gain OC44 has been used as the frequency-changer some instability may appear at the high-frequency end of the tuning range as C_9 is reduced in value to make the Light Programme, or Luxembourg, fall on the correct tuning point. Check the setting of C_2, then slightly reduce the bias on the transistor in the manner already described, shunting R_2 by trial with 100kΩ or less until the stage is stabilized, and works correctly. Alternatively, add a further one or two turns to the secondary winding G-H on the aerial coil.

Switch S_1 for long-wave reception, and set the main tuner to the centre of its tuning range. If C_7 is suited to the adjustments already made to the core of L_1 the Light Programme will be heard at good strength but it is possible that C_7 will need some alteration. One method of finding the correct value of C_7 is to connect a variable padder capacitor in place of the fixed capacitance, using a 750pF max. component, but if one or two 50pF silver mica capacitors are available these may be connected in parallel one at a time with a fixed 400pF capacitor to give 450, 500, 550pF, etc. Swing C_1,C_8, after each alteration to C_7 and also vary the position of the long-wave winding on the aerial rod until the Light Programme is received. If reception is poor check the value of C_3 by adding 50pF in parallel to the existing capacitor.

If results are worse change the 150pF component for (say) 100pF; if adding capacitance improves results try a further increase in capacitance. With the correct values for C_3 and C_7, and the aerial coil correctly positioned on the ferrite rod, good results should be had not only from the Light Programme on 1,500 metres, but also from the long-wave Luxembourg and French transmitters.

After altering the position of the long-wave aerial coil, switch back to the medium-wave band and ascertain whether the medium-wave aerial coil setting has been affected, and correct it if necessary. When the receiver is aligned throughout, cement the aerial windings in place on the rod with a dab of *Durofix*. The cores of L_1 and $I.F.T._1$ can be sealed by dropping a scrap of wax on the top of each core and melting it with a hot wire.

When the 1-watt output stage is fitted to the receiver a final check can be carried out on the audio tone. Under ordinary reception conditions the receiver has very little background hiss (unlike some transistor circuits) and when the set is tuned off signals, with the volume control fully advanced, there should be practically no sound at all from the loudspeaker. If hiss is heard when this test is made temporarily disconnect C_{18} from the slider of R_{15}. A reduction in hiss indicates that the noise is arising in the receiver section, probably in Tr_4. If, on the other hand, the hiss level is unchanged, the noise is due to the amplifier.

To reduce noise in the Tr_4 stage, assuming that the transistor itself is in good order, remove R_{12}, 330kΩ, and replace it by a 470kΩ resistor. If hiss arises in the audio stages check R_{18} and try an increase in value; also check R_{22}. A 5 per cent tolerance resistor is specified here and therefore the resistor will be reasonably correct; if Tr_6 and Tr_7 have high *betas*, however, it may be necessary to increase R_{22} by trial for best results.

As a general rule noise will not be troublesome with this circuit and after testing for hiss it should be possible to go straight on to a tone test. To make this trial without test equipment, tune the receiver to a strong signal—the Light Programme on long waves, for example—and check the tone on music with the volume control fully up, then turned down to the lowest volume which can clearly be heard. At high volume the tone should be excellent, and should be maintained as the volume is reduced. At low levels, if there is slight cracking or distortion suspect the bias on Tr_6 and Tr_7, and shunt R_{22} with about 10kΩ to see if the tone improves. This form of distortion at low levels in a Class-B stage indicates that the bias is slightly low, giving cross-over distortion; as one transistor cuts-off, the other is not quite conducting, and a slight rise in bias usually cures the trouble. In one amplifier constructed by the author R_{22} had to be shunted by 4·7kΩ.

A final test also concerns distortion on low volume but in this case the receiver is tuned to the weakest signal which can be heard, the volume control being turned fully on. If cracking or distortion is heard on a weak signal it can probably be improved by increasing the bias on Tr_4 by shunting R_{12} by 1 megohm or 560kΩ by trial. On the other hand, if R_{12} has been increased to reduce hiss a compromise must, of course, be made between noise and tone.

Battery life in this receiver depends to a great extent on the volume required. At full output peak currents of 250mA are drawn, but for average listening a typical battery current is 100mA on peaks, falling to a steady 15mA or less with no signal.

CHAPTER 2

A SIMPLE ALL-WAVE T.R.F. RECEIVER

THE excellent results obtainable from high-frequency transistors such as the OC170 indicate that it should be possible to design a simple receiver to tune over the most popular short-wave bands as well as the medium and long-wave ranges, using a regenerative detector. This stage is the heart of such a receiver and it must be sensitive, have smooth regeneration control, and must employ a tuned circuit which is easy to switch; *i.e.* secondary windings for reaction should not be needed, nor should the coils be tapped. After testing all types of detector circuit the basic arrangement shown in Fig. 14 was chosen. The tuned circuit is connected in the collector line, feedback being supplied from the emitter circuit by C_4. Control over

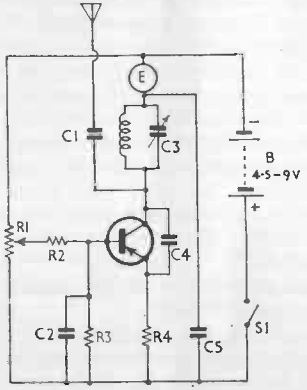

FIG. 14. THE BASIC T.R.F. RECEIVER

regeneration is given by adjusting the base bias by means of R_1. The frame of the tuning capacitor, C_3, is earthed for r.f. by C_5 and, if the receiver is built into a plastic case, presents no insulation problems. By choosing suitable components values the OC170 can operate in this circuit at 100Mc/s and over and, if superregeneration is used, can serve as a single transistor f.m. receiver, as described in the following chapter.

The development of this detector into a three transistor all-wave receiver is shown in Fig. 15. There are six tuning ranges selected by a six-position, 4-pole, rotary wavechange switch, S_1. Section S_{1a} selects the tuning coil for connection across a 500pF single gang tuner, C_3, the approximate ranges being:

(1)	LONG-WAVES	150—300kc/s
(2)	MEDIUM-WAVES	500—1,100kc/s
(3)	TRAWLER BAND	1·1—2·4Mc/s
(4)	S.W. 1	2·4—4·5Mc/s
(5)	S.W. 2	4·5—11·5Mc/s
(6)	S.W. 3	11—20Mc/s

The ranges overlap from 20Mc/s to 500kc/s, with a gap between the medium and long-wave bands.

L_1, L_2 and L_3 are windings on a Repanco DRR2 coil. L_4, L_5 and L_6 are wound on plastic formers.

Switch section S_{1b} selects an emitter by-pass capacitor which, in conjunction with C_4, provides the correct level of feedback from the emitter to

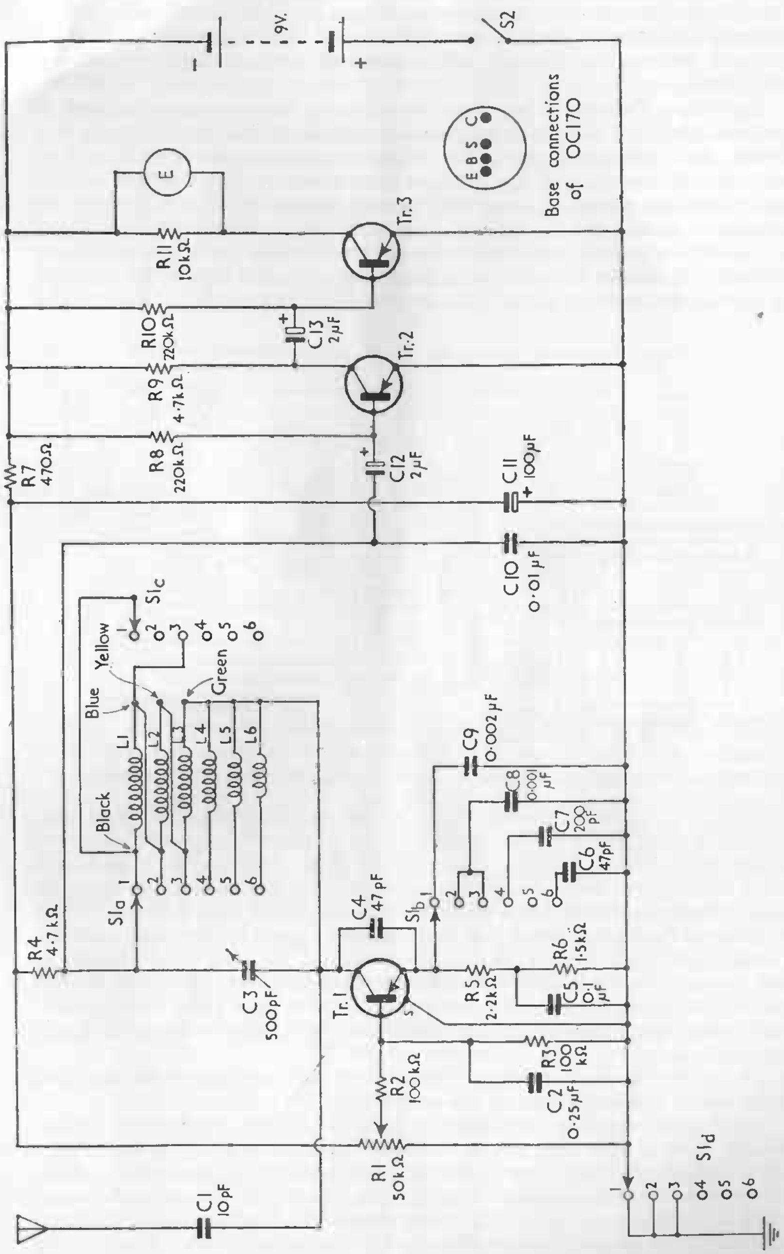

FIG. 15. THE SIMPLE ALL-WAVE T.R.F. RECEIVER

the collector circuit over each range (note that there is no by-pass at the No. 5 switch position). S_{1c} has only one working contact, at position 3, where it short circuits the long-wave winding, L_1, on the DRR2 coil. This is necessary for smooth working over the trawler band since L_1, if left open circuited, resonates with stray capacitance and prevents regeneration over half of band 3.

S_{1d} is hardly necessary but since, on a 2-bank, 4-pole switch the contacts are available, it is used to connect a physical earth for long, medium and trawler band reception, the earth being left disconnected for short-wave working. On the original receiver this was found to give the best results, but in different reception areas this state of affairs may not exist, and the constructor should test his receiver with earth both on and off on all ranges.

The prototype was built into a Woolworth's plastic food box measuring $5\frac{1}{2}'' \times 4\frac{1}{8}'' \times 2\frac{1}{2}''$ which allowed just sufficient room for the coils to be mounted on a small wavechange switch as shown in Figs. 16 and 17. The coils were

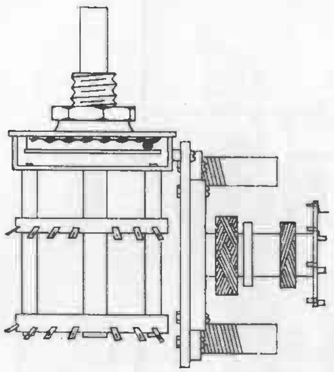

FIG. 16. THE SWITCH ASSEMBLY

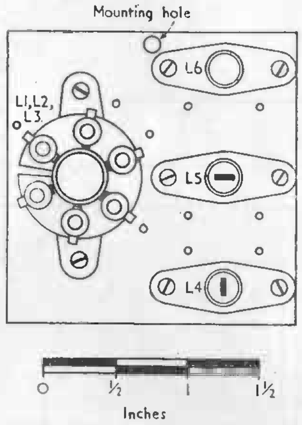

FIG. 17. THE COIL MOUNTING

bolted to a 2" square of paxolin which in turn was mounted by a single 6B.A. bolt to the front frame of the switch drilled and tapped 6B.A., a small spacer washer being placed between the paxolin and the metal. The switch used was a Radiospares *Maka-Switch* but other forms of switch can, of course, be used. Where the switch has a single plate front, rather than a frame, and so provides no flat surface which can be drilled and tapped for the coil mounting, a small right-angle bracket secured under one of the long sidebolts can be used instead. Before making the assembly check the parts for size in the box which is to house the receiver; some switches take up a good deal of room whilst others may have to be dismantled and the spacers between the banks reduced in size.

The emitter by-pass capacitors C_6 to C_9 are mounted across the rear bank of the switch and supported on the switch lugs.

Short-wave reception was found so good on the test receiver that a slow-motion drive is very desirable in order to separate and to log stations; a surplus Muirhead drive with a 180° scale was accordingly fitted and a short-wave station log commenced. The tuning is affected by the aerial, however, which is directly tapped on to the tuning circuit by a 10pF capacitor, a change of aerial length causing a small alteration in the tuning. Where a station log is to be made, therefore, the style and size of the aerial, as well as the

desirability or otherwise of an earth connection, should first be decided upon and fixed. A telescopic whip aerial was fitted to the original receiver and proved adequate for good reception over all ranges, but it was found that the stresses imposed by the aerial on the plastic case were rather too high and caused cracking of the material. (This was with single hole fixing; a whip aerial fixed by two mountings to the side of a plastic case should give no trouble).

The detector is followed by a two-stage amplifier of the simplest type, feeding into a cheap crystal earpiece. If a magnetic earpiece is to be used it should be connected in place of R_{11} and E in Fig. 15, and should have a resistance of about 250 ohms to d.c. The value of R_{10} may need alteration by trial for best results.

Apart from the switched and control components the circuits in the original receiver are mounted on a small paxolin board as already described in Chapter 1 and shown in Fig. 18. A transistor holder is used for Tr_1 however,

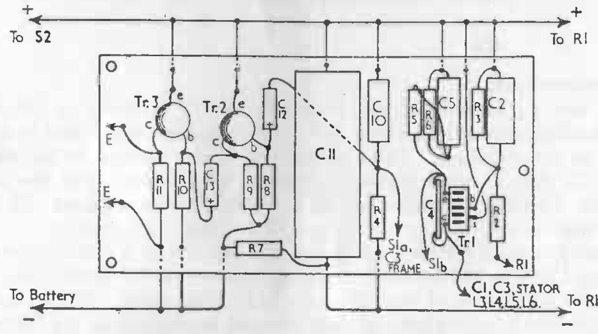

FIG. 18. THE SIMPLE ALL-WAVE RECEIVER CIRCUIT PANEL

in order that different high-frequency transistors may be plugged in for comparison purposes; the holder fitted by the author is of the miniature 5-in-line socket type intended for deaf-aid valves. These holders are ideal for transistors of the OC170 class which have four lead-out wires, one being a lead connecting the case to earth as a screen. Tr_1 can, of course, be connected in circuit by soldering if desired, provided that the usual precaution of using a heat-shunt is observed. When a socket is used this can be secured to the mounting board by *Araldite* or a similar adhesive.

COMPONENTS LIST FOR THE SIMPLE ALL-WAVE RECEIVER, FIG. 15

L_1, L_2, L_3	Windings on 1 Repanco DRR2 coil
L_4, L_5, L_6	See details below
C_1	10pF silver-mica
C_2	0·25μF midget tubular
C_3	500pF midget tuner
C_4, C_6	47pF silver-mica
C_5	0·1μF midget tubular
C_7	200pF silver-mica
C_8	0·001μF silver-mica or ceramic
C_9	0·002μF silver-mica or ceramic
C_{10}	0·01μF ceramic
C_{11}	100μF 15 v.w. midget electrolytic
C_{12}, C_{13}	2μF 15 v.w. midget electrolytic

R_1	50kΩ volume control with s.p. ON-OFF switch
R_2, R_3	100kΩ. All fixed resistors ¼ or 1/10 watt
R_4, R_9	4·7kΩ
R_5	2·2kΩ
R_6	1·5kΩ
R_7	470 ohms
R_8, R_{10}	220kΩ
R_{11}	10kΩ
E	Crystal earpiece
Tr_1	OC170, Mullard
Tr_2, Tr_3	OC71, Mullard, or Red Spot, etc.
$S_{1a, b, c, d}$	4-pole 6-way rotary wavechange switch
S_2	S.P. ON-OFF switch ganged with R_1
Battery	Ever Ready PP3, or similar
Sundries:	Plastic or other insulating case, paxolin panel, battery press-stud-connectors, coil formers and cores (see below), slow-motion drive, 2 knobs, etc.

The Short-wave Coils

L_4, L_5 and L_6 are wound on three polystyrene formers; in the original receiver Radiospares units known as "Core Formers" were used but similar formers can be employed. (The winding diameter should be as nearly as possible 0·31 inch if other makes of formers are utilized). All the coils are wound with 30 s.w.g. enamelled wire; a slightly different gauge will serve if this is to hand.

L_4 has 40 turns, closewound in a single layer, and a ferrite core.

L_5 has 12 turns closewound in a single layer, and a ferrite core.

L_6 has 9 turns spaced slightly apart in a single layer, with no core.

The start and finishing turn of each coil can be secured to the former with a scrap of adhesive tape, the coil leads being left sufficiently long to pass through the holes drilled in the coil mounting panel and so to the switch and external circuits. The former for L_4 requires a winding length of slightly more than a half inch to accommodate 40 turns.

Whilst only two of the short-wave coils have ferrite cores, three cores in all are needed since one core should be inserted into the bottom, long-wave, winding on the DRR2 coil to give the correct frequency coverage. The former is threaded but has too great a diameter for a normal core. No adjustment is needed, however, the core being flush with the bottom edge of the former, so that a core such as the Radiospares Type "A" which fits the plastic formers already mentioned can be set in place with a little melted wax.

The cores in L_4 and L_5 can be secured with wax after the tuning ranges have been aligned.

Construction

The receiver is prepared for assembly in sub-units. The tuning system consisting of the switch and coils has been described, and is shown in Figs. 16 and 17. In Fig. 19 the switch wiring is illustrated, the two switch wafers being separated and viewed from the front, or control knob side. S_{1a},S_{1c} is the front wafer. The lug arrangement on some small rotary switches can be confusing to the eye, and it is as well to check with an ohmmeter or continuity tester to ascertain that the correct slider and fixed contacts have been selected for each bank before wiring up.

The positions of the main components in the plastic case are shown in Fig. 20, and if a case of the suggested size is used neither the wave-change switch nor the tuning capacitor must be too large; it is as well to check sizes

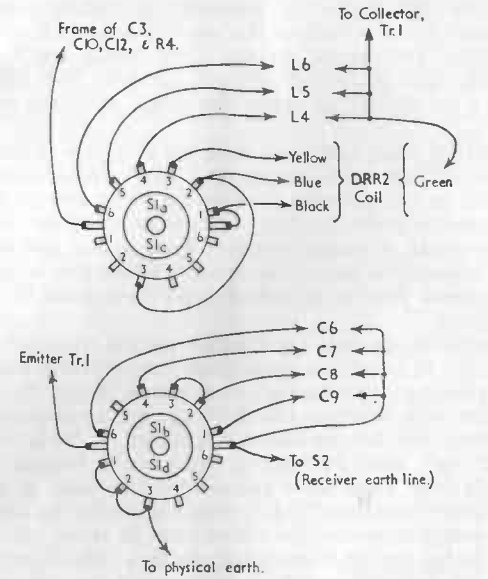

FIG. 19. SWITCH WIRING IN THE SIMPLE ALL-WAVE RECEIVER

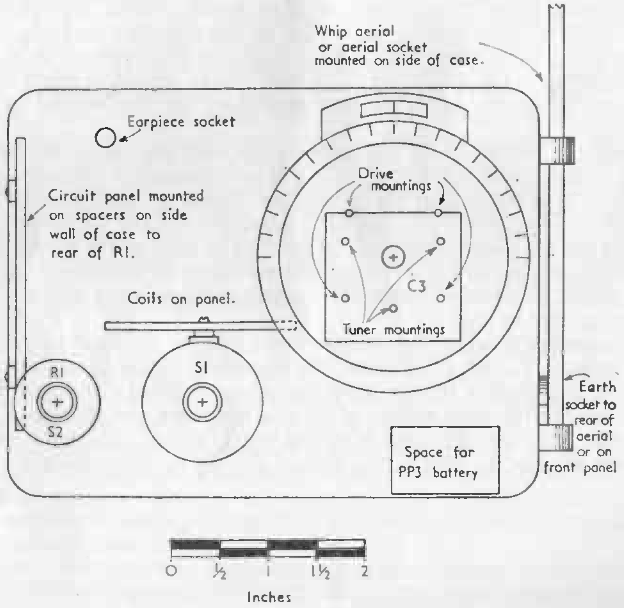

FIG. 20. THE SIMPLE ALL-WAVE RECEIVER CASE LAYOUT

and offer up the parts before any assembly or drilling takes place. Large components can of course be used if a suitable housing is to hand.

In the original receiver the bottom of the plastic box formed the front panel. Drilling must be carried out very carefully with the material well supported on a flat surface, otherwise the plastic will crack as the bit breaks through.

The majority of small tuners are mounted by means of three holes in the front frame on a 1-inch circle, tapped 4B.A. and care must be taken that the mounting bolts do not protrude through the frame and so distort or short circuit the capacitor plates. It is convenient to space the tuner behind the front panel by stacks of washers over the bolts so that just sufficient spindle protrudes to engage the slow-motion drive where this is used. This also permits a Muirhead drive to be bolted to the front panel by 8 or 9B.A. nuts and bolts.

Several mounting positions are available for the components board which measures only $3 \times 1\frac{1}{2}$ inches; in the original receiver it was bolted to one side of the case to the rear, and clear of, R_1 as shown in Fig. 20. The aerial and earth sockets, or whip aerial and earth socket, can be secured along one side of the case, whilst the earpiece socket is mounted on the front panel. Plenty of space is left for a small 9V battery, which can be housed in a small compartment made from balsa wood cemented to the case, or in some similar manner, to prevent the battery from moving about when the receiver is carried.

With the wiring completed the receiver can be tested. If a whip aerial is not fitted use about six feet of insulated wire as a "throw-out" aerial for first trials. Turn the wavechange switch to RANGE 1 for long-wave reception, switch on with R_1,S_2 and turn up the control until the detector just breaks into regeneration or oscillation, then back off the control so that the receiver is in a sensitive condition but not actually oscillating. Turn the tuning control; the long-wave Light Programme should be found without difficulty as well as two or three other stations depending on the reception location.

Switch to RANGE 2 for medium-wave reception and again adjust R_1 so that the receiver is just not oscillating. The local station should be heard as should several other signals; under evening conditions the dial should be full of stations.

Check the trawler band for regeneration over the whole tuning range. At frequencies above 1·5Mc/s or so it will be necessary to allow the detector to oscillate in order to hear the heterodyne whistle on weak signals, backing off R_1 when a station has been found. On RANGES 4, 5 and 6 the same method of tuning can be used, backing off the reaction as soon as the required station is received. It is important not to allow the receiver to oscillate in such a way that it might cause interference in neighbouring sets since this is offensive both in fact and in law.

The overlap between the tuning ranges can be adjusted by setting the ferrite cores in L_4 and L_5. Ideally this requires a signal generator, but one method is to identify a station at the high-frequency end of the trawler band, then to tune in the same station at the low-frequency end of range 4, setting the core in L_4 so that the tuner is almost wholly closed. The same method is employed to align L_5 with L_4; L_6 should overlap L_5 automatically.

CHAPTER 3

TRANSISTORS AT V.H.F.

It was stated in the previous chapter that an OC170 in an adaptation of the circuit shown in Fig. 14 could serve as a single transistor v.h.f./f.m. receiver. Fig. 21 shows the arrangement which makes this possible, and which will suit most v.h.f. transistors including OC169 and XC131s as well

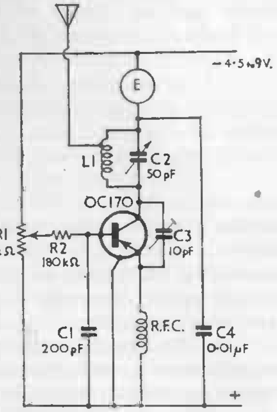

FIG. 21.
THE SINGLE TRANSISTOR V.H.F./F.M. RECEIVER

as OC170 and OC171 types. The transistor is connected into a self-quenching superregenerative circuit.

A superregenerative receiver is one in which the circuit is taken in and out of oscillation at a relatively high frequency—above the audio frequency rate or at a low radio frequency. In a self-quenching circuit with no input signals the bursts of oscillation are triggered by thermal agitation noises and grow to a critical amplitude, then die away. The resulting audio output from the detector is a loud hiss. A signal received at an amplitude greater than the noise amplitude causes the triggering time to be advanced so that the critical amplitude of oscillation and its dying away are accelerated, and the quench frequency increases with incoming signal strength. When the oscillations are rectified in a detector an output is obtained which follows any modulation on the received signal (in a rather distorted fashion) so providing audio signals. The advantage of the system is that it gives very considerable r.f. amplification and works best at v.h.f. and u.h.f. There is also a limiting action which suppresses pulse type interference.

In Fig. 21, L_1 and C_2 form a circuit tuning over the range 88 to 100Mc/s approximately, the circuit being that of an oscillator since there is feedback from the emitter to the collector circuit by C_3. The by-pass capacitor for the base circuit, C_1, together with R_2, forms a charge-discharge circuit switching the base on and off and so providing the quench frequency.

Provided that a superregenerative detector is controlled so that it is just quenching, incoming signals are easily tuned since their carriers cut off the quench hiss, giving a silent spot on the tuning range (provided also that the signal amplitude is sufficiently large). Tuning is fairly broad and unselective, an advantage in some circumstances.

However, the superregenerator has one grave disadvantage—namely, that it is an efficient transmitter of interference. **The simple receiver shown in Fig. 21 should not be built or operated unless it can be used well away from other v.h.f./f.m. receivers and aerials.**

The superregenerator is essentially a detector of amplitude modulation but, like other tuned circuits, it will operate on f.m. signals if the station is tuned to one side of the response curve, as shown in Fig. 22. The excursions

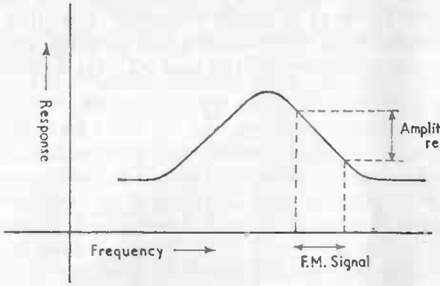

FIG. 22. AMPLITUDE RESPONSE TO AN F.M. SIGNAL

of the frequency modulated carrier provide almost maximum response at the top of the curve, and practically no response at the bottom, the f.m. thus providing an output which varies in amplitude. Each f.m. signal has two tuning points separated by a narrow silent band, one on each side of the response curve.

The 50pF tuning capacitor is the largest component in the circuit and an experimental construction can be made with the parts mounted on to the tuner, a midget socket being provided for the OC170. A conventional potentiometer can be used for R_1 but a small "slider" resistor as now used in the majority of television receiver preset controls takes up less space and is just as suitable since once the correct setting is found the control does not need close or frequent adjustment. The tuning coil, L_1, consists of three turns of 18 s.w.g. tinned copper wire ½″ in diameter, spaced apart by the wire's own thickness; the inductance can be varied to bring the tuning of C_2 to the centre of its range by squeezing or stretching the coils of L_1 closer together or further apart by trial. A quarter-wave whip aerial is made from enamelled wire, stretched slightly to give it spring and to be self-supporting: 22 s.w.g. serves well but other gauges can be used. The whip aerial is supported on the tuning coil and is sweated to the coil at about the centre, or between the centre and the end of the coil connected to C_4 and the earpiece—this end of the coil should also be the end taken to the frame of the tuner. The aerial tapping point giving best results is chosen by trial. The length of a quarter-wave whip is approximately 30″. Where signals are strong an eighth-wave whip 15″ long can be tried.

The r.f. choke in the emitter circuit is made of 22 s.w.g. or smaller enamelled copper wire and consists of 10 turns wound in the screw-thread of a standard coarse-pitch ferrite coil core; alternatively, a 12 turn coil ¼″ in diameter and with no core can be tried. The feedback capacitor C_3 is a 10pF beehive trimmer. A magnetic earpiece of 250 ohms d.c. resistance was used in the original receiver.

To test the receiver, set the slider of R_1 to the positive end, screw in C_3 one or two turns from the fully open position, and switch on. Advance R_1; at some point the circuit should go into oscillation with the characteristic superregenerative hiss. If there is no superregeneration leave the slider of R_1 at about the mid-point of its track and screw in C_3 with an insulated trimming tool until the hiss is heard.

Set R_1 so that the circuit is just quenching, and tune C_2 after arranging the whip aerial with the correct polarization (usually horizontal) for the local transmitters. A point should be found where the quench breaks, when careful tuning will bring in an f.m. station . Adjust L_1, opening the turns slightly if C_2 is almost fully closed, or squeezing them together if C_2 is almost fully open, when it should be possible to tune in the three local signals.

The warning is repeated that this circuit should not be used in a built-up area where it would cause intolerable interference. It is more suited to the experimenter and to the constructor with some experience than to the novice, and for this reason no detailed constructional drawings are given.

A simple f.m. receiver which, properly adjusted, causes no f.m. interference, is shown in Fig. 23. Once again, however, the circuit is intended for the more experienced builder since a superregenerating detector is used on a frequency which, if incorrectly set, can cause television interference.

Tr_1 and Tr_2 form a superhet consisting of oscillator, frequency-changer, i.f. amplifier and superregenerating detector. Tr_3 and Tr_4 provide audio amplification. The circuit is a development of the Hazeltine "Fremodyne" which had a short run of popularity in the U.S.A. after the war.

The local oscillator, Tr_1, is tuned to the low side of the signal to provide an i.f. of 20Mc/s or so, output being fed from the emitter, *via* C_5, to the frequency-changer base, Tr_2. Signals from a whip aerial are fed in across a choke in the emitter circuit of Tr_2, the resulting intermediate frequency appearing at the collector. In the collector line, however, L_2, tuned by its own self-capacitance and circuit stray capacitances, is oscillating due to the feedback capacitor C_8, and self-quenching in a superregenerating circuit *via* C_7. Quench control is provided by R_6. The i.f. amplifier therefore gives good gain at 20Mc/s and an amplitude output from an f.m. signal by the action already described, and shown in Fig. 22. L_2 is shunted by R_7 to broaden the tuning.

In the following audio stages it is very desirable to reduce the quench hiss, and accordingly a fairly large by-pass capacitance is used for C_{10} with rather small coupling capacitances at C_{12} and C_{13}. Depending on reception, it may be found possible to increase these last two values by trial. R_9 and C_{11} decouple the receiving stages from the amplifier; the simplest possible circuitry is used round Tr_3 and Tr_4, and the output drives a crystal earpiece. A magnetic earpiece can, of course, be used in place of R_{13} when some alteration to R_{12} may be needed.

A disadvantage of this receiver is that there is no tuning on the signal frequency, $R.F.C._2$ serving as a very broadly tuned input circuit. Replacing the choke by a conventional tuned circuit gives no improvement in results; a tuned signal pre-amplifying stage with a high gain u.h.f. transistor adds slightly to signal strength and greatly improves rejection of second channel interference, but in such a simple receiver the added expense and complication are not justified. The result is that the receiver tunes to two different frequencies almost equally well at any one time—with an f.m. signal at (say) 90Mc/s the set is also tuned to 50Mc/s (*i.e.* the local oscillator frequency plus and minus the i.f., or 70 ± 20Mc/s). In the author's location this has not led to any interference on the f.m. band.

It is recommended that the receiver, after testing and adjusting, should be housed in a metal case to assist in shielding the quench circuits and so to cut down interference; some quench is re-radiated by the aerial, however, and so the i.f. must be checked and adjusted if necessary when the circuit is first tried.

COMPONENTS LIST FOR THE SIMPLE F.M. RECEIVER, FIG. 23

L_1	4 turns 20 s.w.g. tinned copper wire ½″ diameter
L_2	50 turns 40 s.w.g. enamelled copper wire, wound on R_7. See note in **Coils and Chokes** on page 33.

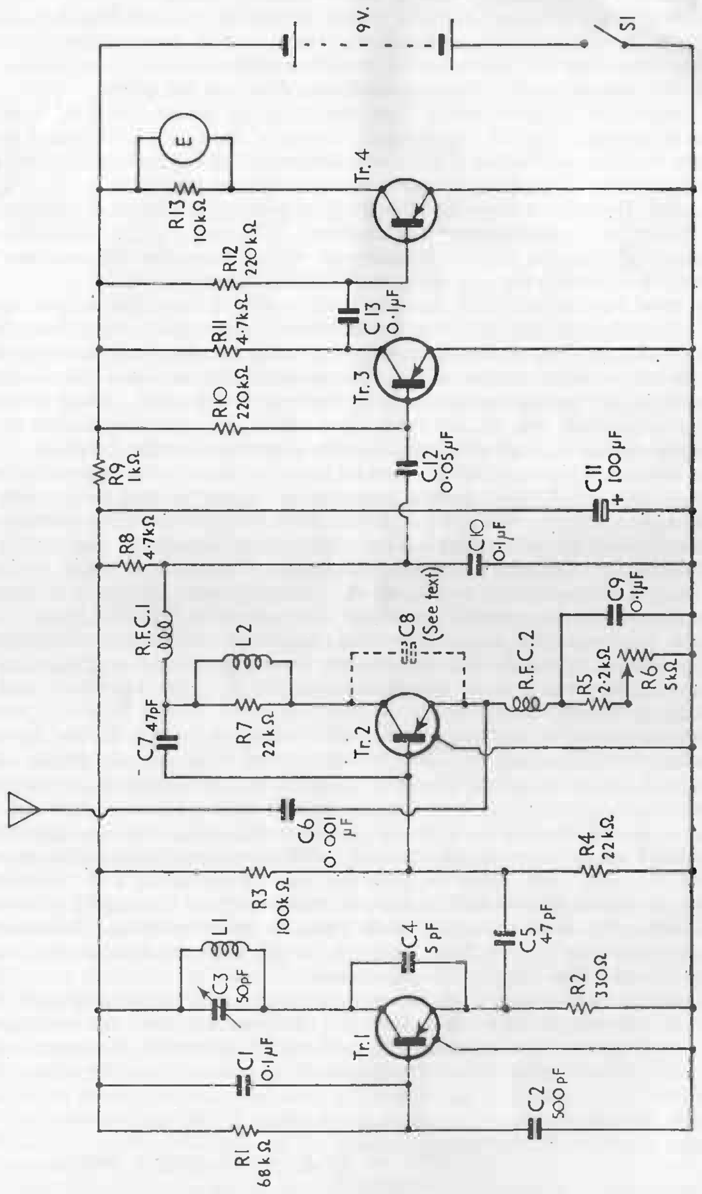

FIG. 23. A SIMPLE F.M. RECEIVER

R.F.C.$_1$	40 turns 30 s.w.g. enamelled copper wire closewound on polystyrene former. See note at bottom of page.
R.F.C.$_2$	12 turns 22 s.w.g. enamelled copper wire, ¼" diameter, turns slightly spaced. See note at bottom of page.
C_1, C_9, C_{10}, C_{13}	0·1μF midget tubulars
C_2	500pF silver-mica
C_3	50pF tuner
C_4	5pF silver-mica
C_5, C_7	47pF silver-mica
C_6	0·001μF ceramic
C_8	See note below
C_{11}	100μF, 15 v.w. midget electrolytic
C_{12}	0·05μF midget tubular
R_1	68kΩ. All fixed resistors except R_7, ¼ or 1/10 watt
R_2	330 ohms
R_3	100kΩ
R_4	22kΩ
R_5	2·2kΩ
R_6	5kΩ volume control with S.P. ON-OFF switch
R_7	22kΩ. ½ watt
R_8, R_{11}	4·7kΩ
R_9	1kΩ
R_{10}, R_{12}	220kΩ
R_{13}	10kΩ
Tr_1, Tr_2	OC170, Mullard
Tr_3, Tr_4	OC71, Mullard or equivalent. See note below
E	Crystal earpiece
Sundries:	Case, battery, control knob, 2 midget transistor holders, etc.

Coils and Chokes

L_1 is a self-supporting coil wired directly across C_3, the frame of the tuner being taken to the negative supply line. The turns should be spaced apart by the wire's own thickness for first trials, the inductance being adjusted by squeezing the turns closer together or spreading them apart as required. The wire gauges specified for the coils and chokes need not be adhered to rigidly; wires similar in size will serve.

L_2 is wound on L_7, the resistor acting as a coil former. A ceramic-bodied resistor, Erie Type 8 or similar, should be used, and the turns closewound evenly along it, running the wire back in a second layer if necessary. The ends of the winding are soldered to the resistor leads close to the body of the component. Different resistor sizes and methods of winding lead to differences in frequency response, and the operation of L_2 must be checked, and the winding corrected if necessary, when the set is first switched on. See **Construction and Alignment**, overleaf.

R.F.C.$_1$. In the original receiver this choke is wound on a Radiospares polystyrene "Core Former" but the same winding on any other type of former about ¼" in diameter is satisfactory. No core is needed.

R.F.C.$_2$. This is a self-supporting coil with the turns slightly spaced and different windings can be tried experimentally in this position, using both fewer and more turns. For example, the 144Mc/s band can be covered with this receiver if L_1 is reduced to one turn of wire. *R.F.C.*$_2$ in that case should have four turns only, when it will give some pre-selection against the second channel of 104Mc/s.

C_8 is the feedback capacitor for the 20Mc/s circuit and in the prototype there was sufficient stray capacitance in the transistor holder and circuit wiring to make an actual capacitor unnecessary. If extra capacitance is needed in this position, shown by the failure of the circuit to superregenerate, only a very small value is needed and it is sufficient to make C_8 from plastic covered connecting wire. Two lengths of ½″ of wire are twisted together, making sure that they are perfectly insulated one from the other, and one end of one wire is soldered to the emitter tag on the holder, one end of the second wire being soldered to the collector tag. The wires are then untwisted, with the circuit operating, until just sufficient capacitance is left to maintain quenching with the quench control, R_6, almost fully advanced.

A number of transistors have been tried in the circuit, best results being obtained from OC170s. An OC169 is satisfactory as the oscillator, Tr_1. Practically any small transistors can be used for Tr_3 and Tr_4, cheap red spot types being excellent in most cases.

Construction and Alignment

Where a metal case is used to house the receiver, C_3, the single tuner, can be mounted directly on to the metal. The case then takes the potential of the decoupled negative supply line, so that the rest of the circuit must be insulated from it. This is a simple matter, however, if the components are assembled on a small paxolin panel, as in the other receivers previously described. The oscillator components can be mounted on and around C_3. Transistor holders are recommended for Tr_1 and Tr_2. There is nothing critical in the arrangements of the circuits which will work perfectly well if hooked-up loosely on the bench. Various aerials can be tried, the original set working on a quarter-wave whip aerial 30″ long; a feed-through insulator is needed to carry the aerial into the metal case.

As already stated, detailed constructional drawings are not supplied for this circuit since it should be attempted only by experienced builders capable of designing their own layouts.

With the circuit completed and the wiring checked two or three tests are necessary before attempting to receive signals, and for the first of these, on the frequency of the superregenerating circuits, a signal generator is most desirable.

Disconnect C_5 from the junction of R_3,R_4, disconnect the aerial, switch on by turning R_6 and slowly advance this control towards the full position to check on superregeneration; the circuit should go into loud hissing oscillation in the manner already described. With C_5 and the aerial disconnected it is just possible in some cases that superregeneration may take place with the whole resistance of R_6 in circuit. In such an event increase R_5 by trial until oscillation can be stopped when R_6 is turned back towards the OFF position.

Note that reconnecting C_5 will make it necessary to advance R_6 considerably, so that in this first test superregeneration should start with the control about a quarter of the way round the track.

If there is no superregeneration at all, wire in C_8 (made as already described), after checking the transistor and the value of C_7.

Switch on the signal generator and run its lead near to L_2; there should be no need for direct coupling. Tune the generator on either side of 20Mc/s until the quench breaks and the audio modulation tone of the generator is heard. Read the frequency of the i.f. circuits from the signal generator dial.

The final frequency obtained is not too important from the point of view of receiver operation, but is very important in preventing harmonic interference with television receivers. In channel 1 areas the i.f. must be no higher than 20Mc/s so that the second harmonic of the i.f. is not above 40Mc/s. In channel 2 areas the i.f. must be no higher than 23Mc/s; in channel 3 areas no higher than 25Mc/s. In areas served by channels 4 and 5 it is necessary to take the third harmonic into account so that for channel 4 the i.f. should be no higher than 19Mc/s; alternatively an i.f. of 22Mc/s or slightly higher would be safe. For channel 5 areas an i.f. of up to 20·5Mc/s or above 23Mc/s should be satisfactory. In a few locations two channels must be taken into account, as in the author's area where television receivers are working on channels 1 and 2.

Correct L_2 as necessary by adding or subtracting a turn or two of wire, aiming at an intermediate frequency as near to 20Mc/s as possible—that is, avoid widely different frequencies such as 15 or 30Mc/s. Then reconnect C_5; superregeneration will cease and R_6 will need advancing to a new setting to obtain quench. Now check the tuning of L_2 once more, and make any further correction which may be required. Connect the aerial to C_6 and once more check the intermediate frequency. Note that if C_8 is required when C_5 is reconnected, or if C_8 is already fitted but is increased in value to obtain superregeneration, this will alter the tuning of L_2, and C_8 must be set to a final value before tests on the tuning of L_2 are concluded.

The signal generator can now be switched off and a listening check made to ensure that no 20Mc/s signals are breaking through, the quench being set by R_6 to its most sensitive level. If any morse or commercial stations are heard alter L_2 slightly by moving a turn of wire with the tip of an insulated trimming tool until a clean and unbroken quench is obtained. (This assumes, of course, that the local oscillator is not tuned by chance to a required f.m. signal). Now rotate C_3 slowly, with the whip aerial in the correct polarization; if the local stations are not received try opening the turns of L_1 and again tune C_3. If necessary squeeze the turns of L_1 and try again—it should not be difficult to find a point where an f.m. signal is brought in, provided that R_6 is not too far advanced. L_1 can then be adjusted so that the local stations are tuned in the centre of rotation of C_3.

Failure to receive stations may be due to a fault in the local oscillator circuit. To test this, break the supply to Tr_1 and insert a 0—10mA meter. A reading of 0·7mA approximately should be obtained, and if L_1 is touched with the finger this current should rise sharply to about 1·3mA. No rise of current indicates that the circuit is not oscillating, due possibly to a faulty component, incorrect wiring or an unsuitable transistor.

Various tests and experiments can be carried out on the circuit. By changing the value of R_1 the effect on the frequency changer of different input powers from the oscillator can be tried; R_1 can be reduced to 33kΩ or increased to about 150kΩ.

R.F.C.$_2$ can be replaced by a resistor, values up to 100 ohms being suitable. C_4 can be varied, especially if L_1 is reduced to tune over higher frequency ranges, as already mentioned, and a twisted wire capacitor such as that described for C_8 can be used.

It will be realized that neither of the v.h.f. receivers described here is a "quality" receiver, nor are they suited to long-range reception. Nevertheless, both circuits have been tested with very interesting results at 25 miles from a "satellite" f.m. transmitter, whilst beacons, v.h.f. links and aircraft have also been received.

The constructor will hardly need reminding that in all experimental work the circuits should be switched off for all alterations of components or wiring, to protect the transistors, and that extra care must be taken over insulation in hooked-up assemblies.

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