

PEAK EFFICIENCY DESIGN ON THE SHORT WAVES

Engineering a Universal
A C & D C Receiver
Especially Designed for
Amateur Band Reception

by
James Millen, M.E.

Price 10 Cents



WE ARE indebted to QST Magazine for permission to republish much of the material contained in this Second Edition, describing the 1933 SW-3 receiver.

This is one of a series of pamphlets concerned with outstanding developments in the field of transmitting, high-frequency and broadcast receivers, frequency measuring apparatus and other equipment of interest to the radio and communications engineer.

James Millen

THE NATIONAL COMPANY



Malden, Mass.

U. S. A.

Copyright 1933

Peak Efficiency Design on the Short Waves

Engineering a Universal AC & DC Receiver Especially Designed for Amateur Band Reception

By James Millen, M.E.

THE truly modern short wave receiver represents an advance in engineering design over the moving tickler regenerator of a decade ago comparable with the superiority of the 1933 broadcast receiver with its quiet a-c, perfected radio and audio systems, over its progenitor of that technically distant era. The short wave engineer has partaken of long wave progress in the improvement of audio frequency and power circuits and in the development of tubes, notably the types 58, 36 and 37, which contribute to quiet and stable operation and, in carefully engineered circuits, permit real radio frequency gain even in the region of megacycles! Simultaneously, the short wave engineer had his own peculiar problems to solve, involving the successful ganging of very high frequency circuits, the development of satisfactory shielding, the reduction of stray coupling effects through the progressive design of more and more efficient choke coils and the segregation of circuits, the perfection of volume and regeneration control systems, and the conservation of high frequency energy through the invention of practically no-loss insulating materials.

It is the purpose of this article to describe a receiver — the 1933 model of the famous SW-3 series — in which the successful solutions to all these considerations have been embodied. In addition to its peak efficiency performance on all short wave lengths, its peculiar adaptability to either a-c, battery or intermediate operation (combining battery and line-power in conformation with individual requirements) recommends the SW-3 to the discriminating amateur.

Battery vs. A-C Operation

Although a little over two years ago a-c operation of an amateur-band receiver was considered

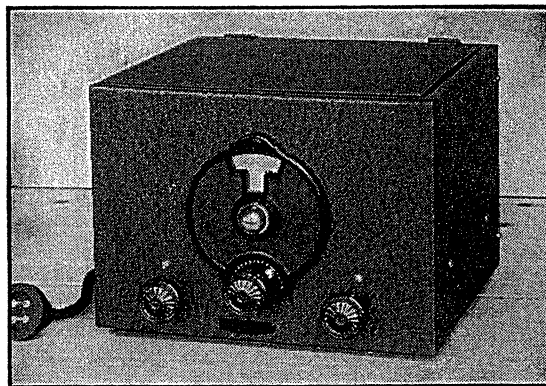
rather impractical by the amateur fraternity, the readily recognized superiority of alternating current tubes over the battery type resulted in such an accelerated development of the a-c receiver that it was not long before the problems of a-c operation were well mastered and the solutions applied to short wave design.

In recent months, increasing numbers of experienced operators have been switching to the use of combination a-c and battery operated receivers, and additional facts concerning their operation have been determined. It is well known that unless an unusually high quality power-pack is employed for the completely a-c operated high-frequency receiver, it is generally found that the combination of a-c filament heating and battery plate supply results in steadier reception when receiving weak cw signals with an oscillating detector. This may possibly be due to

the isolation of the two sources of power supply, or, perhaps, to the elimination of fluctuations in the plate supply voltage caused by minor variations in the line voltage or poor power unit design. Regardless of the exact reason, it must be admitted that battery plate supply is an improvement under some receiving conditions unless the really high grade pack especially designed for high frequency receiver operation is employed.

The life of the "B" batteries will be long, with the usual few milli-

amperes drain demanded by a three-tube set, and the first cost of the filament transformer and 135-volt block of batteries will be considerably lower than that of an efficient power supply designed for satisfactory high-frequency receiver work. There is also another advantage to the use of "B" battery plate supply — namely the elimination of the regeneration-control "detuning effect" almost invariably encountered in com-



SINGLE-CONTROL TUNING OF TWO TUNED CIRCUITS

Band spreading, calibrated volume control, complete shielding and adaptability to either a-c. or battery operation are the salient features of this receiver. The "set and forget" antenna trimmer control is at the left and the regeneration control at the right, with the operating edge of the calibrated volume control disc immediately below the main tuning dial.

pletely a-c operated ham receivers using improperly designed power packs. It is probably the superior regulation characteristic of "B" batteries or high quality pack that overcomes the trouble. In any event, the combination a-c filament supply "B" battery plate supply type of operation seems to be as free from such trouble as when the receiver is entirely battery operated.

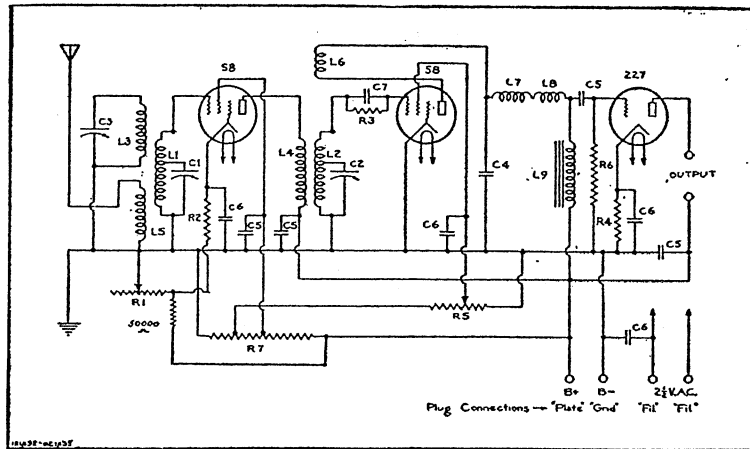


FIGURE 1 — CIRCUIT DIAGRAM OF THE ACSW-3

This receiver employs only a-c tubes, as indicated, and should be selected for complete a-c operation, or for partial a-c operation (using plate batteries) where a 2.5 a-c heater potential will always be available. The circuit constants are as follows —

- L₁, L₂, L₃, L₄, L₅ and L₆ — R.F. Transformers.
- L₇ — No. 100 Ultra High Frequency R.F. Choke.
- L₈ — No. 92 Low Radio Frequency Choke.
- L₉ — 700 Henry Choke — Part of S-101 Audio Coupler.
- C₁ and C₂ — Ganged S.F.L. 270° Tuning Condensers with isolated rotors. 90- μ f per section.
- C₃ — Midget Type Trimmer Condenser — 50- μ f.
- C₄ — 250- μ f mica by-pass condenser.
- C₅ — .01- μ f non-inductive mica fixed condensers.
- C₆ — .5- μ f non-inductive paper by-pass condenser.
- C₇ — 100- μ f small mica grid condenser. Incorporated in Detector R.F. transformer.
- R₁ — 10,000 ohm potentiometer — special taper — used as gain control.
- R₂ — 300 ohm cathode resistor, 2 watt type.
- R₃ — 5 megohm detector grid leak.
- R₄ — 2000 ohm cathode resistor, 2 watt type.
- R₅ — 50,000 ohm potentiometer for regeneration control.
- R₆ — 250,000 ohm audio grid resistor — part of S-101 Coupler.
- R₇ — Voltage Divider-total resistance 12,000 ohms.

For complete battery operation the 6-volt d-c heater type tubes are far superior to any others previously available for such work. Gone are all the noises, microphonics, and other such troubles formerly associated with the use of battery tubes. Also, the heater being designed for 6-volt operation, restores to use the storage battery or "A" eliminator generally to be found in every amateur station. In the case of the 3-tube receiver described herewith, the total current consumption at six volts is under one ampere. Employing the new heater-type battery tubes, it is possible to design a battery receiver of similar characteristics to the a-c models. Thus the amateur in the rural districts, as well as those on exploration parties, expeditions, etc., may have essentially the same type of set as their brother operators located in the a-c districts.

General Design

In a receiver designed with the peculiar requirements of amateur operation in mind, there is little necessity for audio amplification of loud-speaker magnitude. The concentration desirable for communication reception, particularly of weak signals through interference and QRN, is achieved with less effort when ear 'phones are used — a general practice in amateur and commercial stations. The power amplifying stage has therefore been omitted in the design of the SW-3.

This omission is still further justified in consideration of the actual gain secured in the radio frequency circuit, even at 30 mc, in consequence of the new tubes and highly efficient r-f design to which reference has already been made. The high amplification factor, high transconductance and the plate impedance characterizing the new tubes have enabled the engineer to achieve a degree of sensitivity and selectivity that have heretofore been little more than experimental ideals. The use of these tubes has necessitated the redesign of the plug-in inductors in the antenna-radio-frequency and detector circuits.

The tubes employed as indicated in the wiring diagrams (Figures 1 and 2) function, from left to right, as radio-frequency amplifier, beat-frequency-oscillator-detector and one stage audio amplifier. This arrangement is comparable in many ways to the more elaborate short wave superheterodyne receivers, and has the advantage of a definitely better signal to noise ratio.

Aside from the gain achieved in the audio frequency circuit, this tube also serves as a very essential coupling medium between the output of the detector and the headphones (or additional amplification if employed). In this function, it promotes smooth regeneration, freedom from fringe howl and back-lash, and, with other elements in the circuit, eliminates the feedback from the 'phone cord to the input circuit of the receiver.

Shielding

The required stability of a communications short wave circuit presents special problems in view of the peculiar characteristics of very high

frequencies and the maintenance of a stable oscillating condition during beat-note reception. A large part of the burden of stability is placed on the shielding — which must perform a double function in providing adequate circuit isolation with the minimum reduction of high radio-frequency efficiency.

While it would seem that the single stage of r.f. and regenerative detector type of circuit is about as simple an arrangement to build as can be imagined, such has been found far from true where more than mediocre performance is demanded. For instance, if inadequately shielded, the r-f tube will oscillate whenever the detector regeneration control is advanced. This condition exists to a surprising extent in both homemade and commercial receivers in use today. Such receivers are tolerated, it would seem, simply because the owners have never operated a receiver employing the same circuit properly shielded. There just isn't any comparison.

The mere fact that the r-f stage is apparently stable when the detector is approaching an oscillating condition, is not necessarily an indication of perfect shielding, as interlocking still may be present to an obnoxious degree.

Consideration of the receiver being described will demonstrate that there is far more to shielding than the mere boxing off of the different parts of the circuit. Offhand, the arrangement shown in Figure 3A would appear satisfactory. However, this seemingly ideal arrangement, with the coils, tubes and condensers of the two circuits completely shielded from each other, is far from perfect. It was found that with a watertight joint between the shield and the base there was no oscillation trouble with the r-f amplifier, although there was an annoying amount of interlocking. As soon as the chassis was placed in a metal cabinet, however, and the cover closed, the r-f stage oscillated violently!

Next tried was the arrangement shown at B in Figure 3, with even less satisfactory results. Furthermore, the lack of symmetry of the shielding made it very difficult to gang the r-f and detector tuning condensers.

The next experiment comprised the shielding system shown at C in Figure 3. This arrangement worked fairly well in comparison with its predecessors, but here, too, there was still excessive interaction. The compartments were probably too large, for the isolating effect of the coil compartments decreases very rapidly as the

compartment size increases. Another disadvantage of this arrangement was the requirement of tube shields. There was, however, no perceptible change in the shielding effect when the chassis was placed in a metal cabinet.

With the experience gained with models A, B and C, we arrive at the arrangement illustrated at D. Here the compartments are small enough

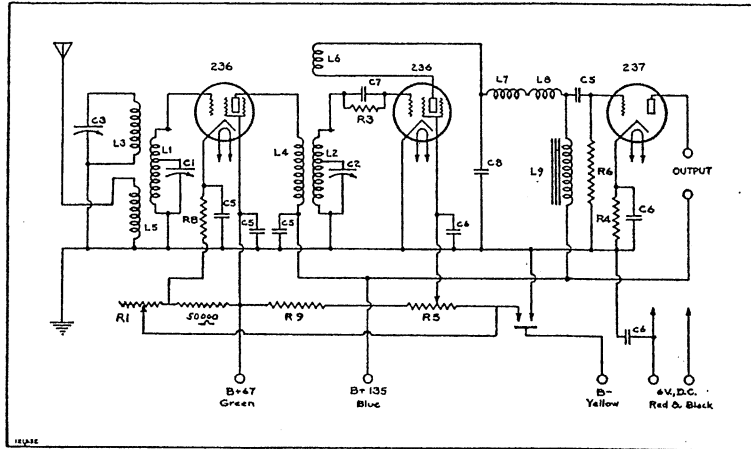


FIGURE 2 — CIRCUIT DIAGRAM OF THE DCSW-3

This is the combination circuit which should always be selected when battery operation may be required. It can, however, readily be converted to a-c operation using the standard 235 and 227 tubes. The circuit constants are identical with those indicated in Figure 1, with the following exceptions —

R_8 — 350 ohm resistor.

R_9 — 20,000 ohm 2-watt type resistor.

SW — Regeneration control and cathode circuit switch.

to shield properly, and yet large enough not to increase the coil losses appreciably. Furthermore, there is no common partition between the coil compartments as exists in designs A and B, which, in all probability, was responsible for the "cover" effect. The r-f tube shield was found essential in order to shield the plate lead from the coil and prevent oscillation.

In the model finally adopted in the SW-3, it was found advantageous to make the vertical parts of the shielding integral with the metal cabinet rather than to weld them directly to the chassis. It is also desirable to insulate the vertical parts of the shielding compartments from the chassis itself with a $\frac{1}{8}$ " air gap and to weld them to the sides of the metal cabinet. The chassis, in turn, is grounded to the cabinet by mounting screws on each side. Such an arrangement completed the shielding job by reducing interlocking to a negligible degree.

A further indication of the trouble to be experienced in attempting to use a common partition between the coils in a shortwave receiver is illustrated at E and F in Figure 3. This problem was recently encountered in the design of another receiver employing the same circuit. The separate compartments completely eliminated the r-f oscillation and interlocking difficulties.