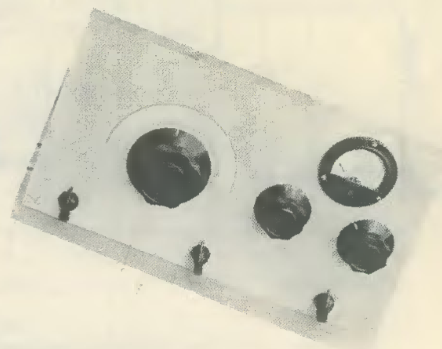
emission without unduly high heater wattage.

Thus, a whole new series of problems arose, a great many of which were concerned with the design of the heater and cathode assembly. The use of indirectly heated valves provided opportunity for numerous developments in circuit design and many such developments, in turn, made more stringent demands on the valves. This is a "battle" which has carried on for more than 30 years and which still continues. Some of the major difficulties encountered in this battle of progress will be the subject of the next article.

(*to be continued*)

Cover Feature



VFO Top Band Phone Transmitter

FREDERICK SAYERS

This article describes a simple design for the 160 metre band which combines efficient operation with low cost. Many of the components are non-critical and may already be on hand, and the author fully discusses suitable types and alternatives. For this reason, such components are not specified by make and type number in the Components List. The design includes a modulation amplifier suitable for use with a carbon microphone or, by employing an external pre-amplifier, a crystal microphone. A further alternative is a separate modulation amplifier, for which details will appear in next month's issue

Readers are reminded that this transmitter must not, of course, be operated without the requisite Post Office licence

THIS TRANSMITTER SHOULD SUIT THE NEWCOMER who wishes to get started without too much outlay, or the old timer who is looking for a simple Top Band phone rig. It is constructed almost wholly from receiver type components, is very free from snags, and is easy to operate.

The circuit is shown in Fig. 1. In this diagram, one section of the 12AT7 twin triode, V_1, is used as a Clapp oscillator, and is tuned by VC_1. This gives complete v.f.o. coverage from 1.8–2 Mc/s. The second half of the 12AT7 is a buffer-amplifier, and serves to help isolate the v.f.o. L_2 is broadly tuned to about 1.9 Mc/s, and needs no further adjustment. The complete v.f.o. and buffer stages occupy a small screened box, with the valve projecting horizontally from the back in order to remove the main source of heat from L_1 and associated components. The 12AT7 will provide about 2mA grid drive for the power amplifier.

The p.a. is a 6BW6 (V_2) which is suitable for r.f. applications up to about 150 Mc/s. If a 5763 is to hand, this may be fitted instead, holder wiring being changed to suit. Bias is developed across R_5. If an initial test shows that sufficient grid drive is available, the choke RFC_2 may be omitted. This depends to some extent on valve performance and h.t. voltage.

Anode current is shown by the 100mA meter and, with 250V reaching the p.a., 40mA corresponds to the maximum permitted input of 10 watts. L_3, in conjunction with VC_2 and the 2-gang capacitor VC_3, forms the customary pi-output circuit, which will load directly into many aerials. For Top Band, an end-fed wire is often used.

The modulator is extremely simple, and was adopted after some experiments with other circuits. The 6CH6, V_3, has very high gain, and was found to give adequate results on its own. The bias developed across R_6 is about 4.5V, and this was suitable for the carbon mike employed, and should suit most carbon microphone inserts. T_1 is a 50:1 or similar carbon microphone transformer.

It will be clear that the r.f. section can be used with a more elaborate modulator, if wanted. Notes on the use of a crystal microphone are given later, and a push-pull modulator will be described in next month's issue.

Choke modulation is used, the inductor LFC_1 being a mains pentode type output transformer, with the speaker secondary unused. With this type of circuit, overmodulation which would break the carrier is impossible, and this was felt to be an advantage. Reports on speech quality and modulation depth are good. If an attempt is made to use

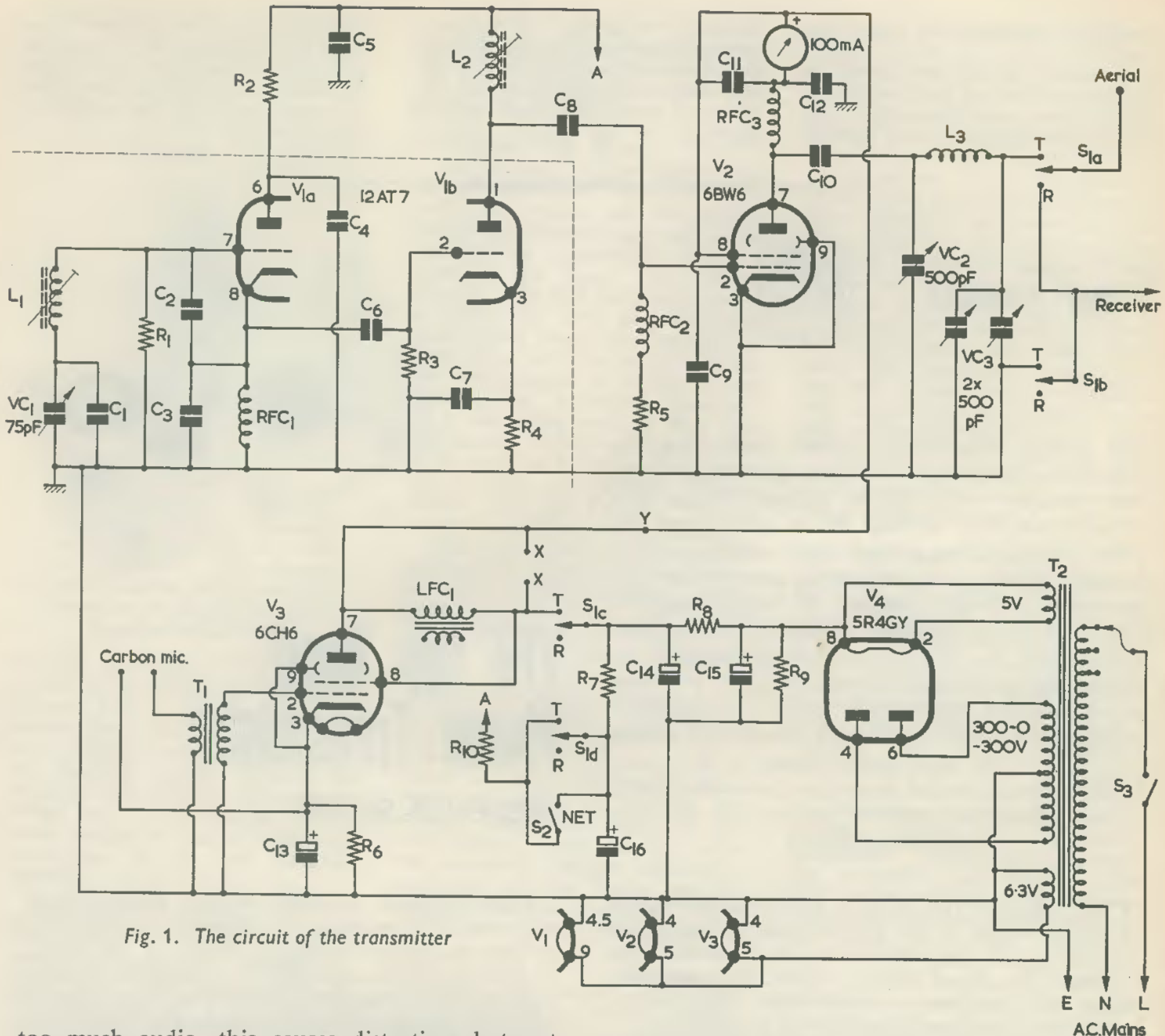


Fig. 1. The circuit of the transmitter

too much audio, this causes distortion, but not overmodulation which would break the carrier.

Transmit/Receive switching is included, and is provided by the 4-pole 2-way switch, S_1. Section $S_{1(a)}$ transfers the aerial from the transmitter pi tank to the receiver aerial socket. Section $S_{1(b)}$ short-circuits the receiver aerial circuit to chassis in the Transmit position, to avoid overloading the receiver. H.T. is applied to the v.f.o., modulator and p.a. by switch sections $S_{1(c)}$ and $S_{1(d)}$. The "Net" switch, S_2, applies h.t. to the v.f.o. only, so that the transmitter can be adjusted to the receiver frequency, or netted on an incoming signal. Resistor R_{10} is included to obviate the slight sparking at the switch which would otherwise occur when applying h.t. to C_6.

Power Supply

The h.t. secondary of the mains transformer, T_2, is best rated at 100mA to avoid undue drop in voltage. An h.t. secondary giving 250V, 275V or 300V may be used. There is some loss of voltage in the rectifier, in R_8, and in LFC_1, causing a reduction in p.a. anode voltage. The d.c. resistance of the speaker transformer primary, LFC_1, was 300Ω, dropping over 25V when passing the anode current of the 6CH6 and the anode and screen currents of the 6BW6. In tests with a 250–0–250V transformer, the p.a. received 200V, corresponding to an input of 8W at 40mA. Loading to 50mA at 200V, for 10W input, gave virtually no increase in r.f. output. Good results were obtained with the 8W input. Nevertheless, it is better to have a more adequate voltage available, so a 300–0–300V transformer is preferred. Should a better component, with less d.c. resistance, be to hand for LFC_1, this will avoid some of the drop in voltage. R_8 can also be replaced by a smoothing choke of lower d.c. resistance, if available, and this will allow a little more voltage on the p.a. So if a 250V 100mA mains transformer is to hand, it

Components List

Resistors

(All fixed values ½ watt 10% unless otherwise stated)

R_1	56kΩ
R_2	3.3kΩ
R_3	100kΩ
R_4	100Ω
R_5	20kΩ
R_6	100Ω
R_7	5.6kΩ 1 watt
R_8	100Ω 2 watts
R_9	100kΩ 1 watt
R_{10}	27Ω

Capacitors

C_1	40pF 2% silver mica
C_2	1,000pF 2% silver mica
C_3	1,00pF 2% silver mica
C_4	0.05μF ceramic
C_5	0.01μF ceramic
C_6	200pF silver mica
C_7	0.01μF ceramic
C_8	200pF silver mica
C_9	2,000pF ceramic
C_{10}	5,000pF 1kV wkg. mica
C_{11}	0.01μF ceramic
C_{12}	5,000pF ceramic
C_{13}	50μF 12V wkg. electrolytic
C_{14}	16μF 450 Vwkg. electrolytic } in single can
C_{15}	8μF 450V wkg. electrolytic } in single can
C_{16}	32μF 450V wkg. electrolytic
VC_1	75pF variable
VC_2	500pF variable
VC_3	500+500pF variable, two-gang

Inductors

L_1, L_2, L_3	See text
$RFC_{1,2}$	2.5mH chokes
RCF_3	2.5mH choke (60mA)
LFC_1	mains pentode speaker transformer primary
T_1	50:1 (or similar) carbon mic. transformer
T_2	Mains transformer; secondaries: 300–0–300V 100mA, 6.3V 1.5A (minimum), 5V 2A (minimum). See text

Valves

V_1	12AT7
V_2	6BW6
V_3	6CH6
V_4	5R4GY

Switches

S_1	4-pole 2-way rotary (Transmit-Receive)
S_2	s.p.s.t. rotary or toggle (Net)
S_3	s.p.s.t. rotary or toggle (Mains on-off)

Valveholders

1 B9A holder with skirt and 2in screen
2 B9A holders, skirts optional
1 octal holder

Meter

1 moving-coil meter, 100mA

Miscellaneous

8 x 3in "Universal Chassis" runner (Home Radio (Mitcham) Ltd.)
Aluminium sheet for chassis
Aluminium sheet or hardboard for panel
Stand-off insulator
Knobs, as required, including large knob or dial for v.f.o.

may be pressed into service.

The heaters of V_1, V_2 and V_3 require 1.5A, and this is easily within the capacity of most transformers. The 5R4GY rectifier needs a 5V 2A supply. Numerous other rectifiers are satisfactory, if able to supply 100mA.

Chassis And Panel

The layout of components and dimensions are not likely to be too important, but a chassis about 13½ x 5½in, and 2½ or 3in deep will allow everything to be accommodated without cramping. The positions of most of the major components can be seen from Fig. 2. The panel is 13 x 8in and can be cut from hardboard or aluminium. If hardboard is employed, a piece of aluminium about 4 x 3½in must be fitted between the v.f.o. box and the panel. There is 2in clearance below V_1 for C_{14} and C_{15}, and a taller capacitor could be used if placed to one side of this valve's screening can, which projects horizontally from the rear of the v.f.o. box.

VC_2 is a *non*-miniature 500pF air-spaced tuning capacitor as used in receivers. Miniature capacitors with very closely spaced plates should not be used as they are likely to spark over. A maximum capacitance of 300pF is actually sufficient. VC_3 is 1000pF in all, this being obtained by wiring both sections of a 500pF 2-gang tuning capacitor in parallel. A 3-gang capacitor is equally satisfactory, and may in some cases be an advantage. These capacitors are bolted to the panel, and grounded to the chassis by short leads to soldering tags.

A meter reading 100mA full-scale is convenient, but a more sensitive meter can easily be shunted, if to hand. Leads from the meter pass through the chassis to RFC_3 and LFC_1. It is not necessary to read grid current, once this has been checked when first testing the transmitter.

The tank coil L_3 was wound on a ribbed former, and fixed to VC_3 by a bracket. See Fig. 2. It is 1½in in diameter, and has 55 turns of 24 s.w.g. wire. A 1¼in diameter smooth former would be perfectly satisfactory, also with 55 turns. If a somewhat similar coil is to hand, it will probably prove suitable.

V.F.O. Box

The v.f.o. box is 2¼ x 3½ x 3in high. It is very easily made by purchasing a "Universal Chassis"

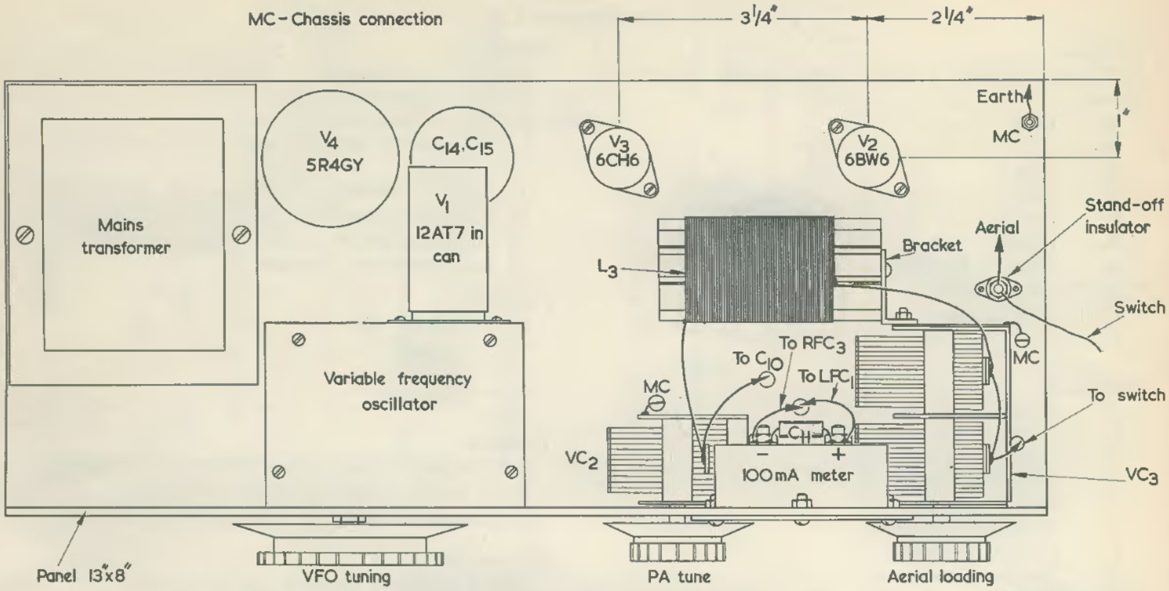


Fig. 2. Component layout above the chassis

runner 8in x 3in (Home Radio, Mitcham) and cutting two 90° sections from the flanges, 2¼in from each end. Two right-angle bends can then be made, to obtain the two sides and rear of the box. After wiring, the box is bolted to the chassis and panel, and closed on top by a piece of aluminium, 2¼ x 3½in, held in place with four self-tapping screws. This forms a rigid assembly. If the panel is not metal, do not forget the screen between panel and box, as mentioned.

The v.f.o. box is not attached to the panel and chassis until the 12AT7 valveholder has been wired. Colour coded leads pass down through a ½in hole in the chassis, and are taken to the appropriate points under the chassis when the box is finally bolted in position. One lead is from tag 6 ($V_{1(a)}$ anode) and another from tag 1 ($V_{1(b)}$ anode).

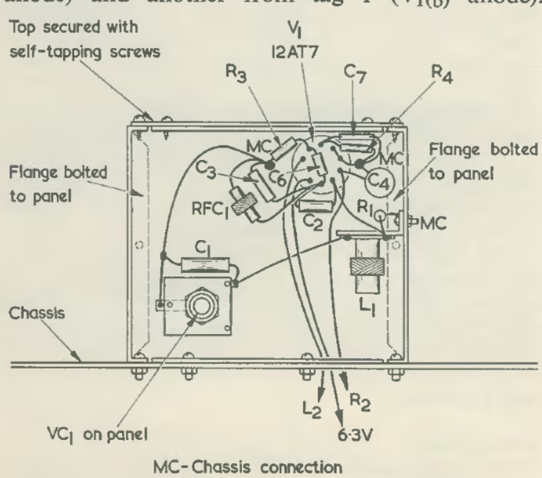


Fig. 3. Layout of components in the b.f.o. box

The final lead is from tag 9 (heater). The dotted line in Fig. 1 shows which components are in the v.f.o. box.

Fig. 3 illustrates the v.f.o. wiring. Connections are short, as movement or vibration will tend to cause shifts in frequency. Various chokes were tried for RFC_1, and a miniature transistor type choke (2.5mH) was finally adopted. The usual type of 2.5mH short wave choke having 4 or 5 sections is equally satisfactory. A small "all-wave" r.f. choke was also found suitable. The choke must be effective at 1.8–2 Mc/s, and without resonances in this band. This is not a very difficult requirement to meet.

Various coils were tried for L_1, and eventually a surplus medium wave coil, with some turns removed, was chosen. No pre-set capacitor is needed in the v.f.o. Final calibration is only made when the transmitter is finished, and has been left running for at least fifteen minutes.

V.F.O. Calibration

V.F.O. calibration can be done with the aid of a receiver and 100 kc/s crystal marker. The v.f.o. signal is coupled into the receiver by placing the receiver aerial lead near C_8. With VC_1 closed, the signal will probably be heard fairly near the bottom of the medium wave band, if a medium wave coil has been connected. The slug of L_1 should be adjusted to a mid-way position, so that subsequent fine changes to inductance can be made. Turns are then removed from L_1 until the v.f.o. signal is heard near 1.8 Mc/s. The coil can then be properly wired, and the v.f.o. box cover may be screwed on.

The receiver is then tuned to the 100 kc/s crystal harmonic which corresponds to 1.8 Mc/s, and the core of L_1 is rotated until the v.f.o. signal gives zero beat with the harmonic, with VC_1 nearly

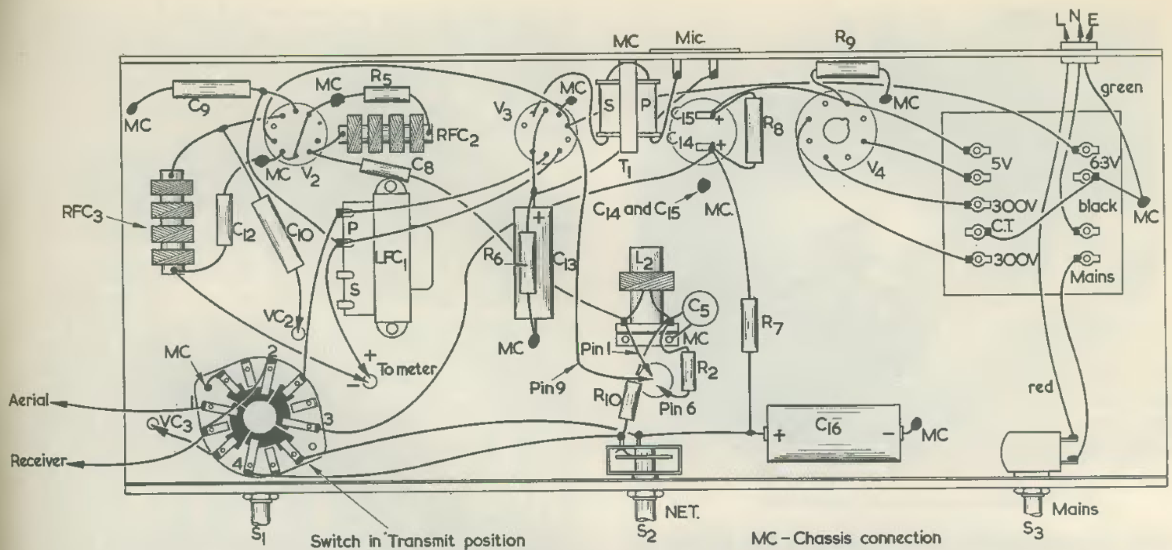


Fig. 4. Components and wiring below the chassis. The tag layout for the two transformers and LFC_1 apply to the components employed in the prototype; other components may have differing layouts or lead-out wires

closed.* The v.f.o. dial or scale is then marked for 1.8 Mc/s. The receiver is next tuned to 1.9 Mc/s by reference to the 100 kc/s crystal, and the v.f.o. tuned again to zero beat, and calibrated for 1.9 Mc/s. This is repeated for 2 Mc/s. Not quite the full 180-degrees rotation of VC_1 will be employed.

For the 0.05 Mc/s marks, tune the receiver to the crystal harmonic which falls on 3.7 Mc/s, and adjust the v.f.o. to 1.85 Mc/s, so that its second harmonic is at zero beat with the crystal. Mark the scale, and repeat for 1.95 Mc/s. The 0.01 Mc/s marks between 1.8 Mc/s and 1.85 Mc/s can be estimated with sufficient accuracy, as can those up to 2 Mc/s.

If a friend has a calibrated v.f.o., this may be used to calibrate the Top Band transmitter v.f.o., by comparing signals with a receiver. An accurate heterodyne frequency meter, or similar apparatus will also be satisfactory.

For a home-wound v.f.o. coil, 95 turns of 34 s.w.g. enamelled wire, side by side on a ½in diameter cored former, can be used. Turns must be sealed to prevent movement.

A large knob was found satisfactory for VC_1, but a small reduction drive could be added. This capacitor should be free from wobble, and of good construction.

Under the Chassis

Fig. 4 shows the under-chassis wiring. Heater and h.t. circuits are run close to the chassis. For the "Net" and mains circuits, on/off toggle switches are equally satisfactory instead of the rotary types shown.

Leads to C_8 and RFC_2 are clear of the chassis, and well removed from C_{10}. With the layout shown, the p.a. is perfectly stable. Wiring should be reasonably short and direct.

When the 6BW6 holder has been wired, a check can be made for grid current, if wished. Alternatively, this test can be left until all construction is finished. The valve should be in place, but no anode or screen-grid voltage should be present. This will occur if the Transmit/Receive switch is left at "Receive" and the "Net" switch is closed. A meter is then inserted between R_5 and the chassis. In the prototype, L_2 was a medium wave coil, broadly resonant with stray capacitance to about 1.9 Mc/s. It is only necessary to set the v.f.o. to about 1.9 Mc/s, and rotate the core of L_2 until a slight rise in grid current shows resonance. It was found that grid current remained at about

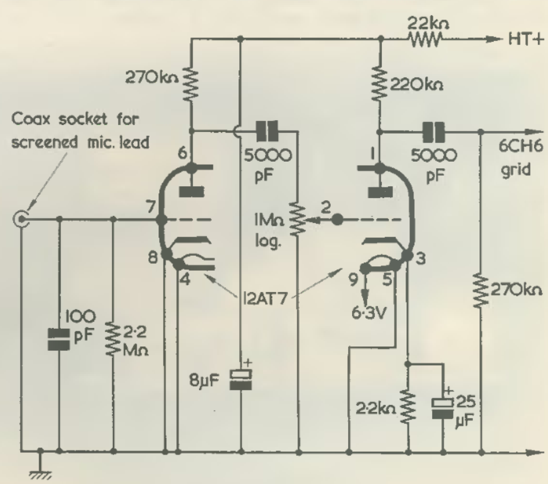
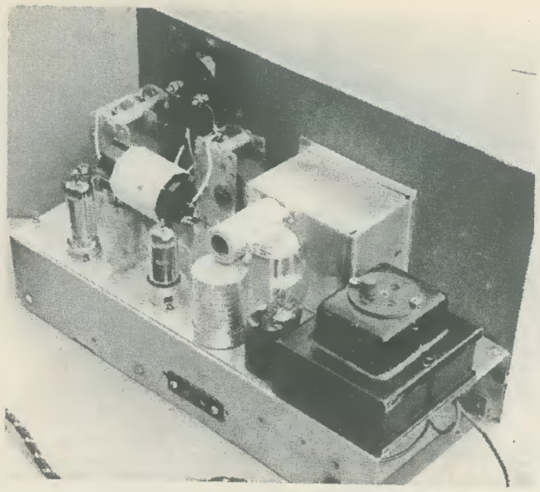


Fig. 5. A suitable pre-amplifier for a crystal microphone

* This adjustment may be made via the ½in hole through which the wires to the v.f.o. pass. Alternatively, a small hole may be provided for this purpose in the cover plate.—EDITOR.



Above chassis view of transmitter

2mA throughout the whole range of the v.f.o.

If grid current is too high (say over 2½–3mA) the resistors at R_2 and R_7 can be increased in value. Should there be plenty of grid current, RFC_2 may be omitted, with no loss of efficiency. If grid current is too low (say under 1¾mA) there may be insufficient h.t. applied to the v.f.o. or buffer, or L_2 may not have been tuned to the band. Small changes in grid current do not produce any significant change in r.f. output, provided the grid current is around the 2mA mark. This represents 40V bias developed across R_5.

Once grid current has been checked, R_5 can be connected to the chassis, and the meter removed. When operating, it is only necessary to monitor anode current, with the panel 100mA meter.

Modulator

This is of the simplest possible type, with d.c. for the carbon microphone developed across R_6, thereby avoiding any need for a battery. If it is wished to cut top somewhat, a 0.05μF or 0.01μF capacitor may be connected from the 6CH6 anode to chassis. This depends to some extent on the user's voice, and the microphone. The telephone insert type of carbon microphone can provide quite acceptable speech quality.

If a crystal mike is preferred, it will be necessary to provide two stages of amplification between this and the 6CH6. While experimenting with an inexpensive crystal microphone, the circuit in Fig. 5 was found satisfactory.

It will be realised that any audio amplifier able to provide some 5 watts or so can be employed as a modulator. The modulator can then run from its own power supply. The speaker output transformer of the audio amplifier must be disconnected, and a modulation transformer substituted. The secondary of the modulation transformer is connected to the points X-X in Fig. 1, and T_1, V_3, LFC_1, and the bias components C_{13} and R_6 taken out of circuit. If the p.a. is loaded to a total input (anode and screen grid) of about 45mA, at 250V, its modulating impedance is about 5,500Ω. A 1:1 ratio transformer will this do when using an audio amplifier with output valves having an optimum load of about 5,000 to 6,000Ω or so. A small 5-watt push-pull amplifier is ideal.

When ample h.t. voltage is available, and a single valve is used as a choke coupled modulator, as in Fig. 1, modulation depth can be increased by introducing a resistor at point Y of Fig. 1. A 2μF capacitor is connected across the resistor. This resistor can normally be between 1kΩ and 2kΩ in value.

Aerial and Loading

A Top Band dipole would be about 246ft long, and is seldom possible. So shorter, end-fed aerials are generally employed. These may often be operated successfully directly from the transmitter, an approach which has the merit of simplicity. In general, the longer the aerial, the better will results be. Aerials actually employed by the writer include 45ft sloping from the operating room to a pole on a chimney; 100ft and 120ft wires in the usual inverted L; and 185ft with a 45ft down-lead. All these gave good results. Signal strength is improved when the wire is reasonably long and well clear of ground, walls, etc.

An earth connection should be taken to the transmitter chassis. With relatively short end-fed aerials, the efficiency of the earth has quite a large effect on the strength of the radiated signal.

When the transmitter is to be put on the air, a clear channel should be sought with the receiver. The "Net" switch is then closed, and the v.f.o. tuned to the receiver frequency. There will normally be enough stray coupling to the receiver aerial circuit for this to be done easily. The "Net" switch is then returned to its "Off" position, and is not required for normal transmitting and receiving.

VC_3 should be closed, and the equipment

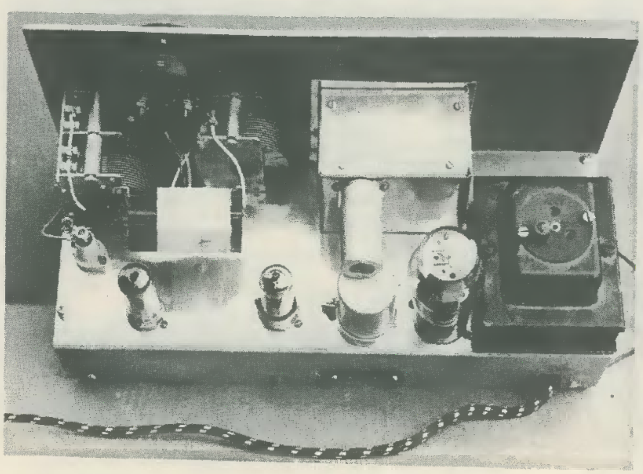


Illustration showing coil and variable capacitors switched to "Transmit". VC_2 is then rotated to find the dip in anode current, as shown by the meter. The dip may be far too low, representing insufficient input to the p.a., so VC_3 is opened, VC_2 being re-adjusted as necessary. This is continued until the p.a. draws the required anode current. VC_2 is always tuned for *minimum* anode current.

An initial test can be made by loading the transmitter into a 15W domestic lamp (200/250V) which should light with fair brilliance. If the signal is monitored with a receiver having a loudspeaker avoid feedback to the microphone, or howling will arise.

Very short aerials will not present an impedance which will load the transmitter. This problem is best overcome by using one of the usual methods, such as placing a loading coil in series with the aerial, or building a 160 metre tuner, and tuning the aerial against ground. The loading coil is particularly simple to use. It may be 2 to 4in in diameter, and should be wound with 16 s.w.g. or other stout wire, to avoid unnecessary losses.

If an 80 metre dipole, or other co-axial or twin-feeder dipole for a high frequency band is available, this will often work quite well as a Top Band aerial. The two conductors are joined, and the whole worked against ground, as for the end-fed wire. It is also quite easy to try vertical wires, whips, and other aerials electrically resembling those used for mobile work. In some cases where it is wished to work into a low impedance with a minimum of trouble, it may be worth adding extra capacitors in parallel with VC_3, or modifying the turns on L_3.

It is worth remembering that quite considerable distances are covered by Top Band mobile transmitters, where the type of aerial is severely restricted. An equivalent, or much better, aerial should generally be possible at any fixed location.

Next Month

In next month's issue, a push-pull modulator suitable for use with this transmitter will be described.

New Edge Contact-Cooled Selenium Rectifiers

A number of new edge contact-cooled selenium rectifiers are now available from Westinghouse Brake and Signal Co. Ltd. They utilise high current density elements which allow improved current ratings. All of these units are fully encapsulated and are ideally suited for electronic or other equipment subject to damp or humid conditions.

Single-phase bridge, centre-tap, voltage-doubler and half-wave units are available. In full-wave circuits maximum current ratings are 180mA and 250mA and in half-wave and voltage-doubler circuits the ratings are 90mA and 125mA.

The following are representative of the range available:

Type EC401, rated at 250 volts 180mA output in single-phase bridge circuit; case size $2\frac{5}{16} \times \frac{1}{2} \times \frac{5}{8}$in. Type EC403 rated at 250 volts 250mA output in single-phase bridge; case size $2\frac{5}{8} \times \frac{5}{8} \times \frac{3}{4}$in. Type EC402 rated at 250 volts 90mA in half-wave; case size $1\frac{3}{4} \times \frac{1}{2} \times \frac{5}{8}$in.
