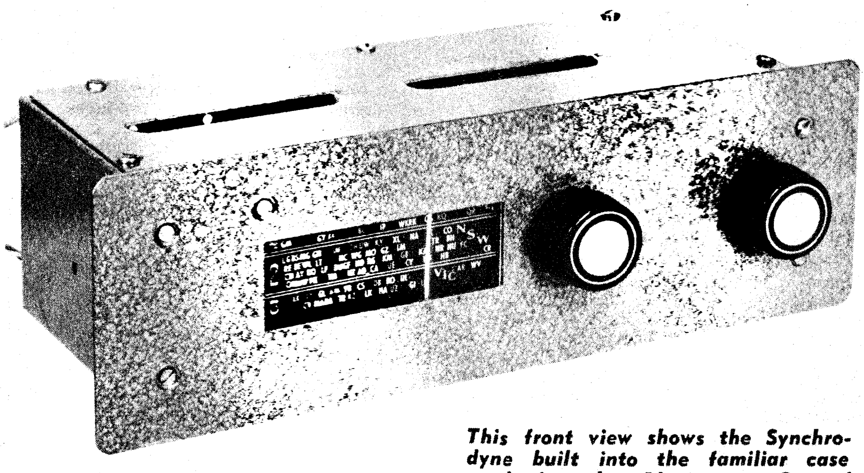
THE SYNCHRODYNE

A.M. BROADCAST RECEPTION WITHOUT SIDEBAND CUTTING

. . . . BUT!

By Ian Pogson

For many years, one of radio's "64-dollar" questions has concerned the Synchrodyne type of receiver. Though credited with the important ability to tune AM broadcast stations without sideband cutting, it has nevertheless remained in obscurity. The following article explains the characteristics and the problems of the Synchrodyne and contains sufficient information for an experimenter to try the circuit for himself.



This front view shows the Synchrodyne built into the familiar case used for the Playmaster Control Units and Program Source. The knob nearest the dial is for tuning; the other knob is the RF gain control.

AS a basic principle of reception, the Synchrodyne circuit dates back to about 1947. From that time onwards, high fidelity enthusiasts have been "discovering" it and asking questions as to why it has not achieved universal acceptance. Such questions make sense, because the Synchrodyne is credited with avoiding the problem which has been the bugbears of nearly all AM tuners to date—loss of treble response through sideband cutting.

Perhaps we should also remark that the Synchrodyne has been credited with a good many other characteristics as well, including complete freedom from 10Kc whistles, "monkey chatter" and other forms of mutual station interference — all this while remaining completely and only receptive to the desired signal!

Recently, a correspondent suggested that, because of its supposed ability to do all these things, a Synchrodyne receiver should be the answer to the present-day problems of the short-wave bands.

On the other side of the ledger we knew of some inherent difficulties of the circuit, the chief one being the strong heterodyne whistle produced as the unit is tuned toward each station. It seemed no more than commonsense, in fact, to assume that the circuit had failed to gain popularity because its practical limitations outweighed its advantages.

So, for many years, we have done no more than given it occasional thought, leaving it to lie among our projects "pending".

A few months ago, however, we were thumbing through a new book on oscillators, wherein the Synchrodyne was mentioned, along with a brief description and a simplified circuit diagram. This time, our interest was really stirred and it was decided to look into it further.

As already indicated, the chief point of interest was in the possibility of receiving local broadcast stations without sideband cutting. In this respect at least, a tuner using the principle might make up for the loss of the FM transmissions.

The circuit referred to consisted of an untuned RF amplifier, a crystal diode balanced modulator and a local oscillator. After studying this circuit for a while, it was reasoned that for purposes of investigation, the RF stage might be dispensed with and the balanced modulator and local oscillator functions combined in a single 6BE6. A pair of headphones could be used in the plate circuit of the 6BE6, with a one-valve Synchrodyne as the end result!

In short order, this arrangement was roughed up and it actually worked. At this stage, however, it was difficult to tell just what order of fidelity was being realised, due to the deficiencies of the headphones. It was also apparent that the RF stage would be necessary, to lift the signals to a more usable level.

The RF stage was duly added and the signals brought up accordingly. The next step was to add an audio amplifier, so that a loudspeaker could be used. A 6BQ5, without further voltage amplification, was driven directly from the plate of the 6BE6. This gave enough loudspeaker volume to assess, for the first time, the worth of the system and the frequency response was such as to spur us on to further efforts.

We had a 10-watt amplifier handy, so this was pressed into service. Our first reaction, after feeding the little Synchrodyne into this amplifier, was that we had not previously heard such quality from AM broadcast stations. There was no gainsaying the fact that the transmissions were very good indeed. From here on, we decided to find out for ourselves, the reasons why this type of receiver had not gained general acceptance. Implicit in this was the challenge to develop a practical tuner and/or receiver for hi-fi reception of local broadcast stations.

The Synchrodyne tuner shown on these pages is the first practical outcome of our experiments. Built, for convenience, into the standard case and chassis for our Playmaster "Program Source" No. 1, it will work with other Playmaster equipment and it will reproduce the full range of transmitted frequencies without significant loss. This much is evident from the response curve plotted from the "External Modulation" terminals of a standard signal generator to the voice coil of the reproducing loudspeaker.

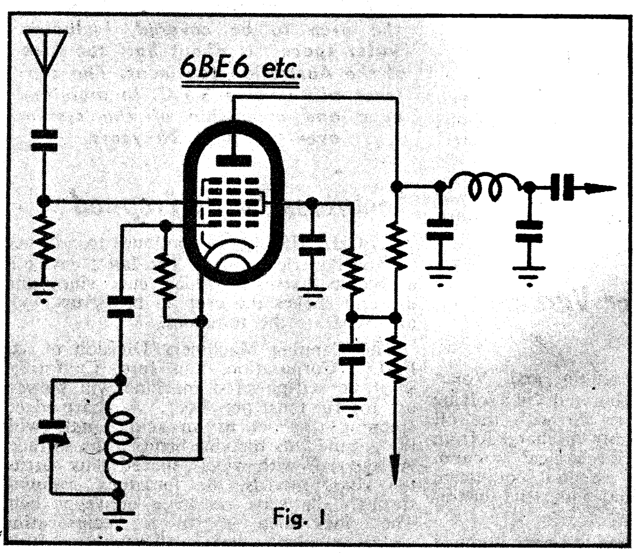


Fig. 1

This simple circuit serves to illustrate the operation of the Synchrodyne, which is explained in the text. Although it would function as it is, it would be of little practical use.

What's more, enough information is given to enable you to build an exact copy, if you want to. Whether you will like the result, however, is another matter.

Just as we had expected, our own experience with the tuner demonstrated why a simple Synchrodyne could only have limited appeal. It separated the actual performance from the false claims and also indicated the complexities which would be involved in turning a rather temperamental device into something which would handle in the same docile fashion as the familiar superhet tuner.

Coincident with these experiments, we looked up available references on the subject and found that several papers had been presented on the subject. It appears that the idea was developed by D. G. Tucker and his staff, at the laboratories of the G.P.O. in London. Dr Tucker published several papers in "Electronic Engineering" in 1947 and 1948. An article by "Cathode Ray" also appeared in "Wireless World" in August, 1948.

In these papers, suggested designs for receivers using the Synchrodyne principle ranged from a very simple version, of the order of the one we present here, to one boasting two RF amplifiers, with RF negative feedback, a ring modulator and a separate oscillator, isolated from the received signal with a cathode follower. It also possessed additional attributes which we will go into later on. This elaborate version was on show at the 1947 Radiolympia in London, where it attracted considerable interest.

The articles referred to contain a wealth of information on the subject and those who want more information than we can give here could well look up the references for themselves.

What is a "Synchrodyne" and how does it work? Already, most of us are familiar with the "Superheterodyne" system. "Hetero" means "different" and "dyne" is a unit of force. Here we have different forces, alias different frequencies which, when brought together in a mixer, give a "super" sonic frequency, better known as the "intermediate" frequency.

The Synchrodyne works on a somewhat similar principle. Where the superhet has a local oscillator which beats with the incoming signal, to give a supersonic or intermediate frequency, the local oscillator of the Synchrodyne is on the same frequency as the incoming signal. The heterodyne product is at audio frequencies, as it is with normal detection.

To gain some idea of how the Synchrodyne functions, refer to figure 1, which shows the system in one of its simplest forms.

Consider first the situation which would exist if the oscillator were not operating.

All signals picked up by the aerial will be fed to grid No. 3, subsequently appearing at the plate, due to normal amplifying action of the valve. If the amplifying action were perfectly linear, the signals would remain at RF, with no demodulation to present a direct audio component in the plate circuit.

Conversely, if the amplifying action were non-linear, some demodulation and intermodulation would occur, producing a mixture of audio components in the plate circuit, in the manner of a chronically unselective receiver.

In point of fact, the Synchrodyne principle relies, for much of its success, upon the preservation of linearity in stages handling the RF signal—except at the one point where intermodulation is supposed to take place. In this statement lies the explanation for an earlier reference to the use of RF amplifiers with RF negative feedback.

Consider that the oscillator section is now made operative. The oscillator voltage on grid No. 1 will vary the amplification of the valve at a rate determined by the frequency of oscillation. This sets up a cyclic state of non-linearity at the same rate. The result is that all the incoming signals will be modulated by the oscillator frequency. We now have appearing at the plate, the oscillator frequency, all the incoming signal frequencies, as well as all the plus and minus frequencies, or beats.

Quite a mixup, to say the least!

For simplicity, consider a special case where the local oscillator has locked to an incoming carrier, on which there is, for the moment, NO MODULATION.

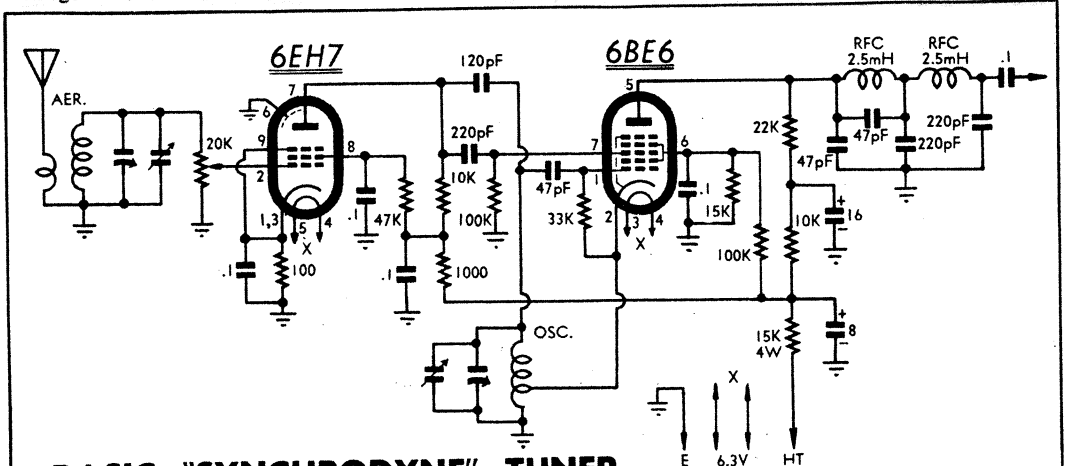
Since there will be no normal sidebands within, say 10Kc of the incoming carrier, there will be no heterodyne resultants within the audio spectrum and no audio signal in the plate circuit of the mixer.

Other carriers and their sidebands, which may be present, will beat with the local oscillator but, because of their separation from the local oscillator in terms of Kc, the resultants they produce will lie in the supersonic region; they can be suppressed readily enough by RF filtering.

The only exception would be the carriers or sidebands from channels immediately adjacent, which might be strong enough to produce a 10Kc whistle or the usual inverted demodulation which goes by the name of "monkey chatter."

With normal modulation on the wanted signal, the sidebands intermodulate with the local oscillator (which is locked to the original carrier) to produce the original audio frequencies.

From the foregoing, it can be seen that the Synchrodyne obtains a basic "selectivity" by virtue of the mixing action. The various received signals are only separated by the fact that the unwanted signals are heterodyned out of audibility. As the audio component is all that is required at the output of the mixer, a low-pass filter is used to get rid of the radio and supersonic frequen-



BASIC "SYNCHRODYNE" TUNER

This circuit is, in our opinion, the simplest practical one of its kind. To ensure correct operation, it would be wise to adhere to the component values given. A sophisticated Synchrodyne tuner would require a great deal more circuitry than the simple version.

PARTS LIST

- 1 Box, with front panel and top and bottom plates.
- 1 Sub-chassis.
- 1 2-gang tuning capacitor (Roblan)
- 1 MSL/48 dial.
- 1 Aerial coil.
- 1 Oscillator coil (see text).
- 2 Trimmer capacitors.
- 1 9-pin socket.
- 1 7-pin socket.
- 2 2.5mH RF Chokes.
- 1 Spring-loaded Plastic Terminal (red).
- 1 Spring-loaded Plastic Terminal (black).

Tagstrips: 1 2-tag; 2 5-tag; 1 10-tag. Hookup wire, coax. cable, screws, nuts, solder, etc.

VALVES

1 6EH7. 1 6BE6.

RESISTORS (½W unless specified)

1 100ohm	1 22K
1 1K	1 33K
2 10K	1 47K
1 15K	2 100K
1 15K 4W	1 20K log. Pot.

CAPACITORS

- 3 47 pF Ceramic or Plastic.
- 1 120 pF Ceramic or Plastic.
- 3 220 pF Ceramic or Plastic.
- 1 .1 mF 25V Ceramic.
- 4 .1 mF 400 V Plastic.
- 1 8 mF 300VW. Electrolytic.
- 1 16 mF 300 VW. Electrolytic.

cies, which could otherwise overload the following audio amplifier.

This looks very interesting on paper but, as we had expected, and as our simple version proved, the principle brings some serious problems in its train.

Undoubtedly, the most objectionable feature of the Synchrodyne is the very loud heterodyne whistle which is produced as the signal is tuned in. It is, in fact, the familiar whistle of an oscillating detector—bad enough in a pair of headphones but intolerable when it happens to be feeding into a husky, hi-fi stereo system!

Measures to overcome the objection include:

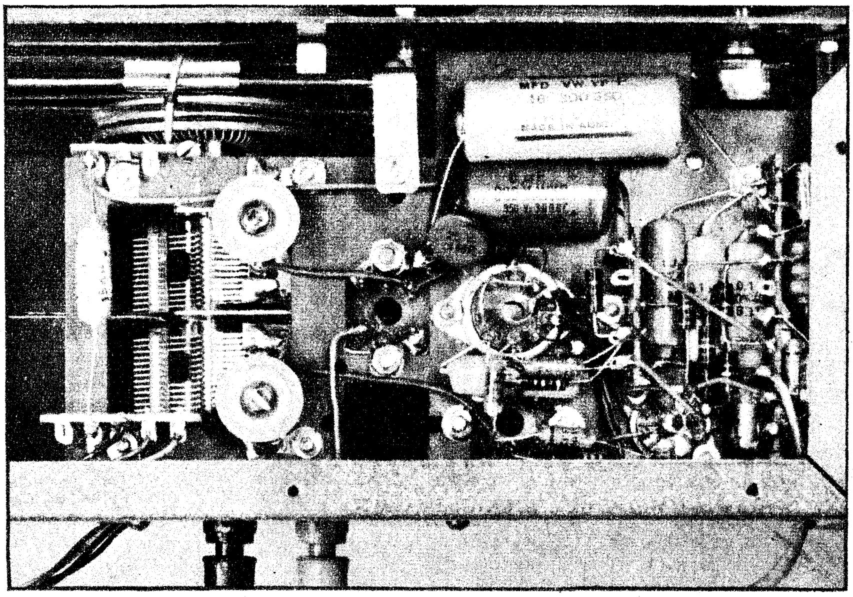
(1) Tuning only with the volume control turned right down;

(2) Resorting to switch-tuned systems comparable with channel selection in a TV receiver.

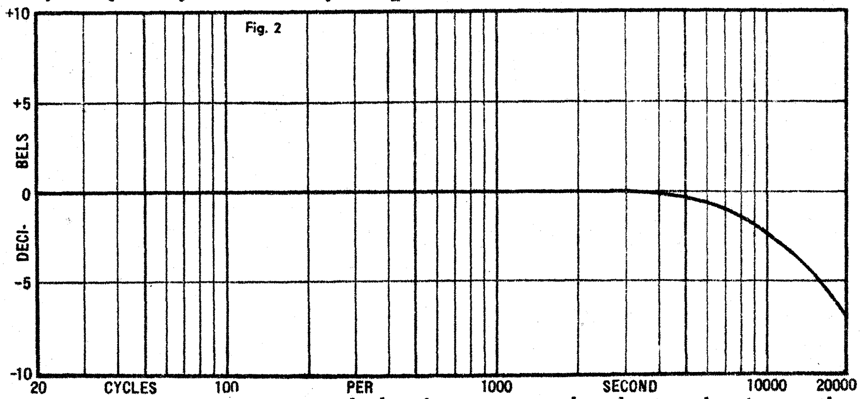
(3) The use of automatic muting systems, involving extra circuitry and, in one typical case, a very special high inductance audio choke.

In a simple version of the Synchrodyne no AGC is available, which results in the different stations being received at different volume levels.

In a switched version, this problem may be partially overcome by using a



The wiring and general component layout may be seen in this underneath view. The components are close together in the corner but no trouble should be experienced, provided a little care is exercised in wiring.



This frequency response curve looks almost too good to be true but is exactly as we measured in our laboratory. The gradual roll-off is due, at least in part, to the RF filter.

preset attenuator for each station. Unfortunately, however, this does not overcome annoying changes in level which can result from changes in line voltage and other variations in power line conditions. This is all too well known by those who can remember the days before AGC was a standard feature of domestic broadcast receivers.

The original author claimed that it should be possible to incorporate AGC into a more elaborate Synchrodyne, though admitting that such a move would not be without some difficulties.

Among the suggestions made, was the use of audio AGC. Another suggestion was to "use a thermistor in the RF path."

Still another idea was to use the DC, which is developed in the output of a crystal diode demodulator, as a control voltage for the RF amplifier(s).

This approach may have possibilities but difficulties could easily arise from the non-linear grid characteristic of variable-mu valves, operating at certain voltage levels and unprotected from powerful unwanted signals by high-Q tuned input circuits.

It may be that modern RF pentodes will exhibit better linearity than earlier types. On the other hand, experience may as easily indicate that this form of gain conrol is impractical and/or that RF stages should have a feedback loop around them to maintain linearity and prevent cross-modulation effects.

Another vital requirement which has only been hinted at so far, is the need to lock the local oscillator with the wanted incoming signal. Here, we have two requirements which are incompatible. On the one hand, a sufficiently high signal voltage is required to lock the oscillator while, on the other, the signal level should be kept low in order to avoid cross-modulation.

In the simple version, reliance has to be placed on critical adjustment of the signal level. With too little signal, sensitivity is lost first; then the oscillator loses synch. and the tuner simply produces a useless heterodyne. With too much signal input, other stations cross-modulate the wanted one.

In a complex version, the difficulties are minimised but—once again—at the expense of extra circuitry.

In common with other wide-band AM tuners, the Synchrodyne is also likely to suffer from 10Kc heterodynes, due to beats with adjacent station carriers. How troublesome the whistles might be depends on various factors, but complete elimination is likely to involve the now familiar whistle filter in the form of a Bridged-T, in conjunction with a cathode follower—another complication.

Our simple version of the Synchrodyne exhibits all the shortcomings which we have just dealt with, to a greater or lesser degree. This is only to be expected, since the design has been reduced to the bare essentials. For those who would like to experiment with this little unit, or if you are prepared to live with the limitations, then have a go by all means. Tuned correctly, it can produce some very nice signals.

If, on the other hand, you want a high-grade receiver for broadcast reception for all the family to use, or you do not live close to the wanted stations, then this simple version is not for you. Should you have a Playmaser Program Source at present, then for goodness sake, don't pull it to pieces to build up this one. Try it out on another chassis.

The question may well be asked at this point, why did you describe such a project anyway? The answer to that one is simple. We have taken the trouble to investigate the characteristics of this method of reception and this is substantially a report of our findings to date. With the information thus gained —although this is not a firm promise— we are hopeful that a more elaborate and generally acceptable unit will be developed in the reasonably near future.

NO EASY WAY

But don't expect it to be simple. As far as we can judge now, there is no such thing as a simple, easy-to-use Synchrodyne. To make it "easy to use" is going to involve a lot of extra circuitry. And, if reasonable performance on other than local stations is going to be sought as well, still more complication is likely to follow.

All this relates to the future, however. For the present, let's take a closer look at the circuit details of the simple Synchrodyne as pictured. Two stages only are involved, a radio frequency amplifier and a mixer-oscillator.

To afford a measure of pre-selection and mimimise cross modulation effects from strong adjacent stations, an ordinary aerial coil is used in the grid circuit of the first stage. The secondary of this coil is tuned by one section of a variable capacitor but is shunted by a 20K potentiometer as well.

The potentiometer performs two functions. The "Q" of the tuned circuit is reduced to a value where its selectivity has very little effect on the sideband response of the system but there is still sufficient selectivity to give some protection from unwanted signals. The potentiometer also functions as a simple gain control, presenting the RF amplifier with no more signal than it needs to operate the mixer and oscillator.

NOT CRITICAL

The valve in this stage could conceivably be almost any RF pentode. We have tried such types as the 6BA6, 6AU6, 6AK5, 9003, 6BX6, 6BY7, 6EJ7 and 6EH7. All these types functioned satisfactorily, with variations in gain, according to the type used. The plate circuit of this stage is aperiodic, with the output capacitively coupled to the folowing stage.

The second stage uses a 6BE6, combining the functions of modulator and oscillator. Signals are fed into grid 3 from the previous stage via a 220 pF capacitor. In addition, a signal for synchronising purposes is fed from the same source, via a 120 pF capacitor, to grid 1 of the oscillator section. There are better ways of doing this but it would be departing from the simple approach.

The oscillator coil is a special one for the job. The requirement is a coil with the same number of turns as the secondary of the aerial coil. As these may not be available over the counter, we give full details how to "roll your own."

The coil we used was honeycomb wound, with two adjacent windings of 75 turns, making 150 turns in all. The cathode tap is made at 15 turns from the start (bottom). One way would be to get a "band-pass" coil, which is similar but has no tap. Unwind 15 turns from the finish and reterminate it. Use the wire thus obtained, to add 15 turns to the bottom of the winding. These turns should be wound as close as possible to the main winding and care must be taken to wind in the same direction as the rest of the coil.

ALTERNATIVE APPROACH

Should a bandpass coil not be available, the secondary of an aerial RF coil may be used. The primary should be stripped before making the tap. The number of turns quoted are as used by RCS but other manufacturers' figures should be much the same. We would like to point out that the amount of feedback should be kept as near as possible to the original.

The screen voltage of the 6BE6 is maintained at quite a low value, by means of the 100K and 15K resistors forming a voltage divider. The 15K 4 watt feed resistor is necessary when the HT supply is taken from a 300 volt source, such as a Playmaster Amplifier. If another voltage source is used, the resistor should be selected to give a voltage of 150, at the position of the 8mF electrolytic capacitor.

As we are primarily interested in the audio component appearing at the plate of the 6BE6, it is not surprising that the circuitry here is reminiscent of audio voltage amplifiers.

Again, although we are only interested in audio frequencies at this point, the fact is that there is a large amount of RF at the frequency of the received signal. This is mainly due to the oscillator and, if left unchecked, would seriously overload the following audio amplifier, with disastrous results. This accounts for the rather elaborate filter at the output.

As mentioned previously, we have built this unit into the same set of metalwork as was specified for the Playmaster Program source, which was published in November, 1959. A power supply has not been built into this model but there is no reason why readers should not do so if desired.

The 2-gang tuning capacitor, dial and aerial coil are mounted in the positions as originally provided. The 6EH7 RF amplifier valve takes the place of the former 6AE8 mixer while the 6BE6 modulator valve makes use of the 6BA6 IF amplifier position.

The new oscillator coil is mounted in the position occupied by the first IF transformer. The two square holes for the oscillator coil and the second IF transformer are left unused. On the front panel, the position provided for the band-width selector is now occupied by the RF sensitivity control.

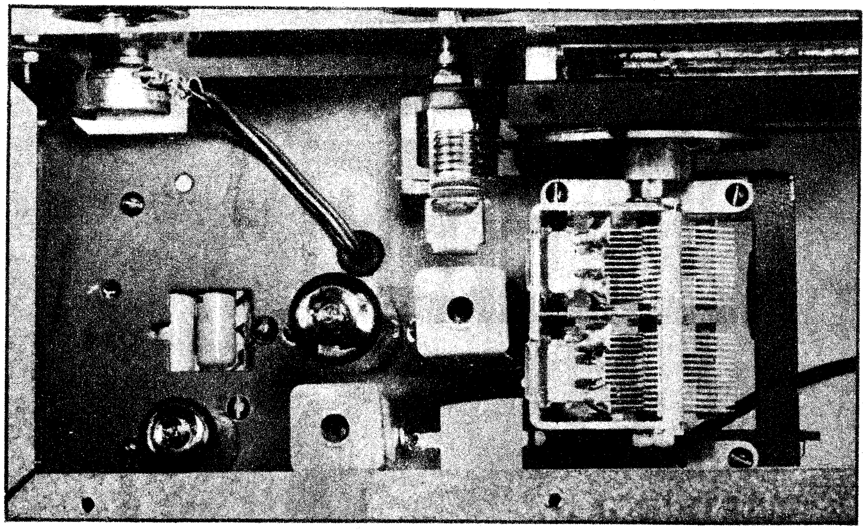
Looking at the underneath view, it can be seen that there is very little spare room after all the components have been grouped around the major items such as coils and valve sockets. However, provided care is taken, no trouble should be experienced in fitting all the components into the available space.

Whilst on the subject of space, a few comments on the RF valve would be in order. Earlier, we stated that quite a number of valves were suitable for this position. In point of fact, any of the 7-pin types would be usable. However, as the hole for the socket in this particular chassis is made for a 9-pin socket, we decided to limit our choice to this field.

A 6BX6 was used for the preliminary tests and proved to be quite satisfactory — until we tried to fit the lid to the case! The valve was much too long. Fortunately, the newer frame grid types are shorter and the 6EH7 went in with about 1/16in to spare. There is a bonus, as this valve gives higher gain than the other.

From a constructional point of view, this unit is fairly straightforward. The dial and tuning capacitor are mounted in the same way as for the Program Source. The coils and valve sockets may also be fitted now. A 5-tagstrip is fixed to an existing hole of an unused IF transformer and another under the rear mounting foot of the gang. A 2-tag also goes under the gang front mounting foot.

The 10-tagstrip which accommodates the RF filter, HT and output points, is conveniently placed near one end as can be seen in the photograph. Before this



The layout of all major components can be clearly seen in this top view. Use has been made of holes in the existing metalwork which accounts for the two unused coil holes in the chassis.

strip is mounted, the two RF chokes must be wired to it. The rest of the wiring only calls for the usual care, with neatness consistent with short leads.

With the wiring completed, the job of alignment may be undertaken. In spite of the apparent simplicity of the tuner, alignment is not quite so easy as may be first imagined. Due to the fact that the grid circuit of the RF amplifier has such a low "Q" and that varying this circuit also has a tendency to "pull" the oscillator, it is not easy to determine the correct adjustments.

This problem can best be overcome by the use of a modulated signal generator and an output meter. After feeding the tuner into a suitable amplifier, with the output meter connected, set the signal generator to 600Kc. Set the dial to this frequency and adjust the slug of the oscillator coil until the oscillator "locks in" with the incoming signal. This point can be recognised as being between the two whistles or heterodynes which will be heard as the signal is tuned across. The RF gain control and the generator output must be adjusted to obtain a suitable signal level.

Before attempting to adjust the slug in the aerial coil, make sure that there is sufficient signal from the generator to lock the oscillator solidly. Now adjust the slug for maximum audio level. Then set the dial to say, 1300Kc. Feed a signal in from the generator at this frequency and adjust the oscillator trimmer. With the same conditions applying as before, adjust the aerial coil trimmer.

It will be necessary to return to the low frequency end of the dial and go through the process again. The high frequency end must also be rechecked and this process repeated until you are satisfied that alignment is correct.

If a signal generator is not available, it will be necessary to compromise and make the best possible use of a suitable station towards each end of the band. Once alignment is completed, an aerial may be connected and the fascinating task of learning how to "drive" it may be started.

Not the least part of this phase of the proceedings, will be the necessity to determine the best amount of aerial to use. This must be decided in conjunction with the operation of the RF gain control. The best setting for this control can be found by advancing it just sufficiently to make the station lock the oscillator reliably. It may be found necessary to readjust the gain control when changing from one station to another.

By the time all this has been achieved, the really good point of the tuner will have become apparent. We refer to the wide frequency range which is available. This was checked in our laboratory, by means of an externally modulated signal generator. A frequency run was taken up to 20Kc and the resulting response curve is shown in fig. 2.

We went to the trouble to check on the transmission characteristics of some broadcasting stations. A spokesman for the A.B.C. transmissions assured us that the frequency response from the studios to the aerial of the transmitter is substantially flat from 40 cycles to 10Kc. It should be pointed out that this range is not always made full use of, particularly in the case of interstate hook-ups. However, after listening to some programs of local origin, we are convinced of the validity of the figures already quoted.