

A Multi-Range Receiver With Four Tuned Circuits

By Robert S. Kruse*

There is a marked tendency in high-frequency receiver design towards single-control tuning of two and more circuits. The receiver described by Mr. Kruse involves true single-control tuning of four circuits, and the trick is successfully accomplished. The receiver has a number of features which can be profitably adopted for amateur use. — EDITOR.

THE amateur receiver with but one tuned circuit seems to be passing, at last, as did the "single circuit" broadcast receiver of evil memory. Two tuned circuits are now accepted as a matter of course, even though one is sometimes accompanied by another control. Logically, and surely, we shall proceed to more tuned circuits, more r.f. gain, and easier operation.

The widespread opinion that such receivers cannot be built to operate with single control at high frequencies has some basis in fact, but is not wholly correct. The single-control receiver with two tuned circuits has indeed reached commercial form for frequencies as high as 33,300 kc. (9 meters), and is in wide amateur use.

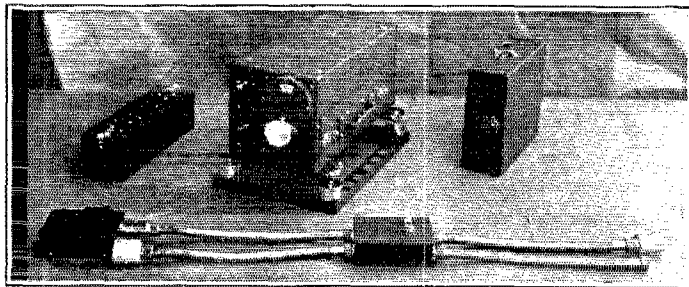
With so definite a tendency in view it is interesting to look ahead toward the future receiver. This need not be done blindly for there has only just appeared a receiver which, though designed for aircraft use, may very well be the forerunner of the amateur receiver of the future. That is our story.

The Stromberg-Carlson Model D Aircraft Receiver operates at frequencies as low as 235 kc. (1276 meters) and as high as 8000 kc. (37.5 meters) with its normal coil equipment, maintaining over this range a very high degree of sensitivity and selectivity much above that found in the usual high-frequency receiver. It is purely single-control, uses but five tubes, makes small demand on the plate supply, and is designed with particular attention to the reduction of noise. The frequency range, incidentally, can be perfectly well extended above 8000 kc. by means of additional coils, not normal to the commercial

set. This has been done at Aircraft Radio Corporation, where the set was designed. Again the performance was greatly superior to that of the usual amateur set.

GENERAL ARRANGEMENT

Since the Model D is primarily meant for use in aircraft, its construction has considered the requirements of that severe service. As may be seen from the photograph, a cushioned mounting is provided for the set, and the inter-connections between the set, the control-head, the junction



THE AIRCRAFT RECEIVER AND ITS ASSOCIATED EQUIPMENT

The receiver is in the center with the spare coil box at its left and the special B battery case at its right. The control box containing the volume control and "off-stand-by-on" switch is at the left end of the assembly in the foreground. The junction box is the affair in the center.

box and the battery box, are run through highly flexible metallic braided hose. This hose provides electrical shielding and mechanical protection. It is obtainable in lengths of 2, 3, 4, 7 and 10 feet and is connected to the various units by means of screw-couplings. This arrangement provides ease of servicing and great flexibility in the placement of parts in various types of ships. A remote tuning control can be supplied, but this has not been shown here, as it is solely of aircraft use, being intended to permit placement of the set in the fuselage at distance as great as 35 feet from the pilot or other operator. One may, however, note that the set cannot be fussy if such an installation is to be practical.

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From other photographs and from the general diagram of Fig. 1 it may be seen that there are 3 stages of straightforward r.f. amplification, a "bias" detector, and one resistance-coupled audio stage. Study of the diagram will show that unusual attention has been paid to the "de-

were to be used primarily for c.w. reception it would be simple to introduce controllable regeneration and self-oscillation. This, however, would be of no advantage whatever for modulated signals.

The antenna used in the plane is a vertical

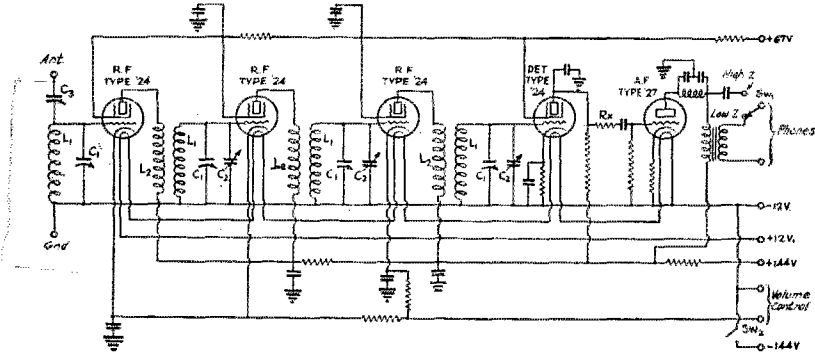


FIG. 1.—THE SCHEMATIC CIRCUIT OF THE RECEIVER

The heaters are connected in series and are supplied with filament current from a 12-volt storage battery. The switch SW_1 is part of the three-position switch in the control box; it is opened in the "stand-by" position, cutting off the "B" supply but leaving the heaters on. The volume control resistor is in the negative "B" lead to the r.f. amplifiers. The inductances L_1 and L_2 are interwound on the plug-in coil forms. Suggestions for their construction are given in a footnote. The condensers C_1 are ganged for single control. The trimmer condensers, C_2 , are integral with the ganged variables and are set by a special screw-driver when the set is adjusted. Bias for the various tubes is obtained by resistors in the cathode circuits.

The resistor R_2 in the coupling circuit between the detector and audio stage is an interesting feature. It has a resistance of about 250,000 ohms and serves to prevent r.f. overloading of the audio tube's grid circuit but does not materially affect audio-frequency coupling. The output is arranged to work into either high-impedance or low-impedance phones, a special output transformer being used for the latter. Specifications for the various resistors and by-pass condensers are not available but should follow usual practice quite closely.

coupling" of different r.f. stages by means of by-pass condensers and de-coupling resistors. As shown, the circuit does not provide for oscillating-detector reception, but this does not mean that the thing is impossible with this sort of a set. Much c.w. reception has been done at Aircraft

metal mast—if one may use that term for a stub only 5 feet high. The pickup is at all times sufficient so that the ever-present background makes a great racket when the sensitivity control is at maximum, even though the ignition system is carefully shielded and the metal parts of the plane well bonded to prevent loose-contact noises. When used at a ground station the set needs no more than a 10-foot antenna; even this is sometimes excessive at quiet places miles from the electrical disturbances of any town.

NOISE LIMITING FEATURES

With such sensitivity the noise problem is of some importance. It is attacked at several points in the set. The usual broadening effect of antenna resistance is avoided because the high sensitivity permits the use of an antenna too small to produce such broadening. Thus there is good preselection of the desired signal, as against noise and interfering signals. The selectivity through the r.f. system as a whole is about that of a very good broadcast receiver with four circuits, when working in that frequency range. The selectivity unavoidably



A COMPLETE SET OF COILS IS PLUGGED IN WITH ONE MOTION

Each coil carries its own shield and the four shields are fastened permanently to the metal strip which serves as a side-plate for the set when the coils are in use or as the cover for the coil box when they are not in service.

Radio Corporation with the set using a separate heterodyne. As in the case of modulated reception, the only limit on reception has been the noise level due to electrical disturbances arriving at the antenna. If, for any reason, the receiver

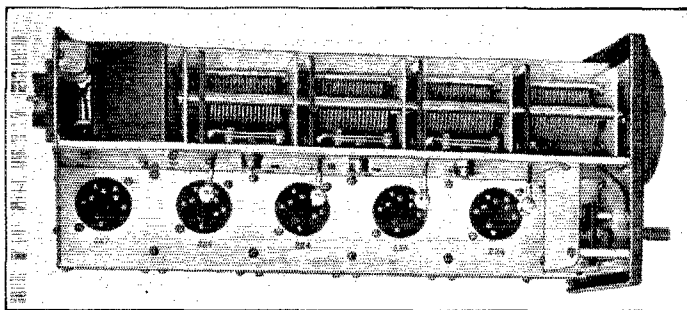
decreases at the higher frequencies but remains much superior to that of sets with fewer tuned circuits—especially to the type of amateur receiver with one lonesome tuned circuit. The noise which reaches the detector is, of course, passed through to the audio tube. At this point, it encounters an audio filter which cuts off all high-pitched noises, passing only audio frequencies below 3000 cycles. A very large part of the energy of static and of man-made electrical noises, as well as the notes of off-tune c.w. stations, lie above that pitch. These things are severely attenuated without the undesirable features of a peaked audio transformer which reduces noise but spoils voice reception for the phone man and afflicts the c.w. man with a wearisome and unchangeable fixed pitch at which all signals must be heard. Another feature of particular interest to the headset man is the output device. This keeps the "cans" free from the plate supply voltage and also permits the use of either normal high-impedance phones or the new 120-ohm phones which weigh but half as much as the old sort and are thinner, flatter and far more comfortable.

The use of heater-type tubes through the entire system is in itself a noise-eliminating feature in the plane where a battery-charging generator is operating during reception. On the ground this is of no great consequence but may be pointed to as offering a useful suggestion for future sets with a.c. supply.

Anyone who has used shielded high-frequency receivers must be aware of the exceedingly irritating performance given by a set with various parts of the case in uncertain contact, as for instance, in the tongue-and-groove aluminum cases of several years ago. The noises and jumpy reception of such a set are bad enough on the ground and would, of course, be intolerable during the vibration of a plane. All contacts between parts of the case are, therefore, either screwed or riveted permanently or confined to points where good pressure-contact (spring) can be maintained. Thus the removable tube-compartment cover and the removable panel carrying the coil-gang are felt lined and make no contact with the case except at the retaining pegs, where positive spring contact is made by the latches holding the part to these pegs. These latches, incidentally, are in themselves something of an innovation after so many years of sets with loose screws, thumbnuts, snaps, turn-buttons and springs—

not one of which ever contrived to combine ease of removal with positive action and silent electrical contact.

One other anti-noise provision must not be overlooked. This is a 3-position switch providing points for "off," "on" and "stand-by." The third of these is used during transmission and leaves the filaments hot while cutting the r.f. cathode returns free from ground. The shielding and filtering of the set is so thorough that this leaves the detector and audio stage almost com-



THE TOP OF THE RECEIVER'S WORKS

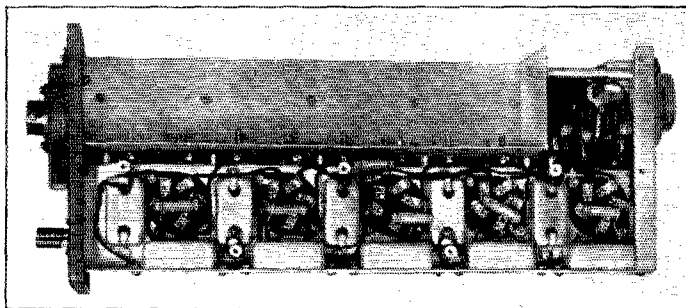
The control-grid connections between the tubes and the tuning condensers are extremely short and pass through the shielding at right angles. The mechanical construction is obviously rigid. The four condenser rotors are all on one shaft. One end-plate of each condenser is metal and the other is high-grade bakelite, the intervening metal end-plates serving as baffles. The coil compartment is immediately below the condenser gang. The antenna trimmer condenser is in the small compartment to the right of the tube sockets and the auto apparatus is at the left end of the condenser gang. The battery input and audio output multiple plug is mounted on the left end and the tuning control on the right end of the set.

pletely silent, even in the presence of a transmitter in the same room.

THE FOUR-GANG CONDENSER

To gang four tuned circuits successfully the stray capacities must be reduced as far as possible and made as nearly equal as is practical. In addition to this, the operation of the set, including coil changes, should not vary any capacity in the set, except the tuning capacity. This last ideal is not altogether attainable since it is necessary to change the r.f. cathode-return resistance in controlling volume, also to tolerate a gradual decrease of plate potential (if dry cell plate supply is used), together with some small unavoidable mechanical irregularities in the gang itself. Since these things all produce small capacity alterations in one or several stages, one may not work at too low a value of tuning capacity. The gangs in this case have a capacity of 150 $\mu\text{fd.}$ per section and are shunted by an air-dielectric trimmer of 25 microfarads capacity, except for the antenna-input circuit which uses a trimmer of twice this capacity in series with the antenna capacity. A fairly high minimum capacity is thus assured and minor variations are decreased in importance.

To any possible objection of such a high C/L ratio one may reply that the set has sensitivity in excess of any need, and one might as well trade some of it in for the exceedingly valuable feature of single control, which would not otherwise be practicable. The design of both the air-dielectric trimmers and the tuning gang itself has been aimed at very low loss and extreme mechanical rigidity. Thus, though there is a fairly high minimum



BENEATH THE CHASSIS

By-pass condensers, resistors and supply wiring are judiciously placed.

capacity, it is not through a high-loss material. The condenser gang has rotors and stators of the familiar soldered-plate type. It is very rigid because of the small size of the plates and the use of 5/16" steel rods for the lengthwise members of the frame. Cadmium plating is used on rotor and stator to prevent corrosion of the conducting surface under conditions of high humidity. The air trimmers are simply small variable condensers of a substantial sort with their shafts slotted for screwdriver setting. After setting they are sealed with wax and need no further attention. The antenna trimmer may be reached through an opening in the case as there is occasionally some reason for antenna alteration and a realignment at this point.

THE COILS

The set, although having many coils, is altogether free from the usual bunch of loose coils. As may be seen from one of the photographs, all four coils of a set are mounted on a panel with a handle. This panel acts as a cover for the coil box, or closes the side of the set when coils are inserted in it. The thing is done with one motion and with less effort than is required for some single coils. This is due to nice construction and to the use of spring-contact plugs of the familiar "spring banana" type.¹

Each coil carries its own shield with it, which at once affords protection and absolutely assures that the coil will be at the same distance from its shield and therefore will have the same tuning range. The possibility of repairing the coil or

replacing a plug is provided for by making the coil shields sectional with the cover secured to the panel or base and the shallow can bottom carrying the coil, which is removable by means of a bayonet catch released when the can bottom is turned slightly. One of the photographs shows a coil removed from its can. From this picture and the one showing a set of coils one may see the construction. The coil form is of R-29 low-loss bakelite, moulded into a smooth cylinder with a flange at one end to carry the terminals. Threads are machined into the form for carrying the windings. The flange does not carry the plugs in the familiar manner but instead carries the jacks or sockets. The plugs are inside the set where they will not be bent over by accident. The primary of each r.f. coil is "inter-wound" with the secondary, in other words, the primary turns lie between the secondary turns.²

Each coil set gives a tuning range of approximately 2 to 1, in terms of wavelength. The familiar objection to such a range is not substantiated with a high-gain set. In order to understand this one must recall how exceedingly hard it was to "juggle" a distant broadcast station into tune with the early broadcast receivers and how much easier it is to do the same thing with a modern high-gain receiver of enormously greater selectivity.

SPECIAL FEATURES

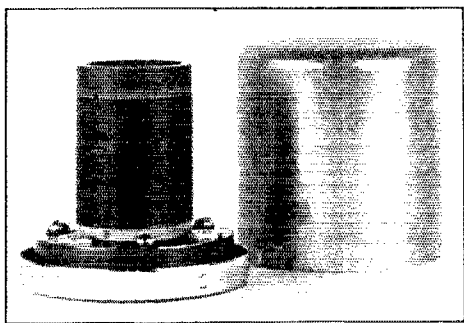
The battery drain of the receiver is surprisingly modest, being about 7 to 12 milliamperes (depending on the setting of the volume control) at 144 volts on the plates and 67 volts on the screens. The odd voltages are due to the use of a special compact battery (Eveready Type 769 Aircraft) but are not exceedingly critical, as is shown by the continuance of good performance during a long battery life. When connected as shown, the filament circuit is adapted to use at 12 volts (the rating of the common aircraft storage battery) and the drain is accordingly that of a single filament, 1.75 amperes.

The story is not complete without some mention of features of aircraft interest. Among these is the flexibility that has been referred to. The

¹ The General Radio plugs familiarly known to amateurs are of this type. — EDITION.

² This is the same type of coil construction used in the new National single-control high-frequency receiver. The plate coil of a preceding stage is wound between the turns of the grid coil of the following stage (or detector). The number of plate turns being 66% to 100% the number of grid turns. The specifications for the amateur bands will depend on the capacity range of the tuning condenser as well as the minimum capacity across the coil. The figures given for the various bands in articles describing other tuned r.f. receivers can be used as a basis. — EDITION.

set can be located almost anywhere in the ship and may be set on its cradle or hung from it by one simple change. Coil changes are not normally made in flight, but where this is to be done the set may be located in an accessible place and coils can be changed by the pilot, even when he has no one to whom he may turn over the controls. This has been done repeatedly. The junction box is simply a place into which go cables from the



ONE OF THE COILS WITH ITS SHIELD

Plugs in the receiver fit into the jacks on the flange at the bottom of the R-29 coil form. The grid coil is space wound with enameled wire and the plate coil is wound between turns of the grid coil.

"A" and "B" battery and the switch box, and out of which goes a single cable leading to the set. The junction box must be near the set; the other units may be located at convenience, the actual tuning control being intentionally separated from everything (including volume control and off-on switch) which need not be visible. Thus even the most cramped plane may be fitted out with a set.

Fine tuning by means of a remote mechanical control may seem dubious. It is actually quite workable. The drive is through a flexible shaft of any necessary length up to 35 feet. At one end of the shaft is a small reduction gear which goes into the place of the tuning knob shown in the set photograph in this paper. The shaft turns a great many times while the gang tuning condenser is moving once across its range. Thus the wind-up or slack (which is not altogether avoidable in even a very good flexible shaft) is of little importance. On the other end of the shaft is other gearing — for it is not practical for the operator to turn a knob several hundred times to "go across the scale." Actually he turns a small crank 30 times to traverse the tuning range. At the same time a small dial on the tuning unit makes $\frac{3}{4}$ of a turn. This dial has a 100-division scale, distributed over 270 degrees. The entire machinery, though it sounds rather fearsome, is easier to tune than most broadcast receiver controls — and smoother in the bargain. When direct control is used, as shown here, the control is that of a normal good direct-drive micro-dial.

Other things that are not visible in the photographs and rather tiresome to detail may be mentioned in brief. They are the care in dust and moisture proofing by means of gaskets, the mechanical solidity and the extreme accessibility for repairs. The last may be better appreciated by examination of the photograph showing the by-pass condensers and small resistors under the tube shelf. The connections between the shielded metallic conduit and the various units have been spoken of as being made by means of screw collars. This is correct only as applied to the junction box and battery box. The other connections — set, dynamotor and control head — are by means of armored multi-plugs which are retained by means of a spring catch when in place but may be released by thumb pressure.

The dynamotor just mentioned is a small affair which mounts on a hollow base containing the filter for the plate current supplied by the dynamotor. Whether dry battery or dynamotor be used depends on the preference of the aircraft owner.

The utility of a multi-range high sensitivity set that is not cranky in tuning is manifest enough in aircraft work. "Range" signals — radio beacons — operate on high frequencies where not a great deal else save occasional weather information is to be found. For entertainment of passengers, handling of message traffic, or two-way telephone additional frequency ranges are essential, although hitherto aircraft have had to be content without this utility, for it is even less practical to manipulate four separate coils into their respective sockets on a plane than in a land station.

Editorials

(Continued from page 8)

And, it seems to us, real progress has been made. We would like to urge upon those who are displeased a sober realization of the fact that A.R.R.L. decisions must be made on the plan of the greatest apparent good to the greatest number, and the further realization that the plan of government is bound to work out satisfactorily if one is willing to accept the idea of majority control on which A.R.R.L. is founded. When members do not agree with policies, their remedy is to change the policy-makers if they can, and admit they're wrong if they can't. Half of the A.R.R.L. divisions are holding elections this autumn. The new directors should be truly representative of majority sentiment in their divisions on all major amateur questions. Right now is your constitutional opportunity to see that this condition is satisfied, and it's nothing short of a bounden duty that you see that it is.

K. B. W.