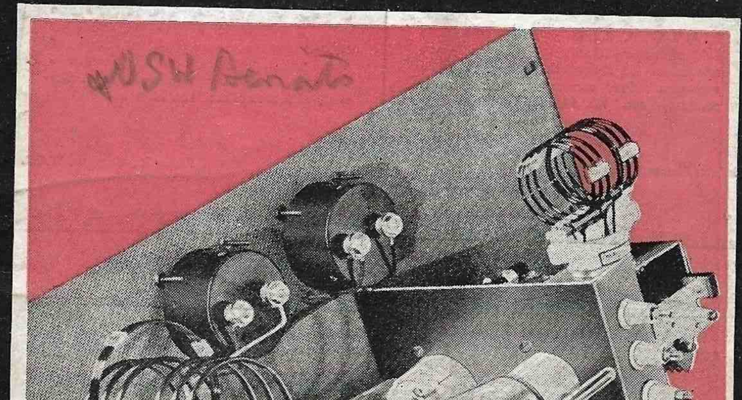
ULTRA SHORTWAVE HANDBOOK



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ULTRA SHORTWAVE HANDBOOK

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ULTRA SHORT-WAVE HANDBOOK.

INTRODUCTION.

Early in 1945 radio magazines in Britain and America were publishing reports of various committees formed to deal with proposed allocations of wavebands and frequencies for use after wartime conditions had passed on. It was with considerable surprise that many saw the American F.C.C. proposals of amateur transmitting bands to be situated at frequencies as high as 144 megacycles, 220 megacycles, 1,125 megacycles and even at 2,500 and 10,000 megacycles, these latter frequencies corresponding, as they do, to wavelengths of 12 and 3 centimetres respectively. At frequencies of this magnitude it is of no practical use to express the wavelength as a measurement, and clearly high frequency work has recently undergone considerable development for such bands to be included in a Government paper.

It has been known for some time that the former "ultra high frequencies" did not always conform to the generally accepted rules—chiefly it was thought that they were of value for communications over optical paths only. The Alexandra Palace television transmitter was received to give good programme value on the South Coast whilst the sound signals from the station were heard on several occasions in South Africa. It had also been believed that a critical frequency existed about the 40 mcs. band, where lower frequencies were propagated in the usual manner from the reflecting sky layers whilst higher frequencies underwent no such reflection, due to penetration of the layers, and so encircled only a very small portion of the earth's surface before escaping into space.

Experiments were continued, always with enthusiastic support from amateurs, and occasional long distance reports were obtained not only on the 56 mcs. band but also on the 112 mcs. band, and this latter frequency has had great wartime use in the U.S.A. by the War Emergency Radio Service, a voluntary body formed for A.R.P. duties with great stress laid upon quick radio communications. The W.E.R.S. has developed much excellent apparatus for work on these bands.

The ultra high frequency picture is constantly changing, however, and there is now reason to believe that what were once considered utterly useless frequencies, except in the laboratory, are actually of great value both for important business and Government work and also for the amateur, who, as always, will play a very great part in the ultimate development of this work.

The frequency spectrum has extended to such great limits that it is becoming common practice to refer to what was once "ultra high frequency" work as "very high frequency" or V.H.F., this covering the bands up to at least 112 mcs. The frequencies above these now receive the title of "ultra high frequencies," or U.H.F.

The modern valve, in one form or another, can be worked at frequencies up to about 800 megacycles, although this figure will probably be increased in the near future if it has not been already. At the U.H.F. of the new orders of tens of thousands of megacycles per second, however, the valve, so far at least, proves useless, and totally new apparatus has been developed which generates oscillations by a combination of strictly governed electrical and physical features.

Such apparatus is so far unavailable to the amateur, of course, but a short description is given in the Manual for the sake of completeness.

Those taking up high frequency work for the first time are advised to commence with a simple receiver, even of the battery operated type. The layout and constructional work involved for efficient reception of the high frequencies is more advanced than that used in ordinary short wave work, and a little experience is better than a great deal of theory.

This Manual is set out along these lines, the chapters including both battery and mains operated receivers, transceivers and transmitters, together with an account of Frequency Modulation reception, Ultra High Frequency laboratory gear such as the Klystron and notes on the aerials best suited to give good results at the high frequencies.

It must be remembered that, although transmitting gear is shown in this Manual, to transmit without a licence is contravening the law.

Moreover, should any amateur receive signals from Government stations by chance, as the author occasionally has, he is advised to re-read Article 4 on the back of his Post Office Receiving Licence.

CHAPTER 1.

The Nature of Ultra Short Waves and Simple Receivers.

Everyone interested in radio transmission and reception is now aware that one of the greatest future uses of the ultra short wave bands will be in the broadcasting and relaying of television programmes, together with their allied sound, whilst it has already been proposed that the B.B.C. should utilise at least one high frequency channel for the purpose of transmitting high class concerts and good quality sound in general. Undoubtedly there are novices who are far from certain why the higher frequencies are so excellent for these and similar services, and who wonder whether there is any basic difference in the type of wave transmitted.

The answer, of course, lies in the fact that at the higher frequencies greater separation between channels can easily be given so that each station can use a greater proportion of "ether room" and thus can consequently transmit a higher range of audio or video frequencies.

Before the war it was internationally agreed that transmitters should be separated by a frequency of 9,000 cycles or 9 kcs. per second. Some separation is necessary, for the stated frequency of a transmitting station is really the mean point of a band of frequencies, the bandwidth consisting of the mean radiating frequency to which is added two sidebands, one higher and one lower than the mean. These sidebands contain the modulating or sound characteristics of the signal, becoming wider as the sound frequencies are impressed upon them with greater fidelity. The point is soon reached, therefore, where the sound frequencies have to be suppressed in order that the sidebands of adjacent stations shall not mix or interfere one with the other, and this suppression point is below the optimum point for many programmes. Speech can be transmitted well on a surprisingly small range of frequencies, but music with the many instrumental harmonics which go to make the real tone requires a wide bandwidth for true reception. It was for this reason that for a season the Promenade concerts were relayed on the Alexandra Palace television sound channel, and the result on a good receiver was a revelation.

Consider the usual tuning range of a medium wave receiver, of, say, from 200 to 550 metres. Allowing the conventional 9 kcs. separation between stations this means that in the space available 106 stations can operate without mutual interference. The latest high frequency commercial receiver at the time of writing, as made in the U.S.A. has a frequency range of from 130 to 210 megacycles; that is from 1.42 to 2.30 metres, apparently a very restricted range. Yet, in between these two frequencies, still supposing a station separation of 9 kcs., is room for 9,000 stations, nearly 90 times as many as in the previous case. For reasons such as this, then, it becomes pointless to deal with the ultra short waves on a wavelength basis, for stations are separated only by minute fractions of a metre.

It can be seen that at these high frequencies each transmitter can be given a far wider band than 9 kcs. within which to operate so that the frequencies of the programme material can be unrestricted. So far as sound is concerned it is sufficient to use limits of 30 to 15,000 cycles per second—it will require a well designed receiver and loudspeaker system to utilise such a band—but a television video signal generally requires a bandwidth of 2 megacycles. Such a station would more than fill the medium wave scale, but on the high frequencies the video transmitter is tuned through just as is any other station.

The ultra short waves, then, give great selectivity, excellent programme value or considerable bandwidth economy, according to the need to be met, and before building a receiver it should be decided which of these advantages it is most desired to stress. Three types of receiver are commonly used; the superheterodyne, which takes full advantage of the selectivity obtainable and also gives good reproduction of sound, with suitable precautions; the tuned R.F. receiver with reaction, which is selective and also capable of giving good programme value; and finally the super-regenerative receiver, with poor selectivity but enormous sensitivity and amplification, suitable for long distance work although high quality sound cannot be reproduced.

Despite this last disadvantage, however, the super-regenerative receiver is the one used chiefly by amateurs. For ordinary contact and experimental work the sensitivity gained is well worth the loss of quality, and the first receivers to be described are of this type.

The super-regenerative receiver (generally shortened to "super"), was introduced by Major Armstrong and in form it is a simple oscillating circuit with a secondary oscillation impressed upon the first. It is common knowledge that with any reacting receiver the signal strength increases as the reaction control is brought into play until, just before the circuit breaks into complete oscillation, a sensitivity gain of a very considerable amount is obtained. If the receiver could be kept at this threshold point it would be working under the most efficient conditions, and the "super" device ensures that this is so by allowing the receiver to break into and fall out of oscillation at a frequency of perhaps 10,000 or 20,000 times a second, so that oscillations occur in short groups or "bursts". The control of this threshold oscillation is the second oscillating circuit attached to the receiving circuit, and this control oscillation, known as the quenching frequency, may be introduced either by a pair of coils or by a capacity-resistance combination with a time constant chosen to cause the oscillating receiver to "squegger"—that is, the grid of the oscillating valve is coupled in such a way that the fundamental oscillations give rise to their own quenching frequency. This control frequency must be much lower than the reception frequency so that the groups of oscillations have time to build up.

The net result of breaking up the oscillations at the signal frequency in this way is to impose a hiss on the

received signals, although on any signal of good strength the hiss is partially eliminated and sometimes it vanishes altogether. The modulation still undergoes some distortion but programme value is still fairly high, whilst for speech contacts the noise of the circuit can be disregarded. Indeed it has been pointed out that a well designed super circuit can introduce less noise than a superheterodyne receiver, since at the high frequencies a large number of I.F. stages have to be used, each stage adding its quota to the sum of valve noise.

The actual quenching frequency for most efficient operation depends on the frequency being received, for as working frequency rises so may the quenching frequency. It is not usual to design for a single quenching frequency, however, for the final quenching frequency may so easily be adjusted by alterations in capacities that it is most simple to adjust the receiver under working conditions.

Besides the addition of quenching components it will be seen that most V.H.F. oscillating detectors differ from the common throttle-control reacting circuits used in ordinary short wave work. Such a circuit can be used but it is unstable, especially when the reaction controls are brought into operation, for the detuning of the grid circuit by the changing anode characteristics is very considerable. The V.H.F. circuit is also highly sensitive to electrical disturbances so that a hand capacity effect is always found in an adapted throttle control circuit, making long extension spindles necessary. Extension spindles are desirable in all ultra short wave gear, but a short spindle should suffice.

The basic circuit used in these battery receivers is due to Franklin and has given great satisfaction not only as an oscillating detector but also as a low powered, self-excited transmitter. The change in the circuit to convert it from one to the other is so small that it can be used as a transceiver.

In the Franklin circuit the two coils should actually be considered as one inductance for the capacity of the condenser is to all intents sufficiently large for its impedance to be reckoned as a short circuit for R.F. The two coils are therefore wound in the same sense—that is, the turns are wound in the same direction—but the oscillating circuit is dependant upon the interelectrode capacities of the valve and so no inductive coupling is necessary. It must be noted that all the feeds to the valve and its circuit are through high frequency chokes, for wiring external to the circuit can have an effect upon the frequency of operation unless the R.F. currents are kept within bounds.

The tuning of the Franklin circuit is performed by the very small variable condenser connected across grid and plate, and this condenser, like all ultra short wave equipment, must be of reputable make Poor insulation or inefficient components will have great effect upon a V.H.F circuit, causing losses in many unexpected ways and possibly preventing the valve from oscillating. Coils and H.F.

chokes can be made by the experimenter but all other equipment should be the best obtainable.

A proven axiom for ultra short wave working is "What looks well works well", and this applies particularly to the layout and wiring of the circuit. The Franklin oscillator, as may be seen from the theoretical diagrams in Fig. 1 and others, lends itself to a symmetrical arrangement which reduces the lengths of the leads to the barest minimum, and that is the standard at which to aim for a good receiver. Wherever possible coils should be wired directly across condensers and if coil holders are used in a multi-band receiver they must be made of low-loss material such as polystyrene, with small sockets. Metal parts should all be small and the size and thickness of insulating parts should also be reduced to the minimum possible.

Bypass and earthing leads should all meet at a common earthing point. If such leads are connected at various points over the chassis, R.F. currents will be flowing in several directions with a consequent possibility of interaction which might well render the bypassing precautions more of a hindrance than a help.

The chassis may be of wood with a sheet of thin copper below it to act as a screen and earthing point, but heavy gauge copper bent to shape out of a single sheet is the best material.

With these preliminary points in mind the circuit of Fig 1 may be studied. It is of a simple one-valve receiver suitable for 56 mcs. working (that is on the amateur 5 metre band) with super coils.

List of Components for Circuit of Fig. 1.

L1, L2.	Windings of Quench coil. Eddystone, or see text.
L3, L4.	6 turns ½" diam. 16 S.W.G. bare copper, spaced own diameter, self supporting.

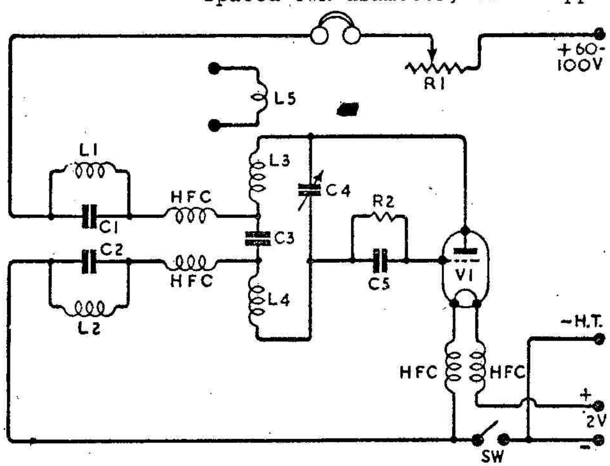

FIG.1. SINGLE VALVE BATTERY SUPER-REGENERATIVE RECEIVER.

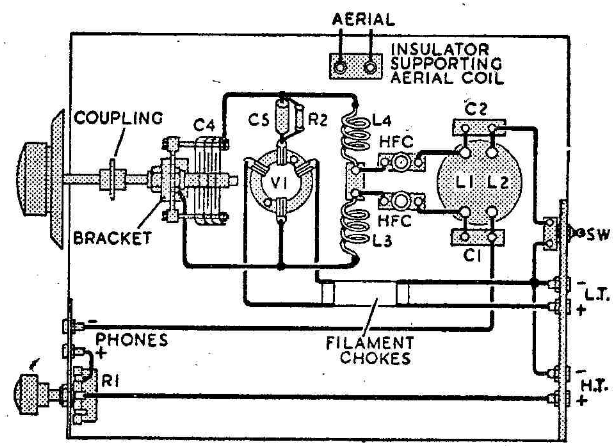

FIG.2. LAYOUT OF CIRCUIT SHOWN IN FIG.1. OMITTING AERIAL COIL FOR CLARITY.

L5.	1 turn ½" diam. 16 S.W.G. supported between L3, L4.
C1, C2.	Quench tuners: .002 to .006 mfd Mica.
C3.	.0003 mfd. Ceramic or Mica.
C4.	Tuner. .00004 mfd. Raymart VC40X
C5.	.00005 mfd. Ceramic.
R1.	100,000 ohms, wirewound potentiometer.
R2.	1 megohm.
H.F.C.	See text.

1 insulating mounting bracket. Eddystone.
1 short extension spindle. Eddystone.
1 flexible spindle-condenser coupling. Eddystone.
3 small stand-off insulators. Eddystone.
V1. Tungsram HR210.
1 ceramic 4 pin valveholder, baseboard type.
1 on-off switch.
Headphones, wire, battery plugs, chassis, etc.

As an example of correct layout the circuit of Fig. 1 is shown diagrammatically in Fig. 2, although not to scale. Note that the tuning condenser is mounted on an insulating bracket and rotated via a short extension spindle. This serves a double purpose, both isolating the condenser from undesirable hand capacity effects and also insulating it from earth since neither set of vanes have direct contact with the chassis.

The four H.F. chokes may be made by the constructor, the two feeding the grid and anode coils being mounted on two of the small stand-off insulators. The simplest method of building ultra short wave chokes is to cut a length of suitable wire one quarter of a wavelength long, winding it evenly in a single layer on a glass or ceramic tube. For the circuit under consideration, therefore, each choke should be made using 1½ metres of wire, the metre being equal to 39.37 inches. The glass tubing should be of the common narrow type of an eighth or quarter inch bore, and for the anode and grid chokes the wire can be 32 or 34 S.W.G. enamelled, preferably wound so that each turn is very slightly separated from its neighbours. The chokes are mounted by putting one end of the tube over the thread of an insulator and securing it with cellulose cement.

The two filament chokes, however, have to carry the filament current, and it is very important that their resistance is as low as possible in order that the filament shall receive its full working voltage. For this reason the chokes are wound of heavy cotton covered wire, 1¼ metre to each choke, and the windings are made on an ebonite former ½" in diameter. The former carries both windings, the two wires being laid on together side by side and separated both for insulation and efficiency, the ends being best terminated in soldering tags held by 6B.A. screws in tapped holes in the ebonite.

At 56 mcs. this circuit will work without filament chokes, and so if desired they may be omitted, but their use will add to the efficiency of the receiver.

If commercially made quench coils are obtained they will be found to have a fixing bracket, but quench coils can be wound by hand on a wooden former which will screw directly to the baseboard or chassis. Such a former may be cut from plywood, three discs each 3" in diameter spaced by two discs 1" in diameter being clamped together through their central drill holes by a long 6 B.A. bolt which will also be the fixing bolt. In each slot thus formed wind 500 turns of 36 S.W.G. enamelled or D.S.C. wire, the turns being laid on in the same direction. Some time should be taken in testing the circuit as a whole with condensers between the stated values across these quench coils until the best reception is obtained.

The U.H.F. portion of the circuit should oscillate at the first test, and if the characteristic hissing of the quench frequency is not heard the connections to one of the quench coils should be reversed. The degree of oscillation both of quench and high frequencies is controlled by R1, and this should be set at the point where the quenching commences. The aerial, which should be of a type to be described in a later chapter, is connected to the single turn aerial coil, and the tuning dial rotated through its arc of travel. The hiss should be constant over the dial, with adjustment, if necessary, of R1, and if the hiss fades out at any point this should be due to the carrier wave of a transmitter.

It is possible, however, that the disappearance of the hiss is due to the loading of the aerial causing a "dead spot"; that is, absorbing energy from the oscillating circuit. In this case the aerial loading is decreased by bending the aerial coil upwards so that whilst it is still between L3 and L4 its coupling is less. This will probably remove the dead spot, but if it still persists it is possible that there is interaction between the anode and grid chokes.

For this reason two chokes which are to be used at the same frequency are sometimes wound on tubes of differing diameters or with different gauges of wire, and this may be necessary. Should there be such interaction, however, it will probably be sufficient to move one of the chokes and place it in a different position.

Super-regeneration, whilst increasing the sensitivity of a receiver, also reduces the selectivity so that even at 56 mcs. a quenched oscillator requires no slow motion tuning device. A large knob should be used for ease of control and the condenser should move easily but without slackness. This lack of selectivity can be of great service when amateur contacts are being sought, especially between self-excited oscillators. Such oscillators (one is described in this chapter) have poor frequency control and not only are they subject to drifting but speech modulation on the carrier often results in a certain degree of frequency modulation besides the desired amplitude modulation. The quenching receiver can hold such a signal whereas a tuned R.F. or superhet circuit would probably be too selective to keep the station in tune.

This virtue, of course, is dependant upon the state of the 56 mcs. band, and should a number of high powered stations come into operation the virtue might well assume the properties of a vice. In such a case, however, the transmitters would of necessity be crystal controlled and properly modulated so that more selective circuits could be used in the receivers.

Self Quenching Receivers.

An even simpler circuit than the one just described can be used for a super-regenerative receiver, although it is the author's experience that self quenching effects when using battery valves are not so readily obtained as with the U H F. mains valves such as the Acorn series or the American type 9000 series.

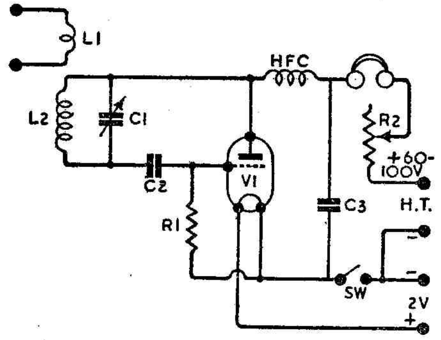

FIG.3. SELF QUENCH BATTERY RECEIVER.

The experiment is well worth trying, however, as the self-quenching receiver is easily convertible into a self exciting oscillator for use as a transceiver.

The circuit is shown in Fig. 3.

List of Components.

L1.	Single turn aerial coil. ½" diameter, 18 S.W.G. copper, mounted at end of L2.
L2.	Tuning coil. 12 turns ½" diam. 18 S.W.G. copper spaced own diameter.
C1.	Tuner. .00004 mfd. Raymart VC40X.
C2.	.00005 mfd. Ceramic.
C3.	.006 to .01 mfd. See text. Mica or Non-inductive.
R1.	.1 to .5 megohm. See text.
R2.	100,000 ohms wire-wound potentiometer.
V1.	Tungsram LP220.

1 insulating mounting bracket. Eddystone.
1 long extension spindle. Eddystone.
1 flexible spindle-condenser coupling. Eddystone.
1 small stand-off insulator. Eddystone.
H.F.C. Constructed.
1 ceramic 4 pin valveholder, baseboard type.
1 on-off switch.
Headphones, knobs, wire, baseboard, etc.

The H.F.C. is made by winding 32 S.W.G. enamelled wire on a glass tube former as already described, the choke being mounted on the small insulator by cementing the tube over the screw.

It will be seen that the receiver can be built to occupy very little space. The coil is mounted directly across the condenser which is driven via the extension spindle and supported on the bracket, whilst the valve-holder is directly behind the condenser. It must always be remembered that the leads from the tuned circuit to the grid and anode pins of the valveholder are in the tuned circuit so these leads must be as short as possible. The aerial coil, as before, is mounted on the second stand-off insulator, and may be either at the grid or anode end of L2, whichever gives better results.

Once again the receiver is controlled by a variable resistance in the anode lead and this should be set at a point where the quench hiss comes into operation.

The frequency of the quenching depends on the two components R1 and C3, and some time should be spent on the choice of the best combination. If the receiver breaks into a low musical note instead of hissing, the resistance should be increased or the capacity reduced, and in cases where quenching is difficult to obtain, or where it dies away at the lower frequency end of the tuning range an alternative circuit might be tried. This system, used widely in America, is known as "Positive drive," and is similar to the circuit of Fig. 3 except for the grid leak. A resistance of at least 4 megohms is connected across the grid condenser, the grid leak R1 of Fig. 3 being discarded, so

that through the high resistance the grid is given a positive voltage derived from the anode circuit. In either case filament chokes may be used if desired.

Either of the circuits so far described may be coupled to an amplifier for loudspeaker reception, for the quenching is not so undesirable, when amplified, as might be thought. A decoupling resistor of 20,000 ohms or so should be included between the power supply and the control variable resistor, the junction of the two resistors being earthed to the negative H.T. line through a 4 mfd. condenser. The headphone terminals are then short-circuited by a length of wire and a coupling condenser of .05 mfd. 350 v.w. is connected from either headphone terminal to the input terminal of the amplifier, the negative H.T. lines of both amplifier and receiver also being connected to complete the input circuit. The volume control of the amplifier should preferably be across the input to prevent overloading.

When a receiver is being used in this way it is always good practice to draw the H.T. supply from the amplifier power pack through a suitable dropping resistor or potentiometer network.

Transceivers.

The most usual form of the transceiver is a battery operated two valve combination circuit, which, at the throw of a switch, is transformed from a receiver to a transmitter working at the same frequency, or nearly the same frequency. A good deal of amateur work was performed with transceivers before the war and developments of the circuit were used for Service duty. Obviously the output power of the transmitter is limited, but for short distance two-way contacts the transceiver is remarkably efficient, and is an interesting arrangement on its own account.

Either of the receivers of Figs. 1 or 3 can be converted into transceivers, the necessary change being the switching out of the quenching circuits. This is most simply accomplished with the self-quenching receiver for it

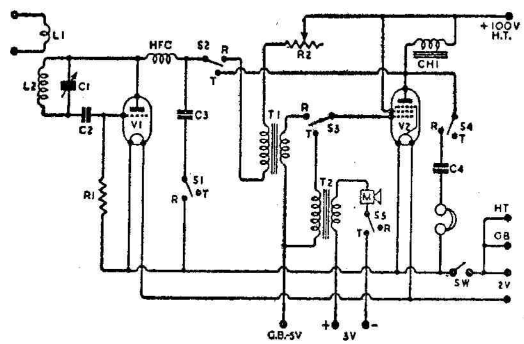

FIG.4. SELF QUENCHING TRANSCEIVER. ADAPTED FROM FIG.3.

is only a case of removing C3 from the circuit. With the circuit of Fig.1 the quench coils are short-circuited whilst the grid leak R2 is dropped in value and run straight to earth. In each case the second valve is used as an audio frequency amplifier in reception and as a choke modulator for transmission.

The simpler circuit, that of the adapted self-quench receiver, is shown in Fig. 4. The following list of components shows the parts required IN ADDITION to those already given for the circuit of Fig. 3.

List of Additional Components for Fig. 4.

T1.	3:1 L.F. Transformer.
T2.	Microphone Transformer.
M	Carbon Microphone.
Ch1.	Pentode Output Choke.
C4.	2 mfd. Mansbridge condenser, 350 v.w.
V2.	Tungsram PP215.

1 5-pin valveholder, baseboard type.
S1 to S5, Yaxley type switch, double throw, five way.

Most important in the transceiver is the switch gear which should give positive action and be trouble free. If a switch with sufficient ways is unobtainable then two wafers

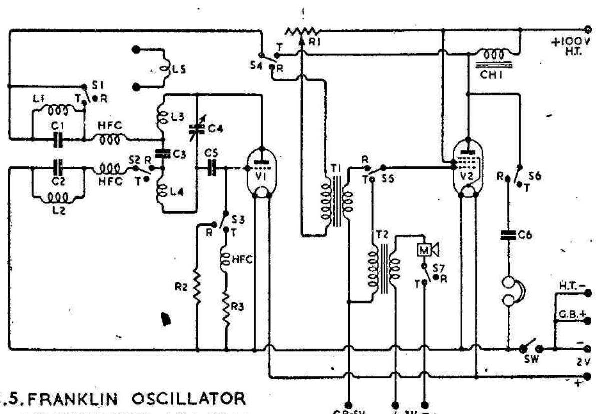

FIG.5. FRANKLIN OSCILLATOR TRANSCEIVER ADAPTED FROM FIG.1.

will have to be built up on a spindle and locator. One advantage of this circuit lies in the fact that no H.F. lead is switched.

The coupling of the aerial coil must remain something of a compromise, for not only must it be adjusted to suit the loading of the receiver but it must also be capable of transferring energy from the transmitter to the aerial with as little loss as possible. Little work appears to have been done in the amateur transceiver so far as including a really efficient aerial tuning and coupling stage is concerned, and there is room for experiment in this direction.

A simple method of effecting a partial solution to the problem is to mount the aerial coil, through insulators, to a spindle which is brought out to a knob on the panel. Rotating the knob through an arc of travel thus swings the aerial coil towards or away from the tuning coil, short flexible leads being taken to the aerial sockets.

The second transceiver shown in Fig. 5 uses the adapted Franklin oscillator circuit, and the list of components shows the parts required IN ADDITION to those already given for the circuit of Fig. 1.

List of Additional Components for Fig. 5.

T1.	3:1 L.F. Transformer.
T2.	Microphone Transformer.
M.	Carbon Microphone.
Ch1.	Pentode Output Choke.
H.F.C.	R.F. Choke, made as per directions given.
R3.	5,000 ohms 1 watt carbon.
C6.	2 mfd. Mansbridge condenser, 350 v.w.
V2.	Tungsram PP215.

1 5-pin valveholder, baseboard type.
S1 to S3. Yaxley type switch, double throw, three way.
S4 to S7. " " " " four way.
1 small stand-off insulator, as mounting for H.F.C.—Eddystone.

The two sets of switchgear used in this circuit must be ganged together on the same spindle and locator, but special precautions need to be taken with S1, 2 & 3 since they are situated in H.F. lines or in their close proximity. The wafer bearing these contacts must be mounted as close as possible to the oscillating valve, the best method being to mount the H.F. portion of the set on a small false baseboard or chassis with the switch directly below it. The leads to the switch might then be well under an inch in length—the shorter the better.

In both of these transceivers the microphone power supply may be taken from the grid bias battery if desired but since the current drain is rather heavy a somewhat larger capacity battery is more suitable.

Filament chokes may be included in both transceivers, but if they are omitted it is often found an advantage to bypass the filaments for H.F. by connecting a .0003 mfd. mica condenser directly across the filament pins on the valveholder.

A T.R.F. Super regenerative Receiver.

Whilst the super regenerative receiver is the most suitable circuit for many purposes, including general communication work, there are often times when it is desired to tune to a controlled station for the reception of high quality sound. The T.R.F. receiver is probably the best battery operated circuit for this, so that if super-regeneration can be added at will to a tuned detector the set will be a useful double-purpose receiver.

In both cases the further addition of a tuned R.F. stage will be a great advantage, for whilst little or no

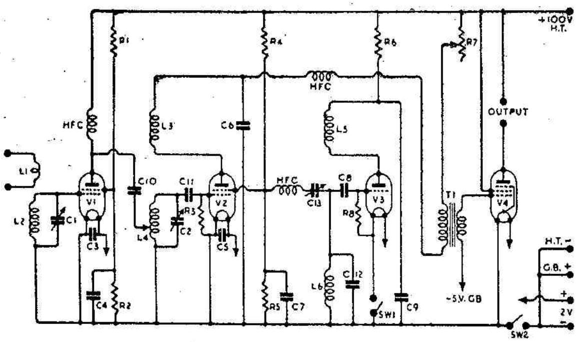

FIG.6. TRF SUPER-REGEN.RECEIVER.

amplification will be gained from its use it will isolate the oscillating stage from the aerial, thus avoiding dead spots, will increase selectivity when the receiver is being used as a "super" and will prevent re-radiation of the quench which can be a source of interference over a wide area. The receiver of Fig. 6 has been designed to include these points, together with an audio output stage for phones or, on a strong signal, loudspeaker reception.

Quench is controllable, not only by a switch in the filament lead to the super regenerative oscillator which cuts the stage out entirely, but also by a variable quench injection circuit.

List of Components for Fig. 6.

L1.	Aerial coil. 2 turns ½" diam. 18 S.W.G. copper, on former of L2, ⅛" from grid end.
L2, L4.	12 turns 18 S.W.G. copper on ½" former, spaced own diameter.
L3.	3 turns 26 S.W.G. D.S.C. wound between turns of L4 at earth end.
L5, L6.	Windings of quench coil, commercial or made as directed.
H.F.C.	Made as directed.
C1, C2.	Tuners. .00004 mfd. Raymart VC40X.
C3 to C9.	.0003 mfd. Mica.
C10, C11.	.00005 mfd. Ceramic.
C12.	.001 to .006 mfd. See text.
C13.	.0005 mfd. Variable, solid dielectric. Quench coupler.
R1, R4.	47,000 ohms. 1 watt.
R2, R5.	68,000 " "
R3.	2 megohms.
R6.	100,000 ohms "
R7.	50,000 ohms potentiometer, wirewound.
R8.	½ megohm.
T1.	3:1 L.F. Transformer.

3 small stand-off insulators to mount H.F.C.'s.— Eddystone.

1 short extension spindle. Eddystone.
2 flexible spindle couplers. Eddystone.
2 insulating bracket condenser mountings. Eddystone.
2 4-pin ceramic valveholders, chassis mounting, for V1, V2.
1 4-pin fibre valveholder, chassis mounting, for V3.
1 5-pin " " " " " V4.

Sw1, Sw2.	On-off switches.
V1, V2.	Osram VS24.
V3.	Osram LP2.
V4.	Tungsram PP215.

Copper chassis, Copper panel, vernier tuning dial, wire, sockets, headphones, etc.

A copper chassis and panel are highly desirable for this receiver, and since it is most likely that such a chassis would have to be made up from sheet metal it is left to the individual builder to decide upon his own sizes. The layout of the receiver will be the chief governing factor and the chassis is best made long and narrow, the controls being at one end. Behind the panel spaced by the length of the extension spindle is the R.F. tuner, C1, mounted on a bracket. The rear end of the spindle of C1 is coupled to the spindle of C2, the detector tuner, also mounted on a second bracket, and the two stages, R.F. and detector, must be separated by a copper screen running across the chassis, the screen being at least as high as the valves. The screen will come between the two tuning condensers and should be drilled or cut to a wide fit so that there is no chance of the spindles touching the metal which would give rise to noise. The layout of the quench and power stages need not be so close as that of the first two stages although they should both be neatly set out and wired, but they need not be screened from the detector stage and might well come directly after it.

In the first two stages all earthed leads should be gathered to one point in each stage and soldered directly to the copper. It will be seen that the connection between the R.F. and detector stages is through a ceramic condenser via a lead which may be clipped on to one of the turns of the detector grid coil. This enables the grid loading to be adjusted and also will help in the ganging of the two tuned circuits.

Ganging, the only necessary preliminary to testing the receiver, is best carried out with the aid of a small signal generator which can be made up as described in Chapter 3. A signal at the high frequency end of the band is tuned and, to bring it to full volume, the coupler connecting the two tuning condensers is loosened and the condensers adjusted individually. The coupler is then tightened and a signal at the low frequency end of the band is tuned. Probably the ganging of the two circuits will be found to require further adjustment and this is best made by gently closing the turns of one of the grid coils together, or opening the turns out slightly, whichever type of adjustment is required, the coupling between the condensers again being checked at the high frequency end of the band. This ganging should be carried out with the quench circuit switched out of action for the tuning is sharper with the set working as a T.R.F. receiver.

The quench coils and H.F. chokes are made as already described, and the tuning of the quench should be changed by varying the capacity of C12 between the indicated limits.

The reaction of the oscillating detector stage is controlled by R7. When the quench is in use R7 is used to set the detector just into oscillation and then left, but when the quench circuit is out of action R7 should be used in conjunction with the tuning controls, the set being kept on the threshold of oscillation as with the normal short wave set. Slow motion tuning must be used, the best type of dial for the purpose having a vernier control which can be put out of action when the quenching circuit is in and used for T.R.F. working when tuning is sharp.

CHAPTER 2.

Mains Operated Receivers.

For both V.H.F. and U.H.F. work the most efficient receiving valve to date is undoubtedly the Acorn triode and pentode, and wherever possible the use of such a valve is recommended. The Acorn will work up to a frequency of about 800 mcs. both as a detector and transmitting oscillator although naturally, due to its small size, its output as a transmitter is limited. Where expense makes the use of an Acorn impracticable, however, the more standard valves will still give good results, and for reception and transceiver work in general the 6C5 and 6J5 together with the MH4 have good reports.

The author has for some time used an Acorn 955 in the circuit of Fig. 3 with excellent results since this valve has good amplification and no trouble at all has been experienced with self quenching. Using the circuit as it stands the grid leak should be about 150,000 ohms, but equally good results are used by changing this leak to 4 megohms in parallel with the grid condenser when the valve is in the positive drive condition.

Some Acorns have a tendency towards hum injected from the heater circuit, but connecting one side of the heater to earth along with the cathode (no cathode bias resistor is used) generally removes the fault.

Mains valves, however, are best used in the superhet circuit where the current economies which need to be practised with battery valves can be disregarded. The superhet can be made to take full advantage of all the ultra short wave characteristics since its selectivity can be controlled, it can be made to give excellent sound quality and has good sensitivity.

The form taken by the very high frequency superheterodyne receiver varies according to the type of work the circuit is to undertake. In the ordinary commercial superhet, designed for broadcast reception, the pass-band of the I.F. stages is set at round about 10,000 or 15,000 cycles in order that whilst the frequencies admitted and amplified are confined to as narrow a band as possible, in

the interests of selectivity, the band shall not be so narrow that the quality of the sound suffers. When the ultra short wave receiver is to be used for amateur contacts on C.W. or telephony an I.F. of the usual 460 or 470 kcs. will be perfectly satisfactory since easily obtained components may be used and the gain of each I.F. stage will be good.

For the reception of television video signals, however, the pass-band of the I.F. stages must be much higher. The video signals, which include synchronising pulses, embrace a wide frequency range, its extent being of the nature of 2 megacycles, so that special I.F. equipment must be used. The I.F. is increased to 10 or even 15 megacycles in order that the band may be passed without attenuation, and as a result the gain of each stage decreases, whilst design must be excellent to avoid interaction and instability. The I.F. transformer in such a circuit is generally modified to a coil, tuned by its self capacity to the I.F., this single coil being in the grid circuit of the I.F. valve and coupled capacitively to the preceding anode. The number of I.F. stages in the video receiver is higher than in the more ordinary sound receiver, and for these and similar reasons the superhet circuits in this chapter are confined to sound reception.

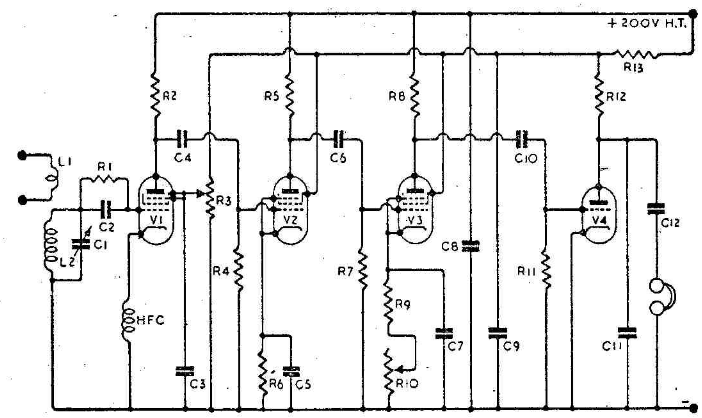

FIG.7. R.C.COUPLED SUPER HETERODYNE RECEIVER.

The first superhet circuit of Fig. 7, however, uses resistance-capacity coupled I.F. stages. The idea is far from new but is still relatively unknown. In brief the receiver consists of an autodyne frequency changer with I.F. stages coupled by suitable time-constant circuits. The first valve has an unusual oscillating circuit, feedback in the cathode choke being responsible for the setting up of reaction which is controlled by the screen potentiometer. Provided that the usual points are borne in mind, and that the layout of the I.F. stages as well as that of the oscillator is neat and with short wiring, good results should be obtained.

List of Components for the Circuit of Fig. 7.

L1.	Aerial coil. 4 turns 18 S.W.G. ½" diam. Spaced ¼" from grid end of L2.
L2.	Grid coil. 12 turns 18 S.W.G. copper, ½" diam. Turns spaced own diameter
C1.	Tuner. .00004 mfd. Raymart. VC40X.
C2, C4, C6, C10.	.0001 mfd. Mica.
C3, C5, C7, C11.	.0003 mfd. Mica.
C8.	.01 mfd. Non-inductive. 350 v.w.
C9.	4 mfd. 350 v.w.
C12.	2 mfd. 350 v.w.
R1.	1 megohm.
R2.	20,000 ohms, 1 watt.
R3.	½ megohm potentiometer.
R4, R7, R11.	220,000 ohms. ½ watt.
R5, R8, R12.	50,000 " 1 "
R6, R9.	150 " " "
R10.	10,000 " potentiometer.
R13.	12,000 " 2 watt.
H.F.C.	90 turns on ¼" bore glass tube, 34 S.W.G. D.S.C.

4 ceramic octal valveholders, chassis mounting.
1 short extension spindle. Eddystone.
1 insulating mounting bracket. "
1 flexible coupler. "
2 Small stand-off insulators. "
V1. 6J7.
V2, V3. 6K7.
V4. 6C5.
Slow motion drive, knobs, chassis, wire, headphones, etc.

It will be seen that the power pack is excluded from the diagram and that headphone reception follows the second detector. It is likely that the receiver will be required to work into an amplifier, however, in which case power supplies may be drawn from the existing power pack with suitable decoupling. To feed into an amplifier, reduce C12 to .1 mfd. and couple it directly to the grid input socket of the amplifier, the negative power supply lines being common.

The receiver includes a volume control in R10. The resistance-capacity couplings can run directly between valveholder pins below the chassis but above the chassis it will be desirable to screen each valve in its own compartment, although not absolutely necessary.

Superhet converters.

For those who already possess a good superhet receiver, especially one of the Communications type, which will tune to about 10 mcs. (i.e. 30 metres), the converter offers a relatively inexpensive method for receiving the V.H.F. bands using the existing apparatus. In Fig. 8 is shown the circuit for a three valve converter using Acorn valves for high efficiency. The stages are a R.F. buffer stage to give a degree of amplification and to enable the

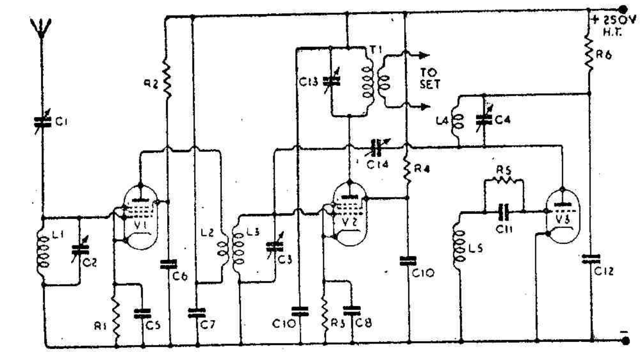

FIG.8. SUPER-HET CONVERTER.

aerial to be more tightly coupled to the receiver than would otherwise be possible, a Frequency Mixer, V2, and a separate oscillator V3. It should be noted that whilst the the first two tuned stages are ganged together the oscillator anode coil is the circuit where the final accurate tuning is carried out, C4 being the condenser fitted with slow motion control. The introduction of the oscillator frequency into the grid of the mixer via a very small variable condenser should also be noted. The efficiency and gain of the converter stage depends on the amplitude of injected voltage, and practice with the controls is necessary in order that the best results may be obtained. The intermediate frequency appears across the primary of T1 which is inductively coupled to the input coil of the receiver which is, of course, tuned to the I.F. of approximately 10 mcs. This frequency, in the receiver, undergoes further conversion to suit the receiver's I.F. stages.

List of Components for Circuit of Fig. 8.

L1, L3.	12 turns 18 S.W.G. copper ½" diam. spaced own diameter.
L2.	5 turns 26 S.W.G. D.S.C. copper, on same former as L3, ⅛" from grid end, close wound.
L4.	10 turns 18 S.W.G. copper ½" diam. spaced own diameter.
L5.	3 turns 26 S.W.G. D.S.C. copper, on same former as L4, ⅛" from cathode end, close wound.
C1.	.0001 mfd. Raymart VC100X.
C2, C3, C4, C13.	.00004 mfd. " VC40X.
C5, C6, C7, C8, C9, C12.	.0003 mfd. Mica.
C10.	.003 mfd. Mica.
C11.	.0001 mfd. Mica.
C14.	.000005 mfd. Raymart MC5DX.

R1.	470 ohms, 1 watt.
R2, R4.	100,000 ohms, 1 watt.
R3.	10,000 " "
R5.	47,000 " "
R6.	10,000 " "
T1.	20 turns 26 S.W.G. D.S.C. copper ½" diameter close wound for anode coil. 10 turns 26 S.W.G. D.S.C. copper on same former, ⅛" from H.T. end of anode coil for output coil.
V1, V2.	Acorn type 956 with holders.
V3.	Acorn type 955 with holders.

3 insulating condenser mounting brackets. Eddystone.
2 short extension spindles "
3 flexible coupling links. "
Chassis, slow motion drive, knobs, etc.

The converter should be built on a copper chassis for the best results, in three separate stages, each screened from the others. The best layout is to keep the stages as they appear in the diagram, arranged one after the other on a fairly deep chassis. This will carry all the components underneath so that two internal screens will supply three screened compartments.

The tuning condensers C2, C3 of the first two stages are coupled together for ganging, C2 being remote from the panel by the length of one extension rod, the other rod being used to drive C4 from the slow motion device. The first two condensers can be given slow driving if desired but a straightforward drive is satisfactory. The loading of the aerial on to the first tuned circuit can be quite heavy and is shown controlled by C1. If a dipole is used an aerial coupling coil of 4 turns can be wound on the same former as L1. All the coils should be wound on ½" ceramic or paxolin formers to give rigidity.

To line up the converter it should be coupled to the receiver with which it is to be used, the receiver being tuned to the 30 metre band at 10 mcs. Whilst the converter can be adjusted by signals it will be found that a simple signal generator will be a great advantage in setting the bands and obtaining the best results possible. It should first be ascertained that the oscillator, V3, is functioning with C14 at minimum value.

Temporarily gang C2 and C3 and set them to half scale, then with the signal generator at full output connected to the input circuit and tuned to the centre of the desired band (say at 57 mcs.) bring in the signal by rotating the oscillator condenser C4, slightly increasing the coupling of C14 if necessary. Two possible settings of C4 should be found, the higher capacity setting being the one required. When the signal is located retune C2, C3 to bring up the volume and finally loosen the coupling between these condensers so that they may be adjusted individually for ganging. As the circuits come into line the output from the signal generator must, of course, be reduced so that the stages are not overloaded. Should the R.F. stage at any time show a tendency to self-oscillation the coupling

between L2, L3 may be reduced by separating the coils a little or by reducing the size of L2.

When the converter has been lined up at one frequency it should be tested over its band. The signal generator is retuned to a higher frequency which is then brought in, first by tuning with the oscillator condenser C4 and then with the tuning condensers C2, C3. These should be moved in slight steps together with C4 until the signal is received when the final tuning adjustments are made. The whole band should be explored in this manner, checking on the ganging between C2 and C3 and correcting errors, if any, by slightly opening out or closing up the turns of their respective coils. It will be as well also to prepare a graph of tuning positions showing relative settings of C4 against the ganged condensers so that the correct frequency difference can be obtained at any point on the band.

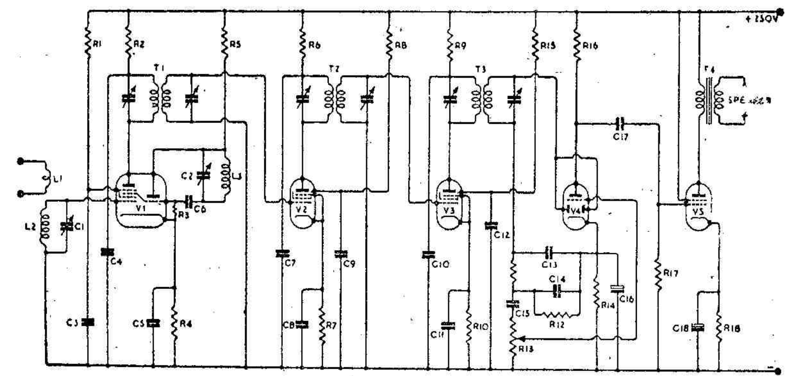

FIG.9. ULTRA SHORT WAVE SUPER HET RECEIVER.

A proposed circuit for a complete superhet receiver suitable for the experienced experimenter is shown in Fig. 9. Signals are fed directly into the frequency changer V1 which has separate tuning of the R.F. and oscillator circuits, and are passed on to I.F. stages working at 470 kcs. If desired one stage of I.F. amplification could be removed, the valve being used as a further R.F. stage, provided that precautions against instability were taken.

List of Components for the Circuit of Fig. 9.

L1.	4 turns 22 S.W.G. D.C.C. ½" diam., turns spaced own diam. on same former as L2.
L2, L3.	12 turns 18 S.W.G. copper, ½" diam., turns spaced own diameter.
C1, C2.	.00004 mfd. Raymart VC40X.
C3, C4, C5, C7, C8, C9, C10, C11, C12, C15.	.01 mfd. Non-inductive. 350 v.w.

C6.	10 mmfd. Silver-ceramic.
C13, C14.	.0003 mfd. Mica.
C16, C18.	25 mfd., 12 v.w.
C17.	.05 mfd. Non-inductive. 350 v.w.
R1.	22,000 ohms, 1 watt.
R2, R6, R9, R14.	1,500 " "
R3, R5, R11, R16.	47,000 " "
R4, R18.	220 " "
R7, R10.	150 " "
R8, R15.	10,000 " "
R12.	470,000 " "
R17.	220,000 " "
R13.	½ megohm potentiometer.
T1, T2, T3.	465 kcs. I.F. screened transformers.
T4.	Loudspeaker transformer, load 5,200 ohms.

2 short extension spindles. Eddystone.
2 insulating mounting brackets. "
2 flexible coupling links. "

V1.	Mazda ACTH1.
V2, V3.	" SP41.
V4.	" ACHL.DD.
V5.	" Pen 45.

2 7-pin chassis mounting valveholders.
3 Mazda octal " "
Slow motion drive, chassis, loudspeaker, etc.

As before, the two tuning condensers are driven via extension spindles and coupling links to avoid any tendency to instability or body effects, the oscillator circuit C2 L3 being the fine tuner. The two tuned circuits should be in separate compartments to avoid interaction apart from the mixing which takes place in the valve. These two V.H.F. circuits should have the usual short, neat wiring with the earthed leads of each stage all taken to one point in each screened compartment. The rest of the receiver follows ordinary superheterodyne practice.

In lining up the circuit, the I.F. transformers must first be adjusted with the aid of a signal generator. A modulated signal is fed into the control grid of the frequency changer whilst L3 is short circuited to prevent the triode section from oscillating. The I.F. transformers should then be tuned to maximum response from the second detector back to the anode circuit of the frequency changer. The signal generator should be swept over a narrow channel as the tuning proceeds to ensure a good response curve shape, the input to the control grid being progressively reduced to as small a degree as can be used.

When the I.F. stages are trimmed, the signal generator should be set to give a 56 mcs. signal, or a V.H.F. signal generator should be used for lining up the signal frequency circuits. The triode section of the frequency changer is restored to its oscillating condition and with the tuning condenser C1 set to half travel the injected signal (which

should be fed into the aerial coil L1) is tuned in by the oscillator condenser C2, signal strength again being reduced if necessary. Volume is increased by tuning C1 when two possible tuning points of C2 should be found, both of which will bring in the signal. The higher capacity point is the correct position.

As before, the band should now be covered by choosing different settings of the signal generator and calibrating the two tuning condensers over their ranges so that as searching for signals proceeds the correct frequency separation can be maintained.

If desired, an ordinary aerial can be coupled to the receiver through a variable .0001 mfd. condenser, connected to the grid side of L2 or tapped experimentally on to L2. In this case L1 may be omitted.

The power pack for the superheterodyne, as shown in Fig. 10 is a straightforward circuit which requires no explanation. If the power pack is to be used for driving any other receiver it may either be constructed as shown or, for use with P.M. speakers or headphones, the 2,000 ohm speaker field may be replaced by an equivalent choke, one of 20 or 30 henries inductance and a current capacity of 100 m/a being suitable.

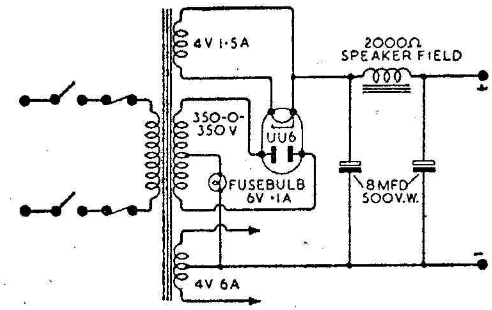

FIG.10. POWER PACK FOR CIRCUIT IN FIG.9.

The tuning and adjustment of V.H.F. superhet circuits is not simple, and it should be pointed out that only advanced amateurs should construct such receivers. The newcomer to ultra short wave will do best to commence by building a simple one valve circuit, not only for the sake of experience but also to ascertain the state of his reception area. It is possible that in some localities there will be a considerable lack of worthwhile signals for some time to come.

CHAPTER 3.

Wavemeters and Generators.

The constructor of V.H.F. and U.H.F. gear, among other things, has always to be prepared for the necessity of experimenting with the range and band coverage of tuning circuits. As has already been pointed out, the capacities and inductances used are so small that they are influenced to a large extent by both lead lengths and external masses of metal—the high frequency I.F. transformers mentioned in Chapter 2 are often tuned by a brass plug acting as a core and which can be screwed in or out of the inductance.

For this reason it is most necessary to have some standard of frequency, the devices possible ranging from a length of wire to a calibrated signal generator, according to the accuracy desirable.

The most elementary frequency or wavemeters depend on absorption effects. An oscillating circuit transmits energy which can be picked up, over varying distances, by a tuned circuit working at the same frequency. When the distance is very small, a matter of feet or inches, the oscillating circuit undergoes a damping effect to such an extent that, with a low powered circuit, the oscillations can be stopped altogether. Actually, when using such absorption effects, the degree of coupling which causes the oscillator to stop working at the absorbed frequency is too great since a detuning effect is also present. The regeneration can be weakened to a marked degree at a selected point by loosely coupling a tuned circuit to the oscillator.

This method, obviously of greatest use for frequency determination with such receivers as super regenerators and tuned R.F. circuits can most simply be put into operation by using a half wave aerial as the tuned circuit. A length of wire resonates at its natural radio frequency, working at a wavelength of double its own length and at the higher frequencies this wire length becomes of convenient size for use even in a small room. The method is as follows.

Determine the central frequency of the band on which it is desired to work—for this example let the frequency be 56 mcs. The length of wire which resonates at this frequency is given by the formula

$$\text{Length} = \frac{467.4}{f} \text{ feet,}$$

where f is the frequency in megacycles. In this case, f being equal to 56, the length of wire is found to be 8.34 feet. The above formula includes a small correction for end effects, etc., on the wire, but in any case the aerial should be erected in as open and clear a space as possible. The receiver under test should be placed so that, with one end of the wire suspended and insulated in a convenient position the other end of the wire may be brought directly to a small semi-variable condenser, such as a 30 mmfd. trimmer. This in turn is connected directly to the tuned circuit of the receiver. If the receiver has more than one tuned stage the circuit to which the aerial is connected must, of course, be the oscillating circuit.

With the trimming condenser set at low capacity the receiver is now switched on and the tuning dial rotated. At one point there should be a marked drop in quenching or oscillation noise—the noise may stop altogether—and at this point the receiver is supplying a degree of power to the aerial at the aerial's frequency.

All that remains, therefore, is to bring this tuning point to the desired position on the tuning range, and this may be done by squeezing or opening the turns of the tuning coil or, in the case of a wide discrepancy, supplying a new coil with fewer or more turns. One advantage of ultra short wave working is the ease with which coils may be rewound and refitted.

A second method of using a simple tuned circuit as a wavemeter is to construct a "standard" coil and condenser absorbing circuit. A small robust variable condenser is fitted to a panel and rotated through a good slow motion device, whilst across the condenser is connected a suitable coil. For the 56 mcs. band the combination of a .00004 mfd. condenser and a 12 turn coil of ½" diameter would be satisfactory. The coil must be wound with heavy gauge wire so that there is no chance of its changing shape. When the wavemeter is held near the tuned circuit of a quenching or oscillating receiver there is once again an absorption of power which is audible in the reproducer, the absorption being greatest when the axes of the coils are in line. It is, of course, necessary to calibrate the wavemeter, but when this has once been accomplished a graph can be drawn and attached to the instrument from which the frequency of any setting of the dial can be determined. Failing any better way of calibrating the wavemeter it could be compared with the absorbing aerial mentioned previously. Several frequencies should be chosen, progressively rising, the aerial being cut to the resonant length of the lowest frequency. The receiver is then tuned to resonate with the aerial, the aerial is then uncoupled and the wavemeter tuned so that once again the absorption effect appears on the receiver. The wavemeter is then at the aerial's resonant frequency and one point on the calibrating graph is established. The aerial is then cut to the second frequency and coupled to the receiver for a second absorption point and so on until all the desired points on the graph are obtained. The wavemeter will not possess a high degree of accuracy, but will be quite suitable for experimental reception work and this method of calibrating is certainly the simplest for the amateur.

In some cases, however, it is needed to introduce a signal into the receiver as, for example, when lining up R.F. stages. As the absorption wavemeter can only take power, not supply it, it is quite useless for this work and a small oscillator must be built, the instrument generally being known as the heterodyning wavemeter.

Battery operation is much to be preferred, not only from the point of view of stability in operating but also since the unit may then be enclosed and portable, and since only one valve is used the current drains on both H.T. and L.T. are economical and dry batteries can be used for both supplies.

The wavemeter combines two oscillating circuits, one for generating the very high frequency carrier, the other for modulation purposes. This is usually obtained from a simple audio oscillator using the two windings of an L.F. transformer as the inductances. A super-regenerative

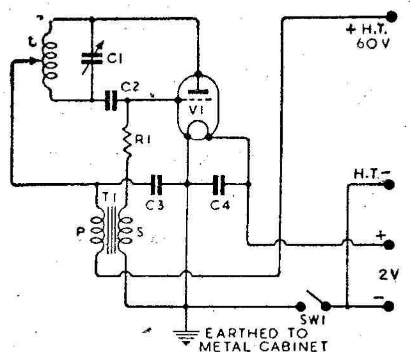

FIG. 11. HETERODYNING WAVEMETER.

receiver might be pressed into service provided the degree of quenching could be suppressed to give a narrowly tuned signal.

The circuit of a suitable generator is shown in Fig. 11, designed for use on the 56 mcs. band.

List of Components for the Circuit of Fig. 11.

L.	12 turns 16 S.W.G. copper, ½" diameter, spaced own diameter.
C1.	Tuner. .00004 mfd. Raymart VC40X.
C2.	.0001 mfd. Ceramic or Mica.
C3, C4.	.0003 mfd. Mica.
R1.	1 megohm, 1 watt.
T1.	Intervalve transformer, 3:1 or 5:1.
Sw.1.	On-off switch.
V1.	Tungsram HR210.

1 4-pin ceramic valveholder, baseboard mounting.
1 long extension spindle. Eddystone.
1 insulating mounting bracket. "
1 flexible coupling. "
Slow motion drive.
Metal cabinet, etc.

The unit should be completely shielded by building the wavemeter in a metal cabinet, although a wooden case lined with metal foil, preferably copper, is the cheaper method. If such a cabinet with a foil lining is constructed, however, care must be taken to see that all the foil sheets are in good electrical contact, and the joints should be soldered by sweating the edges together.

The condenser is mounted well away from the front panel to avoid any chance of capacity effects and driven through an extension spindle from a good quality slow motion drive.

The tapping on the coil should be on the centre turn

at the first test, and different tappings made to determine the best working conditions. Once the results are satisfactory, this tapping should be soldered so that calibration is not affected by a loose contact.

For the first tests on the circuit a pair of headphones in the H.T. positive lead will give audible signs of correct oscillation. Tapping the grid terminal on the valveholder will give a loud "plopping" if high frequency oscillation is taking place, whilst the audio modulating note from the transformer is unmistakable. Should the audio circuit not be working, reverse the leads to one of the windings. If it is desired to alter the note given by the transformer, a condenser, selected experimentally and shunted across the secondary, will give a wide range of control.

No trouble should be experienced in obtaining oscillation of the high frequency circuit, but it may be necessary to add a H.F. choke in the lead between the tap on the coil L and the primary of the transformer. Such a choke may be constructed as already described, winding about 50" of 34 enamelled S.W.G. copper wire on a ¼" glass tube. The choke should be mounted on a small insulating block and no component should be suspended in the wiring if the wavemeter is required to be calibrated.

It will be seen that no provision has been made for coupling the output of the wavemeter to the receiver under test. To avoid undue loading of the circuits it is thought best to rely on direct pick-up in the receiver of the wavemeter signal, and should the shielding of the wavemeter cabinet be sufficient to prevent a useful signal the circuit may be operated with the lid of the wavemeter left open. Under these conditions there should always be sufficient radiated energy to obviate the use of condenser coupling.

The diagram in Fig. 11 shows the filament circuit where an accumulator is to be used, but for all dry battery working this will need some slight modification. To obtain strong oscillation the full two volts on the valve are required so that a three volt battery and dropping resistor will be needed, the resistor preferably being in the form of a small low resistance rheostat. The maximum value of the resistor will be 10 ohms, this being in circuit when the battery is new, the value gradually being decreased as the battery ages.

As with the absorption wavemeter the heterodyning wavemeter can be calibrated by using resonating wires coupled to the tuned circuit. The instrument can be of great use even without any more calibration than band marking points, especially if it is to be used for the lining up of T.R.F. receivers. A fully calibrated instrument is a great asset, however, and the calibration should be completed where possible.

Yet another method of determining wavelength and frequency by power absorption lies in the use of Lecher wires, particularly when dealing with U.H.F. transmitters and oscillating circuits. The Lecher wire system consists of two smooth taut wires, running parallel with each other and separated by a distance of about 1½" for the higher frequencies and about 2" or 3" for the 56 mcs. band. The length of the wires is dependant upon the frequency being measured since they must be at least one wavelength long and preferably longer. The wires are stretched and are supported only at their ends, where they may be insulated by bakelite or ceramic links. If some provision, such as turnscrews can be made to take up the slack, it should be possible to take quite accurate readings.

Two such wires may be built up on a rigid permanent support where U.H.F. work is in progress since an ordinary long bench will provide all the room that is required. For 56 mcs. working the system will generally need to be temporary since the wires will have to be 5 metres long at the very least, and preferably 10.

The wires have one end of the pair situated close to the oscillator tank coil, a single loop of wire coupling the parallel pair to the working circuit. With a transmitter there will be sufficient coupling, in this way, to generate standing waves on the Lecher wires with current loops at which a flashbulb can be illuminated by connecting it directly across the wires. By making a slider with a lamp

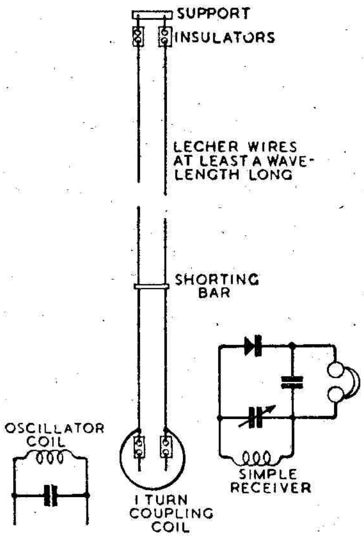

FIG.12. LECHER WIRE SYSTEM.

in it to run along the wires the half wave points can be marked and the wavelength, and thus the frequency, of the oscillating circuit can be determined.

A better method of working, however, is shown diagrammatically in Fig. 12, suited for the calibration of such a wavemeter as has just been described. Such an oscillator will not provide sufficient power for lighting a lamp so that coupled to the circuit are both the Lecher

wires and a receiver. The coupling of the latter should be very loose and finally decided by experiment. Clearly the receiver cannot be of the regenerative type so that a straight tuned triode or diode circuit must be made up, and good results have been obtained with a simple crystal rectifying tuner.

The wavemeter is switched on and left for at least ten minutes to settle down to its working temperature, although the rise should not be high as only a small battery valve is in use. The receiver is then tuned to the frequency of the wavemeter so that the audio note is received in the headphones, at fairly low strength and sharply tuned. The slider bar is then run along the Lecher wires, care being taken to ensure that it is always at right angles to the wires. Starting from the coupling end the bar will be roughly a half wave from the transmitter when the first current loop is found, and at this point the note in the headphones should drop in amplitude as the Lecher wires accept power from the transmitter. Continuing along the wires a second current loop, with consequent drop in volume, will be found at an exact half wavelength from the first point, and the measurement between these points will give the half wave length of the oscillator at the setting under trial.

Since in 56 mcs. work this distance will be about one wavelength from the transmitter the work will either have to be performed by two operators or the simple receiver will need to be coupled via an audio amplifier to a loud-speaker, since long trailing phone leads near the Lecher wires might easily give rise to undesirable effects. It is the author's experience that Lecher wires should be set up with all care, great attention being paid to any likely disturbing factor such as local masses of metal, wiring and piping systems. The wires, if of appreciable length, should be parallel with the ground.

When the points indicating the current loops along the wires have been found it is necessary to mark them and to measure the distance between them with all possible accuracy. When a permanent U.H.F. pair of wires is built up the slider might well run along a rule or marker, but with the temporary 56 mcs. set-up no such method is really possible. One way of overcoming the difficulty is to use a slider bar with a knife edge, pressing it slightly on the wires at the determined point to leave a faint mark, the measurement afterwards being made with an accurate rule between the nicks.

Changing the Band.

In the preceding chapters the receivers in each case have been listed with component values suitable for 56 mcs. operation, this being the "popular" V.H.F. band, but the same circuits will work at 28 mcs. (10 metres) or at 112 mcs. ($2\frac{1}{2}$ metres) with only a change of tuning coil. Receivers using Acorn type valves will work at even higher frequencies, provided that the layout is suitable and that all stray capacities and inductances are eliminated.

The best method of winding coils to suit these bands is undoubtedly by "cut and try", that is, experimentally. The tuning limits should be tested by one of the wavemeters outlined above, since each individual receiver will differ slightly in its requirements. As a rough guide it may be said that a coil to tune to the 112 mcs. band will require about one third of the number of turns of the 56 mcs. coil whilst the 28 mcs. coil will require about twice the number of turns of the 56 mcs. coil.

H.F. chokes may work satisfactorily over the whole range of 28-112 mcs. if they are wound to the middle frequency, but chokes suitable for each range should be used if quick band changing is of secondary importance.

Some difficulty is sometimes experienced in obtaining self-quenching with a 28 mcs. circuit, due to the change in coil inductance and loading. A coil of heavy gauge wire should be used if quenching can be obtained, but it may be necessary to wind the inductance with fine wire on a former, in order to damp the tuned circuit to some degree. Alternatively, with a self-quenching circuit which refuses to operate smoothly, a closer aerial coupling is sometimes of benefit.

CHAPTER 4.

Transmitters.

All transmitting circuits fall into two broad classes, the Self-excited and the Controlled types, and examples of the former have already been given in the Transceivers described in Chapter 1. These circuits, however, are the simplest possible oscillators, and can only be received satisfactorily on a super-regenerative receiver with its wide response band. Under modulation the self-excited oscillator, without stabilisation of some kind, is partially frequency modulated as well as amplitude modulated, the transmitted frequency even splitting into two distinct bands under certain conditions. For regular communication work or serious experimentation the transmitting oscillators so far shown need considerable modification and crystal controlled circuits are preferable. It is indeed becoming a necessary rule that transmitters up to very high frequencies are controlled unless the emitted power is very low. With the likely increase in amateur activity, it will be to every operator's advantage to afford his signal all the stability possible, no matter how high the working frequency.

Self-Excited Oscillators.

The efficiency of the simple tuned circuit consisting of a coil in parallel with a variable condenser, expressed as the "Q" of the circuit, varies with frequency. The "Q" falls in value as the frequency rises due to losses in the rising dynamic resistance of the coil, dielectric losses (particularly in the condenser insulation), skin effects and similar causes. Whilst the power output of a tank circuit (that is, the tuned circuit carrying the main oscillatory currents from which the aerial is fed inductively or capacitively) may be decreased by reason of this low value

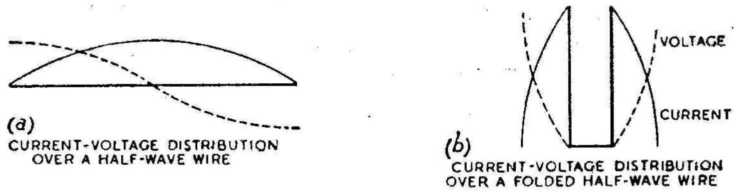

FIG.13.

of "Q" an even more important effect is the consequent lack of stability. A tuning circuit, to be stable, must possess a low L C ratio, that is, the proportion of inductance must be low and the proportion of capacity must be high for the given frequency. One method of satisfying this condition is to dispense with the usual coil and condenser and to use a pair of resonant lines as the tuned or tank circuit.

It has already been mentioned that a half wavelength wire possesses a natural electrical frequency, resonating, as its name implies, at a wavelength of double the length of the wire. The voltage and current distribution along the wire are shown in Fig. 13a, and in Fig. 13b it can be seen that if the wire is folded into a double length this current and voltage distribution is maintained. Furthermore, although a standing wave is set up along the wire (a necessary condition for radiation), the power lost by radiation is extremely small whilst the distance between the wires of the folded half wave is kept to a small fraction of the total wavelength—a state of affairs which can easily be maintained up to the U.H.F. part of the spectrum which is reckoned to commence at about 300 mcs.

Inspection of the distribution of the double quarter wave line will reveal that its impedance varies, apparently, as the voltage and current vary. At the short-circuited end the current is high and the voltage low, corresponding to a low impedance, whilst the reverse conditions obtain at the open ends. Adjustment for tuning can thus be carried out by using a shorting bar arranged as a slider, and by moving such a bar along the parallel lines the resonant length can be changed at a point of low R.F. potential.

Fig. 14 shows a resonant line transmitter in its simplest form. Many transmitting valves have directly heated cathodes—filament type valves—but in any case the heater should be bypassed for R.F. to assist in the stabilising of the oscillator. A further refinement is to tap the anode and grid leads to the parallel lines at points nearer the shorting bar, leaving the high potential line ends undamped. The lines themselves should be of copper tubing, the diameter increasing with the power output of the circuit, and the shorting bar is of substantial copper strip with a screw clamping device to ensure perfect contact on the lines. Self biasing of the grid is obtained, since grid current flows through the resistance which is chosen to suit the valve.

It is possible to tune the lines by removing the shorting bar and connecting a variable condenser in its

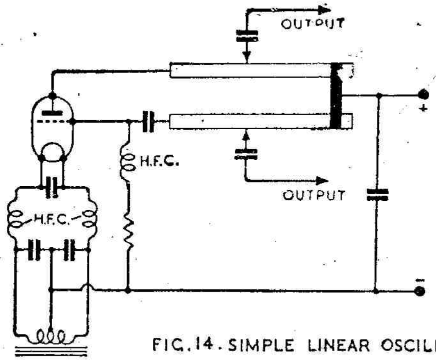

FIG. 14. SIMPLE LINEAR OSCILLATOR.

place, feeding the anode line through a H.F. choke tapped on at the optimum position. Long lines receivers have been constructed using this principle. In general, however the shorting bar technique is the better tuning method for transmitters, for the condenser might introduce the very effects it is desired to eliminate.

The total length of the filament circuit should be a half wavelength, a quarter wave for each lead, presenting a high impedance to H.F. It is therefore necessary to make the chokes in the leads adjustable to some degree if the most efficient operation is to be achieved. A more simple method of tuning the low tension circuit is to use a second pair of long lines with their own shorting bar. This circuit, with a second valve added to give push-pull operation, not only adds to the power output but gives balanced working conditions and is shown in Fig. 15.

Here it will be seen that, using indirectly heated cathode type valves the cathode circuit can be tuned to its resonant frequency and at the same time provides a shield for the heater feeders. Once again the sliding shorting bars can be replaced by condensers if required and the electrode line connections can be tapped at adjustable points.

It has already been mentioned that as the frequency rises the long lines stabilised circuit commences to lose efficiency since the standing waves on the lines no longer cancel out their radiation to the necessary degree. At frequencies above roughly 300 mcs. therefore the long lines are modified to become either concentric lines or "lumped

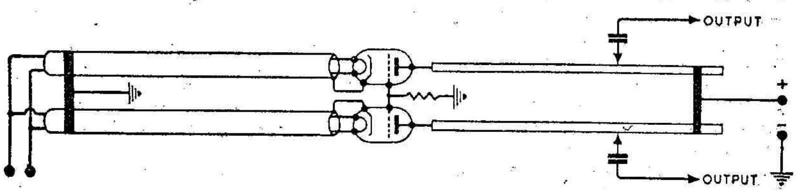

FIG. 15. BALANCED LINEAR OSCILLATOR.

tanks". In both cases the radiating fields are confined within an outer conductor which, in the concentric line system, is at earth potential. The lines may be tuned by changing their length but since this requires a sliding contact in the shape of a washer which makes constantly good contact with both the inner and outer tubes the more conventional method of condenser tuning is frequently employed as is shown in Fig. 16. This circuit also shows a coil and condenser output tank circuit, although a lines circuit once again may be used.

The concentric lines are made of copper tubing, the inner tube being mounted so that it is concentric and evenly spaced with the outer tube throughout its length. The tubes should be, theoretically, a quarter wave long,

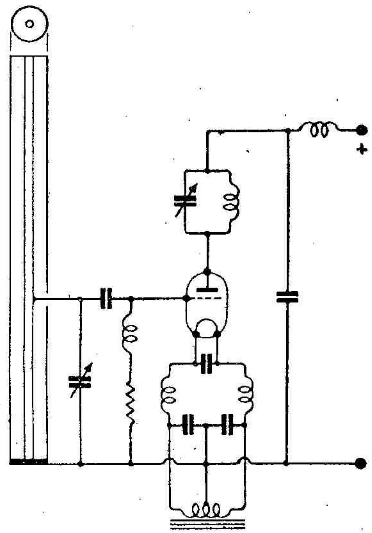

FIG. 16. CONCENTRIC LINES OSCILLATOR.

although better operation is generally achieved with slightly shorter lengths due to the inertia imposed on the circuit by damping. Various authorities give the most efficient ratio of tube sizes as 1:3·6, these figures relating to the ratio between the outer diameter of the inner tube to the inner diameter of the outer tube. The shorted ends of the tubes should be sweated on to a copper disc which may also be the mounting plate since it is at earth potential.

A tank circuit is said to have "lumped" characteristics when, at ultra high frequencies, the conductors are made very large to decrease their resistance, a rod forming the inductance and surrounded by one or, more usually, two cylinders which may be connected to act as a

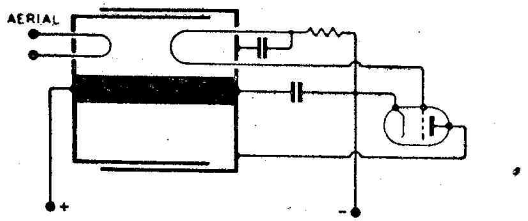

FIG 17. "LUMPED" TANK CIRCUIT.

condenser across the rod. It is interesting to note that in such an arrangement input and output circuits can be in the form of small single turn coils or even plain wire stubs supported inside the cylinders. For the most efficient operation the length of the tank unit, as shown in Fig. 17, should be only about 7 per cent. of the wavelength

Practical Circuits.

For the 5 metre band or 56 mcs. working the long lines or concentric lines transmitter is somewhat unwieldy and in any case excellent results can be obtained at this frequency with crystal-controlled working which is dealt with later in the chapter. The practical circuits of self-excited oscillators are therefore of circuits designed to work at 112 mcs. Naturally some care in the choice of valve is necessary for work at such a frequency but the Osram DET19, a double triode, is rated to work at full ratings at 240 mcs. with an anode dissipation of 10 watts so a design based on this valve should prove of general interest.

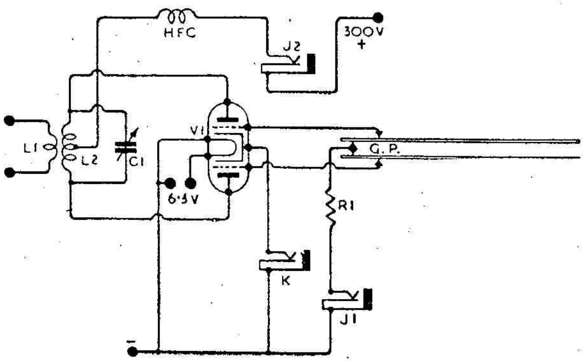

FIG.18. 112MCS LINES STABILISED TRANSMITTER.

List of Components for Circuit of Fig. 18.

L1.	2 turns 14 S.W.G. copper, $\frac{3}{4}$" diam. spaced to enter tank coil without touching.
L2.	Tank Coil. 2 turns 12 S.W.G. copper, 1" diam. spaced $\frac{1}{4}$" between turns.
C1.	Tank condenser. 15 mmfds. Raymart MC15DX.
G.P	Grid pipes. 26" long, $\frac{1}{2}$" diam. copper tubes spaced $\frac{1}{2}$" between walls.
R1.	2,000 ohms, 1 watt.
H.F.C.	U.H.F. choke. Eddystone.
V1.	Osram DET19. RK34.
J1, J2.	Closed circuit jacks for insertion of meter.
K.	" " " " " " key.

Stand-off insulators for mounting tank and aerial coupling circuits, pipes, etc.
Ceramic American 7 pin base.
Tapping clips, knob, etc.

The circuit, shown in Fig. 18, is straightforward and simple and should be constructed to occupy as little space as possible so that the few leads may be short and direct. The long lines or "grid pipes" might well be mounted vertically, the valve being mounted on a small sub-chassis beside the lines. The grid tapping points are determined by experiment to give good oscillation at the correct feed ratings. The tank coil and condenser, together with the aerial coil, must be mounted on insulators, the aerial coupling coil being wound so it may be adjusted on its mounting to allow its turns to slip between those of the tank coil to obtain the desired degree of coupling.

When putting the circuit into operation it is necessary to insert into the main H.T. supply lead a 0-100 milliammeter whilst a 0-25 milliammeter in the grid resistor to earth line is also very useful. One point in self-excited oscillator working which needs careful attention is the fact that bias is not supplied to the grid of the valve until the circuit is oscillating. The bias is derived from grid current flowing through the grid resistor resulting in a voltage drop across the resistor. Until the circuit is tuned to its oscillating point therefore it is possible for the valve or valves to draw a very heavy current, sufficient in some cases to damage the cathode emission, and all possible precautions must be taken against such an occurrence. It is good practice to include a suitable resistor in the H.T. supply lead, especially with a new circuit, so that a rising current automatically results in lowered H.T. voltage, the resistance being removed when the tuning point is found.

The circuit is brought into oscillation by rotating the anode tank condenser, watching the anode current meter. As the condenser is adjusted a point will be found where the current dips sharply, perhaps to as little as a quarter of the valve's rated consumption, whilst the grid current meter will indicate. The circuit is now oscillating, and must be loaded, or have power taken from it, to bring it to the correct working conditions. This is done by coupling either a suitable aerial or, for testing purposes, a dummy load to the aerial coil. A dummy load, for example, consisting of a low voltage lamp of a wattage corresponding to the output power of the oscillator. As the aerial coil is adjusted for coupling with the tank coil the anode current will commence to rise again, whilst the tank may need slight retuning to compensate for coupling effects. With the DET 19 (or its counterpart the RK 34) the maximum ratings are anode supply, 300 volts, anode current, both triodes in push pull, total 80 milliamps, grid current in the combined grid circuit, 20 milliamps. With the valve supplied in this way the output of an unmodulated oscillator is in the region of 15 watts.

The coupling between the grid and anode circuits necessary to cause the self-excited oscillations is given by the inter-electrode capacities of the valve which, in the case of a double triode are relatively large. Twin pentodes can also be used in a similar circuit provided that readjustments are made in the feed conditions, but with these valves it is sometimes necessary to augment the grid-anode inter-electrode capacities before oscillations will commence. Since the added capacities need only be very small, however, they may be obtained by running a few inches of stiff wire from the anode pins of the valveholder parallel to but separated from its respective grid pipe. The wires are trimmed, each by the same amount at a time, to give sufficient capacity for feedback which can be judged by observing the grid current drawn and comparing it with the valve's rated figure. A high grid current reading indicates that the capacity is too high and needs reducing.

Before any lines-stabilised transmitter is put on the air it must, of course, be tuned into its band. The main tuning is performed by adjusting the shorting link on the grid pipes, the frequency rising as the link is advanced, and probably the most satisfactory frequency check will be provided by Lecher wires. The grid pipes are tuned first, the circuit being brought back to resonance by an adjustment of the tank tuning, the grid taps also being adjusted for good stable working and correct feed conditions. For a starting point they might be tapped on to the pipes 3" above the shorting link.

Crystal Controlled Transmitters.

It is well known that a correctly cut slice of quartz crystal exhibits electro-mechanical properties of which great use has been made in branches of radio technique, and possibly nothing has benefitted more than the transmitter proper. When the quartz crystal is stressed mechanically a corresponding electrical strain is set up across the crystal, appearing as a voltage in proportion to the mechanical stress. The quartz slice as used in the grid circuit of an oscillator is so cut that it presents the properties of a very stable tuned circuit. Accordingly, the circuit may be adjusted so that oscillations take place and the crystal will keep the frequency of the oscillations controlled. It is itself oscillating mechanically at a rate depending on its size, thickness, temperature, etc.

Since wide ranges of control of the crystal's mechanical conditions are possible, the transmitted frequency can be stabilised to a high degree. When such control is brought to the very high frequencies an immediate improvement in quality, as well as a greater capacity of each channel for closer frequencies, is possible. On the reception side the most selective superheterodyne receiver can be used without any fear of frequency drift or hunting, or of split or undesirably frequency modulated signals.

A crystal, however, cannot be cut to oscillate directly at a frequency higher than about 14 mcs. since at this frequency it is already very finely ground and very sensitive to shocks and it can easily be damaged by the application of too great an oscillating potential. Crystals have been cut to oscillate harmonically on the 28 mcs. band but even this is out of the question at 56 mcs. or 5 metres, the generally recognised starting point of real V.H.F. work. It is possible, however, to "frequency double" up from a lower frequency crystal, even using as robust a crystal as a 7 mcs. cut. The frequency doubling is accomplished in several steps but does not need a multiplicity of stages since even the crystal oscillator circuit can supply a strong output at the fourth harmonic of the fundamental frequency, that is, at four times the frequency of the crystal in use. Such an oscillator, known as a Grid-Anode Oscillator, is used in the diagram of Fig. 19.

Whilst an oscillator stage can be used to feed power straight to an aerial it is generally necessary to provide for more power amplification in the transmitter, as well as for further frequency doubling where this is desired. The power amplifier stage is best separated from the crystal

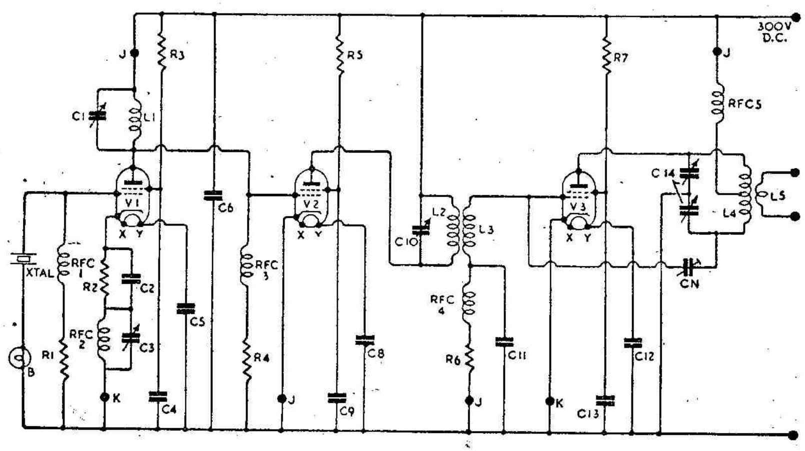

FIG 19. 112 MCS CRYSTAL CONTROLLED TRANSMITTER.

oscillator by a buffer amplifying stage so that varying loads on the amplified output, together with any necessary modulating signals, can be kept separate from the oscillator so that its stability is not impaired. The buffer stage can provide for frequency doubling as also can the power amplifier where desirable In these three stages it is quite possible to reach a frequency of 224 mcs. using a 7 mcs. crystal provided that suitable valves are used. Moreover it is a relatively simple matter to substitute coils and retune the transmitter to cover several amateur bands, so that on the whole the crystal controlled circuit can be an economical and highly efficient piece of apparatus.

In both buffer and power amplifier stages it is sometimes necessary to take precautions against the setting up of local or parasitic oscillations within the valve and tuned circuits of the stage itself. This is the function of neutralising condensers, one of which is seen in the final amplifier of the circuit of Fig. 19. Oscillation would occur by the feeding back of energy from the anode circuit to the grid circuit through the inter-electrode capacity of the valve, so that to counteract this feedback a degree of energy is fed back through the neutralising condenser in such phase as will neutralise the original valve feedback. The method of setting these neutralising condensers is discussed later.

A further precaution, this time in the oscillator stage, is generally taken to avoid overloading the crystal. At high frequencies the crystal is passing H.F. current, and to prevent burning or fracturing, this current must be limited to a generally accepted figure of 60 milliamps. Accordingly a 60 ma. fuse bulb is placed in series with the crystal, serving the double purpose of overload limiter and indicator bulb since it will light with the commencement of oscillations.

With the circuit shown it is possible to obtain an output at either 56 or 112 mcs. with a 7 mc. crystal in the first stage, using the P.A. as a doubling stage in the second instance.

List of Components for Circuit of Fig. 19.

L1.	4 turns 18 S.W.G. 1¼" diam. spaced ¾" long.
L2.	4½ " " " 1 " " " own diameter.
L3.	5 " " " 1 " " " " "
L4.	2 " 12 " 1¼" " " " "
L5.	1 " " " 1" "
C1.	100 mmfds. Raymart VC100X.
C2, C4, C5, C6, C8, C9, C11, C12, C13.	.005 mfd. Non inductive, 1,000 v.w. (Mica).
C3.	250 mmfds. Raymart VC250X.
C10.	40 mmfds. " VC40X.
C14.	40 mmfds. per section, 2 Raymart TC40's ganged.
Cn.	Neutralising condenser. Eddystone.
R1.	22,000 ohms. 1 watt.
R2.	330 " "
R3, R5.	47,000 " "

R4.	220,000 " "
R6.	15,000 " "
R7.	4,700 " "
RFC1, RFC2.	2.5 millihenry RF chokes. Eddystone.
RFC3, RFC4, RFC5.	U.H.F. chokes. Eddystone.
B.	60 ma. fuse bulb.
K.	Closed circuit sack for key.
Crystal.	7 mcs. amateur band, mounted in holder.
J.	Closed circuit jacks for meter insertion.
V1, V3.	6V6.
V2.	6AG7.

3 Ceramic octal valveholders.
Stand-off insulators, knobs, etc.

Construction of such a transmitter as that outlined will ultimately depend on the experience and preferences of the amateur himself. The usual rules of clean and direct layout apply in full force, all the H.F. components being kept above chassis level and mounted rigidly on stand-off insulators. The chassis therefore can be shallow, serving as a mounting base, container of power wiring and a general earthing point. Wherever possible all the earthed leads of each stage should be taken to a central point for that stage, thus obviating the chance of circulating H.F. currents. The final tank circuit will need some attention, since the coil inductance is so small that it will be unduly affected by long leads, and it may be necessary to trim the tuning of the tank by opening or closing the turns in order that the resonant frequency falls within band limits as set by this crystal.

Where coils are coupled together, such as is the case with L2 and L3, the earthed or earthy ends of the coils should be those in proximity.

All the coils are wound to be self supporting, and are best mounted either on stand-off insulators or by plugging the ends, suitably fitted with plugs, into a ceramic coil holder.

Operation.

When the transmitter is being put into service a wavemeter or calibrated receiver is necessary in order that the correct harmonics may be tuned in the oscillator and doubling stages.

To commence, supply power to the oscillator and buffer stages, leaving the power amplifier with the heater supplied but without H.T. on the anode and screen. Tune C1 and L1 to the fourth harmonic of the crystal—28 mcs., choosing the harmonic with the aid of the wavemeter loosely coupled to L1.

Indication of resonance will be obtained by a 0-50 ma. meter plugged into the anode line of the oscillator, the reading dipping at resonant points. Should there be any trouble in obtaining a reading the load may be taken from the circuit by disconnecting the coupling condenser C7. When the oscillator is working at the required frequency the output can be varied by setting C3, and the power drawn from the stage should only be sufficient to load V2 properly. Any crystal heating may be counteracted by reducing the screen voltage on V1.

The wavemeter is now set to 56 mcs. and loosely coupled to L2, C10 being tuned to give resonance. The milliammeter is transferred to the jack in the 6AG7 cathode where, at resonance, a reading of not more than 15 ma. should be obtained. When the doubler is finally tuned the oscillator setting should be checked against any loading effect.

A 0-5 ma. meter is now plugged into the jack in the R6 to earth junction, where a reading will be obtained due to grid excitation, and before the H.T. is applied to the final valve the circuit must be checked for neutralisation. It is possible that, using the 6V6, neutralisation will not be needed, but since this depends largely on circuit layout and design the check is important.

Set the neutralising condenser to its minimum capacity and by varying the coupling between L2 and L3 obtain a grid current reading of not more than 2 ma. It is possible that some adjustment of the value of R6 will be necessary. Then rotate C14, watching the grid current registered on the meter. If at any point there is a slight flicker this indicates that feed-back is taking place and the neutralising capacity must be increased a little at a time until C14 can be rotated without any effect on the grid current. The final stage is then neutralised.

Connect a suitable dummy load to L5, such as a 10-watt lamp, with loose coupling only between L4 and L5 and plug the 0-50 ma. meter into the anode circuit jack of the final stage. Apply H.T. to the anode and screen of the valve and tune the tank circuit to resonance at 112 mcs. as indicated by the wavemeter. There should be no delay in the tuning process since the current can rise to a high figure under certain conditions unless the tank is properly tuned. The load on the tank can now be adjusted by varying the coupling between L4 and L5 to bring up the anode current of V3 to about 50 ma., retuning the tank slightly if necessary.

Modulation.

Having obtained the source of H.F. power, the transmitter, it is still necessary to impress signals on the emitted wave for carrying intelligence, the signals consisting either of straightforward impulses of transmission for telegraphy or the modulation of the wave by speech frequencies. Either method of modulation can be carried out in several ways, but care must be exercised, especially in the case of the lines-stabilised type of transmitter, to avoid causing instability.

For telegraphy the most obvious method of transmitting impulses of power is to interrupt the H.T. supply to the oscillator and provided that the interruption is carried out in a cathode line at low voltages the use of such a system should give no trouble. If the key sparks at the make and break, however, interference with neighbouring apparatus on totally different wavebands might be the result, and in such a case the key circuit would need

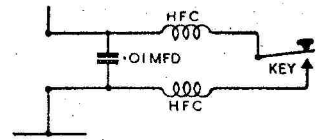

FIG.20. KEY CLICK FILTER.

filtering. The jacks marked K in Figs. 18 and 19 show where keys may be plugged into the circuits.

In Fig. 20 is shown the usual type of filter connected to a key for the elimination of clicking where the trouble arises. The values of the chokes will vary from one type of transmitter to another, but using a .01 mfd. non-inductive condenser the 2.5 millihenry choke makes a good start for determining final values by experiment, and will often clear up the trouble without further adjustment. The more elaborate keying systems such as the electronic keyer are not generally used on the V.H.F. bands and since they are fully covered by published works on lower frequency transmitting, space is not devoted to them here.

It will be seen that in the crystal controlled transmitter two points are shown for the inclusion of a key. The oscillator may be keyed since it has a relatively low plate voltage and the power drawn from it is not high, but it may be found in adaptations of this design that using this keying point and thus removing excitation from the grid of the final amplifier sends up the plate current of the amplifier to an undesirable degree. If this is the case the amplifier itself may be keyed in its own cathode circuit.

Several different methods of speech modulation are possible, but for the transmitters shown, and for self-excited oscillators generally, the plate method of modulation, using a transformer to inject the signal, is probably the best despite the fact that this requires rather more modulator amplifier power. This is easily obtained for these low power transmitters, however, the rule being that the modulator must supply an output in watts equal to half the D.C. input to the transmitting valve.

In the case of the DET19, therefore, the amplifier must supply about 10 watts and to the final amplifier of the crystal controlled transmitter about 5 watts. Since it is as well to have some power to spare a 10 to 12 watt amplifier could be used for either transmitter, the final adjustment being carried out on the gain control using a monitor, preferably of the oscillograph type, to check for modulation depth

Where a tetrode such as the 6V6 is to be modulated it is usual to modulate both the anode and screen. Thus in the diagram of Fig. 19 for the transmission of speech, the screen resistor of the P.A. stage would be transferred from the main H.T. supply line and taken straight to the anode, keeping the bypass condenser C13 at the same value, the current feed to the valve being adjusted by loading to fall to 40 ma.

The load on the modulating amplifier of the two valves shown would be approximately 4,000 ohms for the DET19 and 6,000 ohms for the 6V6 so that transformers may be chosen to transfer this load to the output stage of the modulator, the ratios working out at only 1:1 or 1:2 for a wide range of suitable valves. The 6L6, run at 375 volts on the anode together with a fixed bias of 18 volts from a battery and a screen potential of 250 volts is rated as giving 11 watts into a 4,000 ohm load.

It is preferable, however, to use a modulating amplifier with a Push-Pull output stage, the Class B type of circuit proving very effective, and such an amplifier, together with the method of feeding the signal into the transmitter, is shown in Fig. 21.

List of Components for Circuit of Fig. 21.

R1.	4.7 megohms, ½ watt.
R2.	1.5 " 1 "
R3.	.25 " " "
R4.	20,000 ohms, " "
R5.	1,500 " " "
R6.	.5 megohm potentiometer, Gain Control.
R7.	1,000 ohms, 1 watt.
R8.	4,700 " " "
C1.	.5 mfd. Non-inductive, 350 v.w.
C2, C5.	25 mfd. 12 v.w.
C3, C6.	8 mfd. 500 v.w.
C4.	.1 mfd. Non-inductive, 750 v.w.
T1.	Class B. Input transformer.
T2.	Centre tapped output transformer, matched to load. (See text.)
V1.	6J7.
V2.	6C5.
V3.	6N7 (or 6A6 with UX holder).

3 octal chassis mounting valveholders.
Knob, input sockets, chassis, etc.

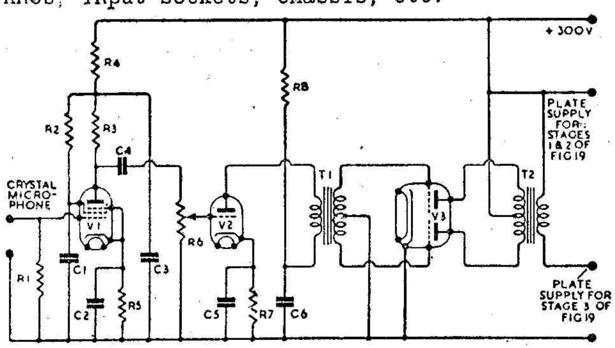

FIG. 21. MODULATION AMPLIFIER GIVING 10 WATTS OUTPUT. CIRCUIT SHOWS CONNECTIONS FROM ONE POWER PACK TO STAGES OF TRANSMITTERS DESCRIBED IN TEXT.

The stated load for the 6N7 valve is 8,000 ohms plate to plate for an output of 10 watts audio, so that the transformer ratio on the output side for the two valves mentioned is, for the DET19, 1-1·4 and for the 6V6 1-1 nearly. The diagram shows the same power supply feeding both modulator and transmitter—for such an arrangement the power pack smoothing must be excellent and should be by-passed for R.F. as well as audio frequencies.

CHAPTER 5.

Aerials.

The V.H.F. receiver will operate on practically any type of aerial and often strong signals can be received without an aerial at all, but for these high frequencies the antenna equipment is in general so compact and so easy to construct that it may be erected under almost any conditions. For the transmitter a properly tuned and directed aerial is, of course, essential, and a rotating beam aerial is always worth the extra complications wherever it can be used.

The receiver circuits in this manual follow usual design technique, each being provided with a double input to a coil. If a V.H.F. aerial cannot be provided, one side of this coil may be coupled to an ordinary broadcast aerial. The aerial may be capacity coupled to the main tuned coil of the receiver by a very small condenser— 00005 mfd. at the most,* except where otherwise stated—tapped into circuit experimentally for the best results. The circuits will probably work better without any earthing.

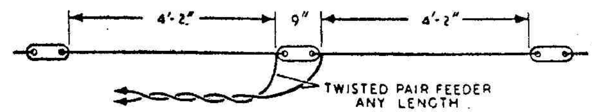

FIG. 22. HALF-WAVE DOUBLET FOR 56 MCS

For general reception, however, a doublet aerial fed into the coil will be far more satisfactory, especially if it can be mounted at a good height and with vertical polarisation—that is, the aerial itself should be vertical. The length of the aerial, controlled by the frequency band in which the reception is taking place, is a half wavelength overall, the wire being cut in the centre for the introduction of a pair of twisted feeders. In sheltered positions this may be of ordinary lighting flex, although to avoid weathering and consequent loss of efficiency commercially obtainable feeders may be used. Such an aerial is shown diagrammatically in Fig. 22.

Since the aerial must be capable of covering a band of frequencies it should be cut to resonate at the central frequency of the band, using the formula already quoted in Chap. 3,

$$\text{Length} = \frac{467.4}{f} \text{ feet}$$

where f is the frequency in megacycles. At 56 mcs.

the length of wire is 8.34 feet, and this would be the length of the aerial of Fig. 22, disregarding the interrupted central portion. The two halves of the aerial are supported by an insulator, as are the ends.

As shown, the feeders can be of any length but care should be taken to ascertain that they have a clear and open run and that where they enter the building they are insulated adequately, the wires being kept away from walls and metal work as far as possible.

Reception may be further improved from one direction by adding a reflector to the half wave aerial. The reflector consists of a second length of wire, equal to the aerial's length and mounted a half wave behind the aerial. Then, whereas the vertical doublet will theoretically receive signals from all directions horizontally without discrimination, the aerial with reflector will receive most strongly from a direction on the aerial side of the array. Signals from the reflector side will be attenuated. For working on signals from a fixed position, as, for example, in television, this system has several advantages, for not only will there be a gain in the desired signal due to the extra energy reflected back on to the aerial, but unwanted signals and echoes will be excluded. The array is shown in Fig. 23.

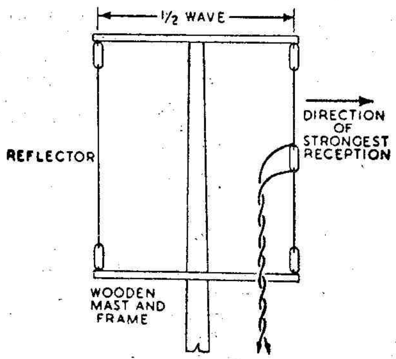

FIG.23. HALF-WAVE AERIAL WITH REFLECTOR.

For portable equipment, especially at frequencies of 112 mcs. and over, the rod aerial is of great use, since it may be mounted rapidly on a simple pole or attached to a car, and has a high efficiency It is, in form, a half wave aerial with a coaxial line feed in place of the twisted feeders, the coaxial cable having a characteristic impedance of 72 ohms. This is the impedance presented to a line connected at the centre of a half wave wire, (See Bernards' Aerial Manual, No.56). Such cable may be obtained commercially In form the aerial has the centre conductor

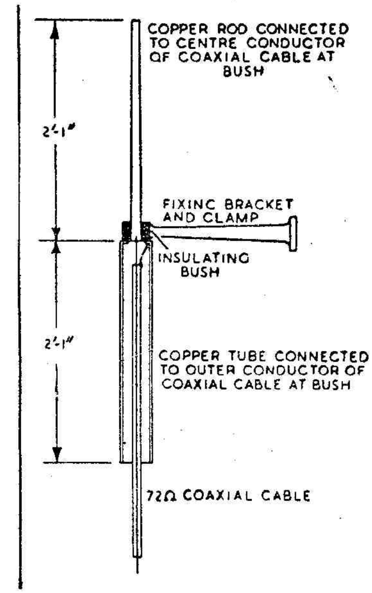

FIG.24. ROD AERIAL FOR 112 MCS.

of the cable extended as a rod whilst the outer conductor is, in effect, folded back on itself to complete the half-wave, this folded-back portion generally being known as the "skirt". The coaxial cable may be of any length, but it should be kept as short as possible The rod aerial is shown in Fig. 24, for 112 mcs.

The aerials so far described may be used for transmission as well as reception, but the problem of transferring energy from the tank circuit to the aerial really requires a better solution than that provided by the twisted feeder and coaxial cable so far shown Feeders for transmission purposes may be classed into two main types, the tuned and untuned feeder The twisted line and coaxial cable both work as untuned feeders having a characteristic impedance roughly equal to that of the aerial at the point to which they are tapped. The tuned feeder, however, has an impedance generally higher than that of the aerial, the necessary matching being performed at the transmitter with a series or parallel tuning system in the feeder circuit. Waves of H.F. energy are allowed to form on the feeders themselves.

For V.H.F. work the untuned feeder presents many advantages but only when the feeder run is short. A long untuned line to a high aerial will result in the loss of a

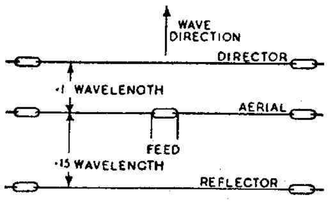

FIG.25. PARASITIC ARRAY

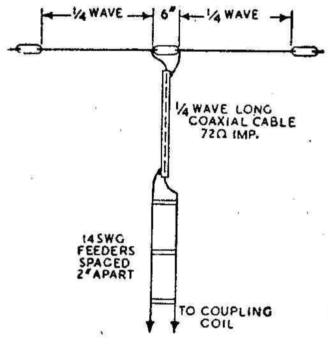

FIG.25 A. METHOD OF AERIAL FEED FOR ARRAY SHOWN IN FIG 25

good deal of energy—the amount can easily be half the transmitter output—so that the choice of feed must depend on the distance between transmitter and aerial. On the other hand the construction of a tuned line is difficult for V.H.F. work since such a line consists of two parallel feeders spaced a constant distance apart. Transmission will take place from the line itself unless the spacing between the wires is only a small fraction of the wavelength of the transmitted wave.

There is room for comparative experiment in V.H.F. installations, therefore, to determine the most suitable type of aerial feed for a given set of circumstances

One solution of the problem which is attaining some popularity is to mount the transmitter with the aerial under a weather-proof housing, this applying, of course, to the simpler self-excited type of oscillator with lines stabilisation. The transmitter has remote controlled switching and the aerial is made rotatable and is fed directly from the coupling to the tank circuit without transmission losses.

In any case the aerial for transmission will probably be made as high and open as possible, and for this reason the receiving aerial must be as efficient as the transmitting array. The obvious plan is to use the transmitting aerial for reception, so that the same area may be covered, a relay or remote controlled switch connecting the aerial array to the apparatus in use.

Fig. 25 shows a parasitically energised array suitable for directive transmission and reception. The aerial, a centre fed half wave, has a reflector behind it and a director in front. These two elements give a considerable gain in signal strength, the whole array being mounted horizontally on a rotating bearing. The spacing between the elements is .1 wavelength between the aerial and director with .15 wavelength between the aerial and reflector, the aerial length being calculated as before. The director should be 5 per cent. shorter than the aerial and the reflector 5 per cent. longer.

The feed to the aerial is, in this case, a compromise, since a high impedance line is matched to the aerial by a concentric section as shown in Fig. 25a.

The high impedance feeder, whose length should be as short as possible, is made of 14 S.W.G. copper wire, the two lines being separated by a porcelain insulator 2" long, situated every 18".

Aerials mounted on a swivelling or rotating head must, of course, have some control and indicating system at ground level. For high frequency systems probably the best mounting, since the aerial is small, is to have a rigid aerial structure firmly fastened to the top of a stout mast, the whole mast being rotatable from the ground. If the mast is erected by the side of a building or a wall its foot can be fitted with a peg riding in a bearing whilst the mast is kept upright by passing through a collar fixed

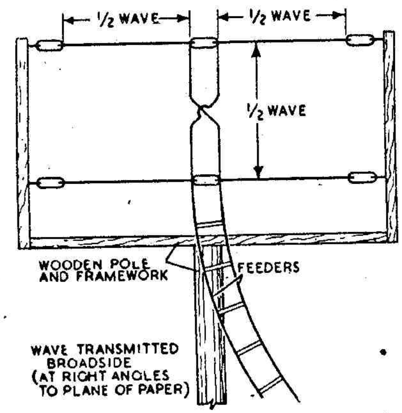

FIG. 26 "LAZY H" ARRAY.

to the wall as high as is convenient. The mast is smoothed and circular at this point so that whilst the collar supports it it does not prevent rotation. Since for most aerials 180 degree rotation is all that is required stops can be fitted and feeders can be given a little slack so that no system of commutation is necessary, the line running from the aerial direct to the transmitter. With the above aerial a full rotation of 360 degrees is required, but feeders can still be arranged to permit of this amount of turning without special precautions.

A suitable directive aerial for use with a tuned transmission line is the "Lazy H" as shown in Fig. 26. The half wave lengths are calculated as before and feeders of

14 S.W.G. copper, spaced every 18" by a 2" porcelain insulator are tapped into the feed point shown. The feeders should be made as short as possible, and, to give simpler tuning arrangements at the transmitter end, they should be an odd number of quarter waves long: 1, 3, 5, etc. Theoretically a correction factor should be applied to the quarterwave length but direct measurements will suffice. The feeders should be clear and well insulated where they enter the building, and the line is coupled to the tank circuit by the arrangement shown in Fig. 27a, the feeder coil being inductively coupled to the tank coil on the "cold" end. The feeder coil, with its condenser, must be capable of being tuned to resonance so that values for the coil and condenser can be based on those used for the tank circuit although generally some adjustment will be required, best made by trial and error. The feeder coil is tuned using the current indicators in the feeders which should show greatest current when the loading on the tank circuit is correct.

The current indicators may well be flashbulbs, several being connected in parallel for heavy currents.

When the feeders cannot be made an odd number of quarter waves long, the tuning arrangement is as shown in Fig 27b Instead of current indicators the degree of feeder energisation is shown by voltage indicators—small neon lamps with one internal electrode connected to the

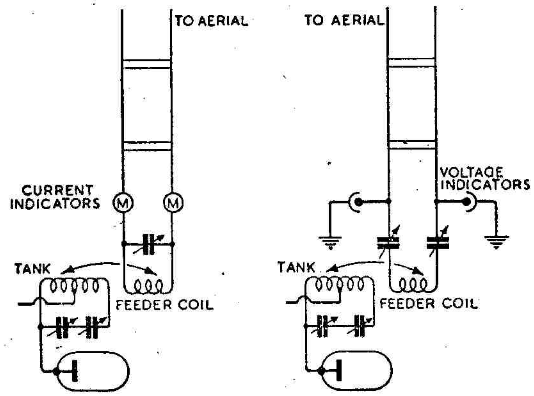

FIG.27.

(a) FOR FEEDERS AN ODD NUMBER OF 1/4 WAVES LONG

(b) FOR FEEDERS AN EVEN NUMBER OF 1/4 WAVES LONG.

tuned circuit. The other electrode is connected to an earthed plate of metal about 4" long and 2" wide mounted beside the lamp to give enough capacity to earth to strike the neon.

If desired the feeder coil may be situated at the point where the feeders enter the building, coupled to the transmitter by a link circuit. Such a circuit consists of a length of transmission line or even of twisted flex, coupled to the transmitter by a single turn of stout wire round the tank coil. This should be mounted to have a variable coupling, the other end of the link being coupled to the feeder coil in the same way The link couplings are adjusted by trial and error for the correct tank loading whilst the linking line may be run between the tank and feeder coils by the most convenient route.

CHAPTER 6.

U.H.F.—Centimetre Waves.

As has already been mentioned, apparatus is still in the course of development for the production of extremely high frequencies and will not be available to the amateur for a considerable time. Much interesting work has been done in the past using, at first, orthodox valve types. Then U H F. adaptations of these types and finally with the Acorn class of valve, rated by the manufacturers to have a frequency limit of about 800 mcs with a fair efficiency at 700 mcs., or about 40 centimetres.

A good deal of interesting work can be performed with battery valves, however, using unusual circuits and methods of valve feed, and it is proposed in this chapter to outline briefly the various techniques of U.H.F. generation from these sources.

Probably the shortest wavelength obtainable from a conventionally coupled battery triode—the valve should be of the super-power type and will need to be chosen for good oscillation characteristics—is between 1½ and 2 metres. The adapted Gutton and Touly circuit for this arrangement is shown in Fig. 28. The inductive loop should be as short as possible, the valve being decapped—that is, having its base

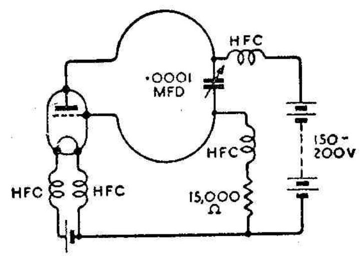

FIG. 28. THE GUTTON-TOULY OSCILLATOR.

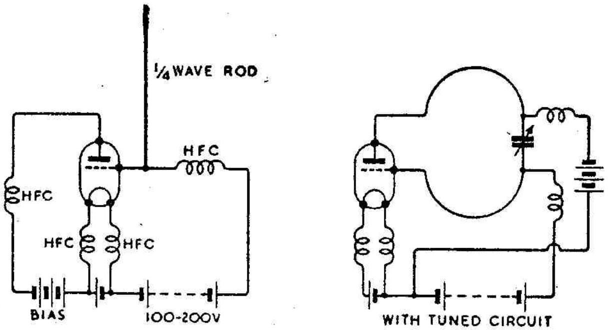

FIG. 29. GILL-MORRELL OSCILLATOR.

removed and the lead out wires taken straight into the circuit. The variable condenser should be of the midget type. The chokes can be made in the usual way, by winding a ¼" glass tube with about 40 turns of fine wire. The filament chokes, being of heavy wire to avoid volts drop, are wound with the same number of turns. The two filament chokes should be wound together on the same former, a half inch ebonite rod.

To generate higher frequencies still, account must be taken of the electron transit time inside the valve itself. The time taken for the electron to travel from filament to plate via the grid and to set up oscillations limits the frequency of that oscillation. A circuit was accordingly developed by Gill and Morrell in which the grid of the valve is made positive. The oscillations take, apparently, the form of a fluctuating space charge around the grid, the filament and anode acting as negatively charged repelling electrodes.

In the circuit of Fig. 29 it may be seen that the first impulse of current in the valve can shock-excite a suitable external circuit, thus setting up an oscillation. Within the valve the electrons will move towards the positive grid at a very high speed, pass through it and be repelled by the anode. They will then swing towards the grid again, pass through it to be repelled by the cathode and so on. Thus the electron swing within the valve may be induced to coincide with the natural frequency of the external circuit. This results in the generation of waves as short as 30 or even 20 centimetres long. It need hardly be said that the valve emission soon deteriorates under such working conditions whilst a valve with the slightest degree of sag in the electrode assembly may, through electrostatic attraction, short circuit the power supply. It may be found that a small degree of negative bias on the anode will assist the working of the circuit, and the oscillator can be used as a receiver

by including this bias together with a reproducer in the grid supply line, or the anode circuit.

One method of providing a tuned external circuit is to couple the valve directly to its aerial which may be either a half wave dipole or a single quarter wave wire. One end of the aerial, in the latter case, is connected directly to the grid of the valve.

Barkhausen and Kurz also demonstrated this type of oscillating circuit, their electron swing being between grid and anode. Both types of oscillation, between anode and cathode and between anode and grid, can be set up in the same valve under certain conditions, depending both on the internal structure and the potentials applied. The chief characteristic of Barkhausen-Kurz oscillations is that external tuning circuits have little effect on the actual frequency generated within the valve itself.

Another oscillator, giving rise to electronic oscillations, was developed by Okabe and called by him the Magnetron since an external magnetic field is used to control the electron flow. The valve is in the form of a diode, generally with a split anode which is concentric with the cathode. Wavelengths of less than one centimetre have been obtained. A recently developed Magnetron is used in the R.A.F. "H2S" device to give a narrow beam of radiation which scans underlying country and is reflected back to receiving equipment. The power of the reflected wave is used to modulate a cathode ray tube to produce a diagrammatical view of the terrain. The valve is also used in other ground and airborne Radar applications.

Whilst some points in the theory of Magnetron operation are still not completely explained there has already been accumulated a very considerable amount of mathematical and experimental data on the subject. All that can be said here is that, due to the interaction of the electrostatic and magnetic fields, electrons which would normally travel from the cathode to the anodes around it in straight lines are caused to travel in swinging spirals. Only those electrons favourable to the oscillation are left in operation since electrons in unfavourable phases are attracted out of the circuit. The concentration of fields at the adjacent edges of the anode sections supply the main driving force, the passage of the electrons at these points being modified in such a way that energy is given up to an external circuit. It is now common practice to tilt the anodes with respect to the magnetic field so that there is an electron drift along the valve, each electron consequently moving in a modified helix with a succession of work producing points. A small subsidiary anode may be used to collect the electrons at the end of their travel.

The Magnetron, shown diagrammatically in Fig. 30, is to date the most efficient producer of U.H.F

Details of the vastly improved "Cavity Magnetron" have just been released by the American Government. In this type of valve, reduced to small proportions for use in aircraft and other war-time applications, the cathode is surrounded by a series of shaped cavities in the circular

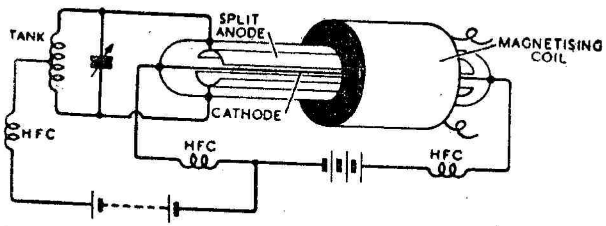

FIG.30. SIMPLE MAGNETRON OSCILLATOR.

anode. Each cavity is shaped so that its inherent inductance and capacitance will resonate at the desired frequency. The magnetic field causes the electron to circle the cathode and, in their passing the cavities in the anode, the resonant chambers respond and an output at the fundamental magnetron frequency is obtained. The chambers are connected in parallel which increases the output and stabilises the transmitted frequency.

The Acorn valve, when used for U.H.F. generation, is generally associated with a tuned circuit developed from the stabilised lines form of tank. The apparatus often appears to be more mechanical than electrical since the valve is enclosed in the tuned circuit. The oscillator is usually the fundamental quarter wave concentric line type, with the heater leads as carefully tuned as the main circuit. To simplify construction and adjustment the concentric line is more often made with the outer conductor in the form of a trough so that the inner conductor is immediately accessible. Tuning is a mechanical adjustment giving greater or smaller capacity between the lines by closing or opening the troughed line. In some cases, by using parallel lines with a metal screen encircling them, the screen distance and hence the capacity are under control. The aerial, of the skirted half wave type, is mounted directly on the transmitter, often being surrounded by reflectors.

American amateurs have given much thought to the designing of such U.H.F. transmitters, and details are often published in the American radio press.

A simpler circuit for use with Acorn valves where it is not desired to use long lines oscillators is the Mesny shown in Fig. 31. The two inductances shown, which should be of copper tubing, are in effect tuned by the inter-electrode capacitances of the valves, whilst coupling is also effected in the same way. Output may be drawn from the circuit via two very small air spaced and highly insulated condensers at the anodes, as shown. The heaters must be fed through chokes, and for these higher frequencies these chokes are often wound with bare wire on a grooved ebonite or ceramic rod with a brass sleeve free to run up and down the turns of the choke. The number of turns in the inductance may thus be tuned and the greatest impedance

presented to the circuit. As with other high frequency apparatus, the length of wire in the chokes at all feed points may be taken roughly as a quarter wavelength.

A mention of "double ended" valves might be made at this point. In characteristics and appearance they are somewhat similar to the Acorn, but in their case both the anode and grid are brought out to two connectors each, one anode and grid pair of pins on one side of the valve and another anode and grid pair on the other. With this method of construction the valve can be mounted directly at the centre of a half wave resonant lines circuit, or even

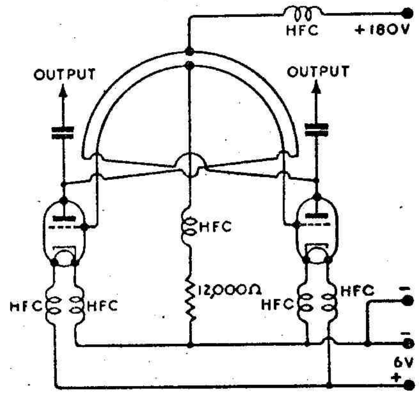

FIG. 31. THE MESNY OSCILLATOR.

directly in the centre of a half wave aerial. The aerial then acts as one tuned circuit whilst the secondary tuned circuit might, for example, be a very small coil and condenser system mounted directly across the valve. It is usual to carry the heater leads away from such a valve through a quarter wave shielded circuit, thus preventing H.F. energy from appearing in the heater system.

Velocity Modulation of Electrons.

As frequencies rise and wavelengths fall the tuning circuit of an oscillator becomes smaller and the efficiency is reduced at the same time. The point is reached, however, when a single metal chamber exhibits effects of resonance to a radio wave, due to its self-capacity and inductance, amongst other things. At the highest frequencies, such chambers, often known as "Rhumbatrons" (a Sperry Gyroscope Co. trademark) of definite form and size, take the place of coil and condenser. This is notably so in the "Klystron" of which only the briefest description can be given.

It is necessary to consider first the behaviour of electrons in a tube, exhausted of air and containing a cathode at one end with an anode at the other. Clearly a stream of electrons will pass along the tube at a substantially even rate. Now consider a pair of grids inserted into the electron stream, separated by a very small distance, the grids being fed with high frequency charges from an external oscillator. A high frequency field will exist between the grids, and the electrons on their way to the anode will be influenced, so far as their speeds are concerned, by the charges within the field which are varying from instant to instant.

When the field is at zero point the electron flow will be unaffected and will continue at its original speed but as soon as the charges become negative the electrons just leaving the grids will be accelerated. In the same way, the electrons leaving a positive field will be retarded, so that the stream will now consist of different groups of electrons. After a short space, known in the Klystron as the drift space, the accelerated electrons will have caught up with the retarded electrons, causing a "bunch" of electrons, a lesser number of electrons coming between the first and the following bunch. The grids, therefore, may be known as "bunchers" and if a second pair of grids are introduced into the bunched electron stream after the drift space—these may be called "catchers"—the bunched electrons will clearly influence any charge on the second grids, causing it to vary in some manner directly related to the charges on the bunchers.

The Klystron, developed by R.H. and S.F. Varian, is shown in diagram form in Fig. 32. Whilst it may be used in a number of ways its chief value is as a generator of extremely high frequencies, the figure showing the circuit for this operation.

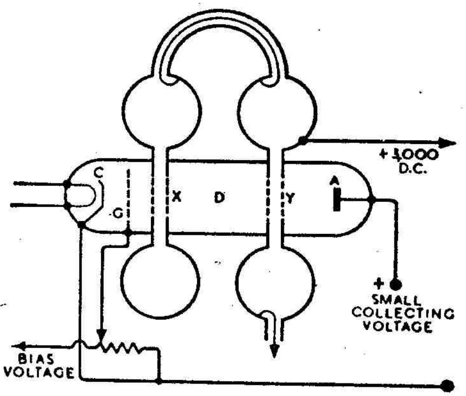

FIG. 32. BASIC KLYSTRON CIRCUIT.

Electrons flow from C, the cathode, and are primarily controlled by a grid, G. X shows the bunching grids which are an integral part of a rhumbatron, the grid structure being very small since the area of each grid is between one and two square centimetres. The grids are separated by only a millimetre or so. Between the first grids and the catchers, Y, also part of a similar rhumbatron, is the drift space, D, the tube ending in a collecting anode A.

The rhumbatrons are connected one to the other by a coaxial cable.

In a suitable oscillating circuit of any type, oscillations are produced when the phase shift round the circuit is either zero or a multiple of 2n, the second condition applying to the Klystron at certain voltages on rhumbatrons. As the voltage rises so do the oscillations gain in strength at each operating potential. The oscillating cycle is maintained by the coupling from the catcher to the buncher via the coaxial cable, the phase shifts produced in this cable, in the drift space and in the inherent buncher to catcher characteristics.

The output of the Klystron is taken, generally by coaxial cable, from the catcher as shown in Fig. 32.

Modulation may be applied to the control grid G,

A simplified Klystron has now been produced, and will be most suitable for amateur operation at frequencies of about 5,000 megacycles, for which it has already been tested in America.

This Klystron, one model being the Sperry 2K43, is known as the Reflex Klystron. Only one resonant chamber is used, this having flexible walls so that it can be tuned to different frequencies. The electron stream is bunched by reason of its passing through the rhumbatron and being reflected back by a negatively charged reflector. The reflector voltage is varied to give a return of the electrons in the correct place. Since frequency varies with the reflector voltage, a simple modulation circuit connected to the reflector plate allows the radio output from the tube to be frequency modulated.

U.H.F. Detectors.

Many simple circuits have been developed for the detection of U.H.F. oscillations, especially for laboratory and experimental use where the oscillator is close at hand. A crystal connected across a sensitive instrument, the assembly being mounted in the centre of a small dipole aerial, has been used for monitoring. A diode connected triode makes an indicator suitable for work with feeders and Lecher wires. Such detectors are shown in Fig. 33.

Another version of the Barkhausen-Kurz detector is shown in Fig. 34 where the reproducer is connected in the anode circuit.

The receivers of Fig. 1 and Fig. 3, adapted for use with Acorn 955 valves and with suitable tuning circuits, however, will be found satisfactory for work on about 1 metre and upwards.

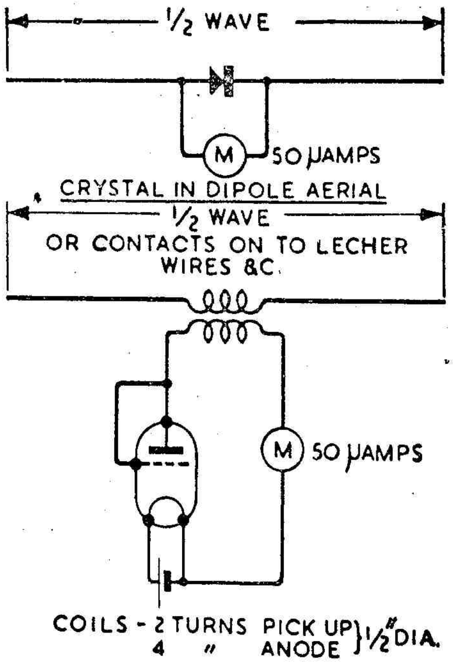

FIG. 33. SIMPLE U.H.F. DETECTORS.

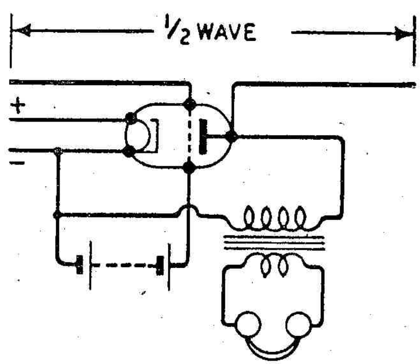

FIG. 34. ADAPTED BARKHAUSEN KURZ OSCILLATOR

Chapter 7.

Frequency Modulation.

No discussion on ultra short wave technique would be complete without some mention of Frequency Modulation, and accordingly an outline of the apparatus is given in this chapter. Since there are at present no commercial F.M. stations in the U.K. and also since the apparatus is far from simple in its construction, circuit values are not given and the circuits shown in the diagrams are of the basic theoretical type.

The main advantages of F.M. are, first, the excellent quality of reception which not only gives perfect sound reproduction but also makes the system suitable for high definition television work. Secondly, the practically complete freedom from interference so characteristic of the system, even in areas where ordinary reception is almost impossible. Moreover it has been found that F.M. stations even when working on the same fundamental frequency, give practically no mutual interference or "breakthrough". Each station will predominate in its own area to the exclusion of others, when these are on the same fundamental frequency.

As has already been noted, the usual method of modulating a radio wave with sound or other intelligence is to affect the shape of the wave's envelope—that is to vary the amplitude of the wave. Thus reception is always on the same frequency, the signals being a function of the strength of the wave.

In the F.M. system the wave or carrier is always at the same amplitude, but is varying in frequency from instant to instant in a manner controlled by the signals to be transmitted. The receiver, therefore, must be sensitive, not to variations in the strength of the carrier but to variations in its frequency. The band over which the receiver can maintain a linear response determines the amount of frequency swing at the transmitting end.

This accounts for the freedom from atmospheric and man-made interference, since almost all such extraneous noises are conveyed by variations in wave amplitude. In the F.M. receiver amplitude variations are carefully eliminated.

So far as the transmitter is concerned, the frequency swing is introduced in the master oscillator stage, so that a crystal controlled oscillator may not, of course, be used. The oscillator, of the self-excited type, is constructed in such a way that a valve or section of a valve carrying the modulation voltages acts as an extra inductance (or capacity). This varies in value with the signal, the variation being impressed on the oscillator output. A similar circuit is used in the swinging oscillator used in conjunction with an oscillograph, as described in Bernard's

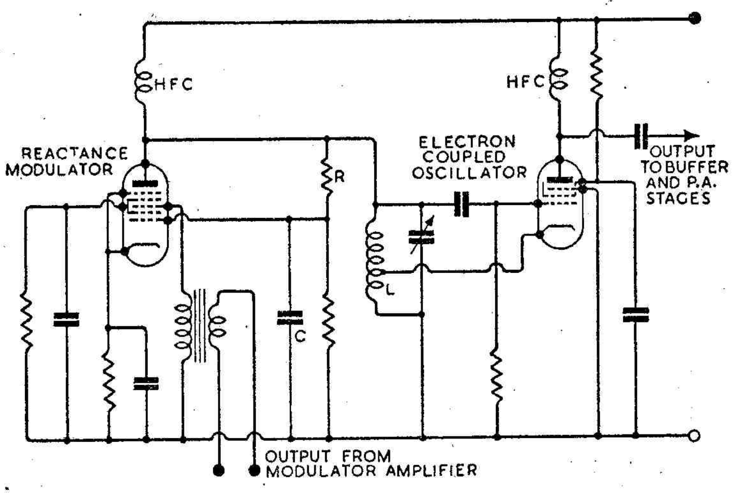

FIG. 35. F.M. TRANSMITTER MODULATOR AND OSCILLATOR.

Cathode Ray Oscilloscope Manual. A typical oscillator circuit is shown in Fig. 35, and is known as a reactance modulated oscillator, the phase shifts across the R.C. network giving the apparent inductive changes across L.

The output from this controlled oscillator is amplified for transmission in the usual way, and frequency doubling stages can be used if desired. However it must be realised in such a case that the total frequency swing will be doubled as well as the main frequency. The total swing or deviation factor is the figure by which the upper signal frequency is multiplied to obtain a suitable band of frequencies to be swept across by the transmitter. Amateur workers consider a deviation ratio of 5 to be suitable, which means that for an audio input of up to 5,000 cycles the frequency swing of the transmitter will be 25,000 cycles.

In the transmitter, as at the receiver, the circuits are adjusted at the mid-point or unmodulated point of operation, and must be capable of passing the band of frequencies to be used.

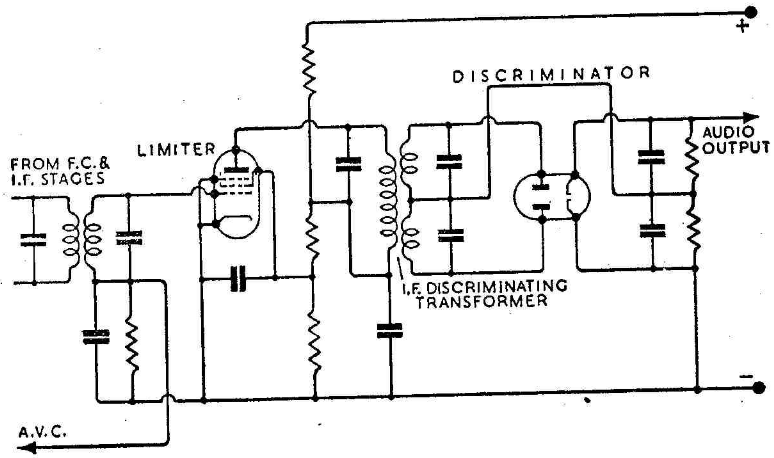

FIG. 36. F.M. RECEIVER LIMITER AND DISCRIMINATOR STAGES.

The F.M. receiver, in its first stages, differs only in the pass band of the R.F. circuits. A superheterodyne is always used for F.M. reception, and the conventional first R.F. and frequency changing stages feed into I.F. amplifiers. These sometimes have their pass bands widened by damping the transformer coils with resistors in parallel with the inductances. The chief difference lies in the demodulating system, since the ordinary diode circuit will not respond to frequency variations.

To avoid any chance of amplitude modulated signals entering the detector circuits the I.F. stages of the receiver feed into a Limiter, whose function is to give a constant output no matter what the strength of the input voltage may be, within working limits The limiter of Fig. 36 performs this action by feeding the valve electrodes with low voltages so that any voltage on the grid over a certain level will cause only the same plate current to flow, the valve being in a saturated condition The device is also used in some more conventional receivers to limit atmospheric "crashes", the adjustment in this case allowing the signal amplitude voltages to pass without attenuation. The limiting action only comes into play when a sudden voltage rise warrants it.

The limited or constant level frequency fluctuations in the F.M. receiver are then passed via another I.F. transformer to the discriminator circuit, where the detecting action is carried out. The secondary of the transformer is in two parts, one tuned to a higher and one to a lower frequency than the transformer primary. The changing frequencies in the primary thus will induce changing voltages in the secondaries—that is, the circuit will discriminate between the extremes of frequency deviation. The amount of deviation possible is ultimately decided in this stage.

The induced voltages are rectified by the diodes and appear across a resistance from which the audio amplifier stages may be fed in the usual manner.