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QST Issue: Oct 1938
Title: A Low-Cost Single-Signal Receiver
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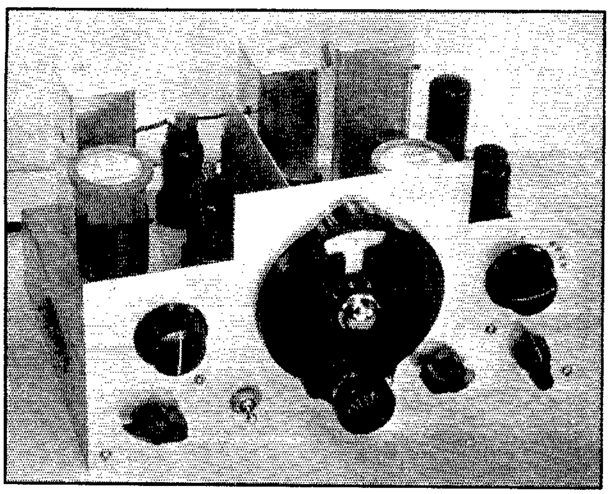
A Low-Cost Single-Signal Receiver

Double Regeneration for I.F. Selectivity and Image Reduction

By George Grammer,* W1DF

THERE is no doubt that with amateur activity at its present height something considerably better than the t.r.f. receiver is not only desirable but essential. But recognition of that self-evident fact does not give material aid to the fellow with a t.r.f. pocketbook. Something more concrete than sympathy is needed—to wit, suggestions for what to do about it. We propose to offer some herein, in the form of a description of a superhet which will do a real single-signal job, but which costs little if any more than the average t.r.f. set—maybe less. Figures prove the case, and we rest ours on the fact that the receiver pictured here can be built for $21, plus approximately $4.50 for the six tubes used in it. It is a ham-band outfit, using plug-in coils adjusted so that each band is spread over practically the whole dial range. What you get out of it depends to some extent on how intelligently you use it—but then, that is also true of high-priced receivers. It is quite easy to build and put into operation, with only one original adjustment which requires more than ordinary care.



THIS SIX-TUBE S.S. RECEIVER CAN BE BUILT FOR ABOUT TWENTY-FIVE DOLLARS, WITH TUBES

A regenerative i.f. stage gives single-signal selectivity; a regenerative mixer is used to provide good signal-to-image ratio. Power supply requirements are 2.1 amperes at 6.3 volts, and 60 milliamperes d.c. at 200–250 volts, for loud-speaker operation.

The circuit, shown in Fig. 1, will not be hard to follow by anyone having an understanding of the operation of a superhet receiver. The mixer, a 6L7, is coupled to the antenna. To reduce image response and provide additional gain, this stage is made regenerative. The oscillator is 6J5 triode, one of the most satisfactory types for this purpose. There is a single i.f. stage, using a 6K7 and iron-core transformers. The second detector is a 6C5 operated as a plate rectifier to handle large signals and to provide good headphone output; this type of operation, incidentally, does not load the i.f. transformer and hence better overall selectivity results than when a diode detector is used. The audio output tube is a 6F6. A 6C5 beat oscillator completes the tube complement. Metal tubes were used throughout because they are self-shielding and thus eliminate the need for extra tube shields. Although not indicated on the circuit diagram, the i.f. amplifier is made regenerative by a very simple method to give the single-signal effect.

Taking the circuit features individually, the mixer stage uses the familiar tickler circuit to obtain regeneration. This method was used in preference to the popular cathode-tap arrangement for three reasons: First, it is much easier to change the number of turns on a separate coil in making preliminary adjustments than it is to move a tap; second, the possibility of hum, always likely to be present in regenerative circuits using 6-volt tubes, is lessened by having the cathode at ground potential for r.f.; third, with the cathode grounded it is less likely that any oscillator voltage will appear in the mixer grid circuit. The appearance of oscillator voltage on the No. 1 grid of the mixer is not only undesirable from the standpoint of tube performance, but also, since in this case the mixer works directly from the antenna, is likely to bring in unwanted signals. This is particularly so on the lower-frequency bands, where high-frequency commercial signals can be picked up on oscillator harmonics.

To avoid constructional complications, the mixer tuning is not ganged with the oscillator.

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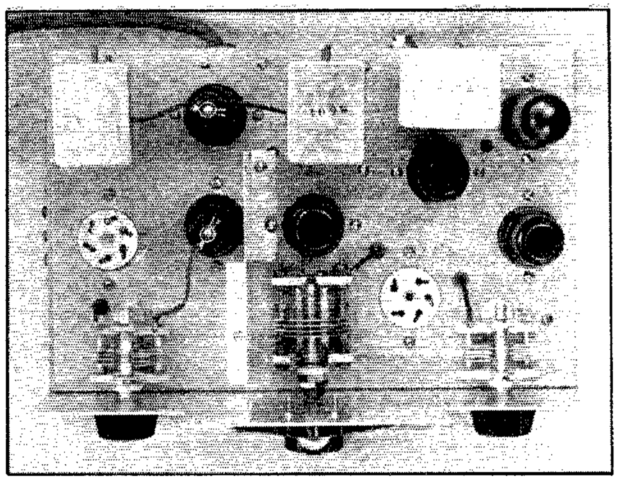
Although this might seem a disadvantage, in that the two circuits must be tuned separately, in practice it has not turned out to be so. In fact, the mixer tuning condenser, C_1, makes a quite effective volume control, and for c.w. reception in particular its use in this fashion is quite advantageous. The regeneration control is a variable resistor, R_2, in series with the 6L7 cathode resistor.

In the high-frequency oscillator the tickler circuit again is used, the reason being to keep the cathode at ground potential to reduce hum. Our previous experience with 6-volt oscillators using the cathode-tap circuit has been none too good—all of them were only too prone to turn "r.a.c." on 14 Mc. and practically refused under any circumstances to be "d.c." on 28 Mc. Results so far with this receiver have justified grounding the cathode. Band-spread is by the usual tap method, C_3 being the tuning condenser and C_2 the band-setting trimmer. The oscillator grid is coupled to the No. 3 grid of the 6L7 through a small trimmer condenser, C_5.



THE TUBES AND MOST R.F. COMPONENTS ARE PLAINLY SHOW IN THIS PLAN VIEW

The location of various parts is discussed in the text. The i.f. transformers are permeability-tuned, with high-stability fixed mica condensers. Any type of air-tuned iron-core transformer may be used instead.

The i.f. stage as shown in the diagram is quite conventional. Its gain is controlled by R_4, which varies the control-grid bias. The stage is made regenerative by simply running a short length of insulated wire from the control grid of the 6K7 through a hole in the shield can of i.f. transformer T_2 so that a small amount of energy is coupled back to the grid from the plate. When

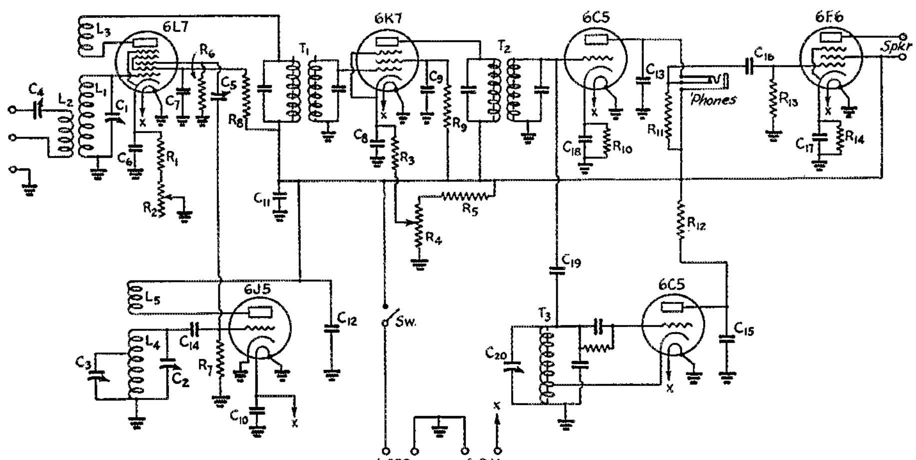
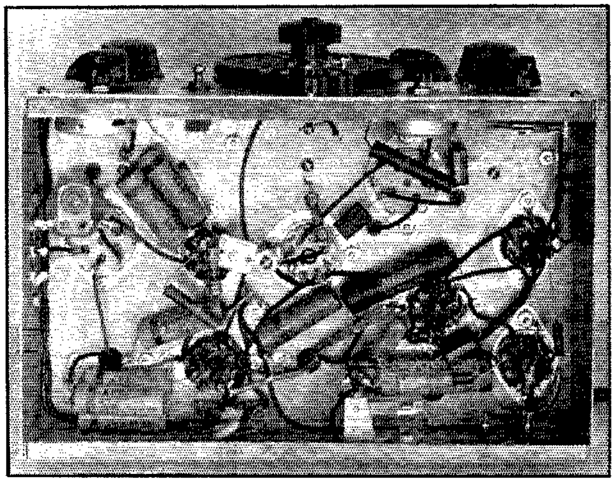


FIG. 1—CIRCUIT DIAGRAM OF THE REGENERATIVE S.S. RECEIVER

C_1, C_2—50-μμfd. variable (Hammarlund MC-50-S).
C_3—35-μμfd. variable (National SS-35).
C_4—70-μμfd. mica trimmer (Hammarlund BBT-70).
C_5—30-μμfd Isolantite-insulated mica trimmer (National M-30).
C_6-C_{10}, inc.—0.1-μfd. paper, 400-volt.
C_{11}—0.2-μfd. paper, 400-volt (or larger).
C_{12}, C_{13}—0.005-μfd. mica.
C_{14}—100-μμfd. mica.
C_{15}, C_{16}—0.01-μfd. paper, 400-volt.
C_{17}—10-μfd. 25-volt electrolytic.
C_{18}—5-μfd. 25-volt electrolytic.
C_{19}—See text.
C_{20}—25-μμfd. variable (Hammarlund SM-25).
R_1—300 ohms, ½-watt (see text).
R_2—500-ohm variable, wire-wound.
R_3—300 ohms, ½-watt.
R_4—25,000-ohm volume control.
R_5—50,000 ohms, 2-watt.
R_6—50,000 ohms, ½-watt (I.R.C. Type F).
R_7—150,000 ohms, ½-watt (I.R.C. Type F).
R_8—12,000 ohms, 1-watt.
R_9, R_{10}, R_{11}, R_{12}—50,000 ohms, ½ watt.
R_{13}—0.5 megohm, ½-watt.
R_{14}—450 ohms, 1-watt.
T_1, T_2—455-kc. interstage-type i.f. transformers (Sickles 6504).
T_3—455-kc. beat oscillator transformer, with grid condenser and lead (Sickles 6577).
L_1-L_5, inc.—See coil table.
Jack—Double-circuit type.
Sw—S.p.s.t. toggle.



BELOW CHASSIS—CHIEFLY BY-PASS CONDENSERS AND RESISTORS

this is done R_4 serves as a regeneration control and is more effective in varying the selectivity than gain. If the high selectivity afforded by regeneration is not wanted, the regenerative coupling may be omitted and the set becomes a straight super insofar as the i.f. is concerned.

The second detector, beat oscillator and power amplifier need no special comment. The headphones plug into the plate circuit of the second detector; the signal level is quite high here and no additional audio amplification is needed. For simplicity, no audio gain control is incorporated in the set, since the various r.f. controls afford quite a range in volume

LAYOUT

The various photographs show the layout, both top and bottom, quite plainly. The chassis is a standard item measuring 11 by 7 by 2 inches. The band-spread tuning condenser, C_3, is at the front center, operated by the vernier dial. At the left is C_1, the mixer tuning condenser, and at the right, C_2, the oscillator band-setting condenser. The oscillator tube is directly behind C_3, with the mixer tube to the left on the other side of a baffle shield which separates the two r.f. sections. This shield, measuring 3¾ by 4¾ inches, is quite effective in preventing unwanted coupling between oscillator and mixer. The mixer coil socket is at the left edge of the chassis behind C_1; the oscillator coil socket is between C_2 and C_3.

The i.f. and audio sections are along the rear edge of the chassis. The transformer in the rear left corner is T_1; next to it is the i.f. tube, then T_2. The transformers are mounted so that the adjusting screws project to the rear where they are easily accessible. With the particular type of transformer used this requires drilling a new hole in the shield of T_1 so that the grid lead to the 6K7 can be brought out the proper side. In T_2, the grid lead should be pulled through the side of the can and brought out the bottom with the other leads, since the grid of the 6C5 second detector comes through the base.

The transformer at the rear right is for the beat oscillator. The 6C5 second detector is directly in front of it and the beat oscillator tube is about midway along the right chassis edge. The 6F6 output tube is in the rear right-hand corner.

Power cord, headphone jack (insulated from the chassis) and a tip jack for the speaker are on the rear edge of the chassis. The antenna input terminals are on the left edge, near the mixer coil socket.

The controls along the bottom edge of the panel are, from left to right, the mixer regeneration control, R_2, the on-off switch, *Sw*, the i.f. gain or regeneration control, R_4, and the beat-oscillator vernier condenser, C_{20}. The latter has the corner of one rotary plate bent over so that when the condenser plates are fully interleaved the condenser is short-circuited, thus stopping oscillation.

WIRING POINTERS

Study of the bottom view will show how the various resistors and by-passes are wired in. The tube sockets are bakelite except that for the high-frequency oscillator, which is Isolantite. The coil sockets also are Isolantite, a six-prong socket being used for the mixer coil and a five-prong unit for the oscillator. In most cases the various components can be mounted by their wire leads, but one or two insulated lugs will be needed for "B" connections.

As shown in Fig. 1, one side of the heater circuit is grounded, so that only one filament wire need be run from tube to tube. The more conventional method of running heater current through a twisted pair can be used if preferred. The method indicated has proved to be quite satisfactory, however, in that it does not seem to introduce any particular hum. On each tube socket the shield prong and adjacent heater prong are tied together and grounded.

In making ground connections the practice of bringing all by-pass condenser returns for each individual stage to a single point has been followed when possible, the cathode ground (through the by-pass condenser, when used) being the focal point. In some cases, where long return leads would have been necessary, separate grounds are used on the same stage. If desired, such grounds can be tied together with heavy wire, but since no instability resulted without them they were not used in this case. In any event, it seems desirable to make the r.f. path from cathode to chassis as short as possible, as a fundamental requirement.

The oscillator-mixer coupling condenser, C_5 is mounted from one of its connection tabs on a small ceramic pillar (furnished with one of the tube sockets) between the oscillator and mixer tube sockets. The antenna series condenser, C_4, also visible in the bottom view, is mounted between one terminal on the antenna strip and one of the mixer coil-socket prongs. These condensers do not require readjustment in normal operation, hence are screw-driver adjusted from the bottom.

The i.f. plate by-pass condenser, C_{11}, actually consists of two 0.1-μfd. units in parallel. A minimum of 0.2 μfd. was found necessary to prevent i.f. instability, but any convenient larger value can be used, or a single unit of the proper capacity may be substituted.

In doing the actual wiring, it will be found convenient to start with the filaments and follow with all the by-passes and resistors, leaving the r.f. until last. This method makes it possible to find room for the larger parts first and thus avoids any rewiring if things don't fit right toward the end of the job. It also keeps the condensers close to the chassis and leaves the r.f. wiring out in the open.

The grid and plate leads from T_2 are covered with shield braid to help prevent coupling back to T_1. This precaution probably is not necessary, but may mean avoiding unwanted i.f. oscillation.

COIL DATA

Band	*Coil*	*Wire Size*	*Turns*	*Length*	*Tap*
1.75 Mc.......	L_1	24	70	Close-wound	—
	L_2	24	10	"	—
	L_3	24	3.5	"	—
	L_4	22	42	"	Top
	L_5	22	8	"	—
3.5 Mc.......	L_1	22	35	"	—
	L_2	22	7	"	—
	L_3	22	2.5	"	—
	L_4	22	25	1 inch	17
	L_5	22	5	Close-wound	—
7 Mc.......	L_1	18	20	1 inch	—
	L_2	22	4	Close-wound	—
	L_3	22	2	"	—
	L_4	18	13	1 inch	6
	L_5	22	3	Close-wound	—
14 Mc.......	L_1	18	11	1 inch	—
	L_2	22	4	Close-wound	—
	L_3	22	2.5	"	—
	L_4	18	7	1 inch	2.4
	L_5	22	2	Close-wound	—
28 Mc.......	L_1	18	5	1 inch	—
	L_2	22	3	Close-wound	—
	L_3	22	2.5	"	—
	L_4	18	3.6	1 inch	1.3
	L_5	22	1.4	Close-wound	—

All coils 1½ inches in diameter, on Hammarlund SWF forms. Spacing between coils on same form approximately ⅛ inch. Band-spread taps are measured from bottom (ground) end of L_4. All coils are wound with enamelled wire.

The b.o. coupling condenser, C_{19}, is not an actual condenser unit but is simply the capacity existing between the grid prong on the 6C5 socket and the adjacent prong on the side away from the plate. This prong, ordinarily unused, is connected to the b.o. as shown; more conveniently, it may be connected directly to the grid of the

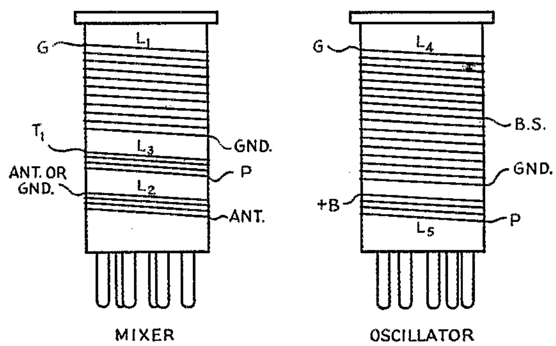


FIG. 2—THIS DRAWING SHOWS THE METHOD OF WINDING THE MIXER AND OSCILLATOR COILS
All coils are wound in the same direction.

b.o. tube with identical results. This coupling puts a rather strong beat voltage at the grid of the second detector; sufficient coupling was used so that strong signals give loud audio response. If a weaker beat signal is wanted, the coupling should be from the cathode of the b.o. tube.

R_1, the fixed cathode resistor in the 6L7 circuit, is an adjustable unit furnished with R_2. It was set to 300 ohms before installation.

COILS

The method of winding coils is shown in Fig. 2, and complete specifications are given in the table. All windings are in the same direction. With connections brought out as shown, reversing L_3 with respect to L_1, or L_5 with respect to L_4, will prevent oscillation.

In Fig. 1, the ticklers, L_3 and L_5, have been shown coupled to the grid ends of L_1 and L_4, respectively. This was done purely to make the diagram less awkward; the actual method of construction is given in Fig. 2, with the ticklers coupled to the grounded ends of the grid coils.

The specifications given should be followed rather closely in the case of L_4 if complete band-spread is to be obtained in each band. The tickler, L_5, is not so critical; use enough so that the tube oscillates readily with fairly low plate current, but not so much as to cause blocking. There is a good deal of leeway in the case of L_1, since the tuning condenser has sufficient range to compensate for moderate changes in the inductance of this coil. The tickler coil L_3, however, is another story, and it may be necessary to "tailor" it to fit the antenna. It must be large enough to make the mixer circuit oscillate readily, but yet not so large that oscillation continues over the whole range of R_2. The desirable condition is that of having the circuit go into oscillation when the optimum bias, approximately six volts, is applied to the 6L7. The number of turns on L_3, or the coupling between L_3 and L_1, should be adjusted so that the mixer goes into oscillation with R_2 set at about half scale. The antenna coupling condenser, C_4, affords some compensation for the antenna loading effect, and is particularly useful on the higher frequencies where the number of turns is small and the adjustment therefore more critical.

Where spaced windings are called for, the turns may be spaced by hand or by winding small wire or thread between them. After the windings are finished they may be held permanently in place by Duco cement spread along the coil-form ridges. After soldering the coil ends in the pins, be sure to clean off any rosin which may have formed a thin film over the contact surfaces.

Any convenient pin-connection arrangement may be used. Make the connections so that the shortest leads between coil socket and circuit points result.

I.F. ALIGNMENT

The i.f. alignment procedure is an oft-told story and probably does not need too detailed treatment here. Undoubtedly the most difficult feature is that of securing proper equipment for the job, but a service-man friend or the local parts store may be able to help out. A test oscillator and 0–1 milliammeter make a suitable combination. The i.f. should be aligned without the regenerative connection and with the h.f. oscillator coil out of its socket. A mixer coil may be in place in order to complete the 6L7 plate connection; without the coil it is necessary to connect a jumper across the L_3 prongs on the coil socket. Incidentally, if no speaker is used either the speaker terminals must be short-circuited to prevent damage to the 6F6, or else the tube must be out of its socket.

Connect the test oscillator output between the 6L7 grid and chassis, with the normal grid connection to C_1 removed. Hook the milliammeter to a 'phone plug and insert plug in the headphone jack. Set the oscillator to 455 kc. and adjust the trimmers on T_1 and T_2 to give maximum meter reading, with R_4 set for maximum gain or slightly below. The beat oscillator should be off. Without signal the second detector plate current should be between 0.1 and 0.2 ma.; adjust the test oscillator output so that the reading with signal is about 0.4 or 0.5 ma. As the circuits come into line, reduce the signal input to keep the reading about the same. Line up the circuit as accurately as possible, since correct alignment helps both gain and selectivity. If the i.f. is unstable, the meter will not show a smooth rise and fall through maximum as a circuit is adjusted but will be jumpy, probably to full scale or more if oscillations start. There should be no trouble on this account if adequate by-passing and reasonable circuit isolation are employed.

If no 0–1 milliammeter is at hand a fair alignment job can be done by ear. Using a modulated test oscillator, peak all the trimmers for maximum audio output, using a fairly weak input signal for the final adjustment. With a little practice an equally good result can be obtained even without modulation on the oscillator, careful attention being paid to the change in character of the hiss as the circuit is tuned through resonance.

If no regular test oscillator is available, the beat oscillator can be used as a substitute, preferably set up temporarily in a separate unit. The output can be taken, in many cases, without formal coupling, the oscillator simply being on the same table as the receiver. A resistor of several thousand ohms should be connected between the 6L7 grid and ground to complete the d.c. grid circuit and give some impedance for the i.f. The beat oscillator can be set to the correct frequency by coupling it to a broadcast receiver and adjusting the tuning so that its 2nd and 3rd har-

(Continued on page 80)

Next Month—National Convention Story

CLICK-CLACKING train wheels punctuate the echo of tootled c.w. from "2-lung-power" whistles as we head homeward from the Chicago National A.R.R.L. Convention—the greatest amateur convention ever held, bar none. We had hoped to bat out a hurried story of the convention activities that would "make" this issue of *QST*, despite the stern fact that final press date was but two days after the convention ended. But now we know that can't be done—the affair was too big, too spectacular to be jammed into any hurriedly-written piece. The wealth of color and incident that characterized this convention is only hinted when we repeat that it was half again as large as any held heretofore—and set a faster pace, with more going on, than anything we have known. So pardon our enthusiasm until next month, when we will hope to weave all the threads into a detailed account worthy of amateur radio's greatest gathering of all time.

The "safety" story is worth telling too and we hope that you will use any *one*, or *all* the measures in your own shacks, to improve on some of the situations we have seen. We have personally added an inexpensive electric warning sign to our own "heap." "Familiarity breeds contempt." We find it advisable, then, to keep the idea of safety constantly before us.

The safety features of W1AW, in brief: (1) Interlock switches. In series with 110-220 volt power, "kill" the transmitters instantly, if a dust cover door is opened in the rear of any unit. (2) The lattice—prevents "burning curiosity" from burning fingers. (3) Grounding antennas, accomplished by plug jacks, protects from lightning—fire hazard—and grounding metal frames of the sets—putting meters in B minus (no metal cased meters) completes the job. (4) The danger sign, within *each* unit automatically warns the operator to be ever watchful—as well as showing if fuses have been removed on either side of the power circuit. These signs are turned *on* by an interlock at the same time the *power* is turned *off*.

A Low-Cost Single-Signal Receiver

(Continued from page 18)

monics fall on broadcast carriers of the proper frequency, *i.e.*, 910 and 1360 kc., in round numbers. The i.f. does not have to be exact; anything beween 450 and 460 will be satisfactory. With the beat oscillator serving as a test oscillator, the alignment procedure will be the same as before, but adjustment of signal level will not be so convenient.

ADJUSTING R.F. CIRCUITS

After the i.f. is aligned, the next step is to get the r.f. end working. No special equipment is needed for this purpose. Plug in a set of coils for some band on which there is a good deal of activity—7 Mc. in the evening, for instance. Set the oscillator padding condenser, C_2, at approximately the right capacity; with the coil specifications given, the proportion of total C_2 capacity on each band will be about as follows: 1.75 Mc., 80 per cent; 3.5 Mc., 75 per cent; 7 Mc., 95 per cent; 14 Mc., 90 per cent; 28 Mc., 45 per cent. Now set the mixer regeneration control, R_2, for minimum regeneration—all the resistance in circuit. Connect an antenna and set C_4 at maximum capacity. Switch the beat oscillator on by turning C_{20} out of the maximum position, and adjust the screw on T_3 until the characteristic beat-oscillator hiss is heard.

Now tune C_1 slowly over its scale, starting from maximum capacity. Using the 7-Mc. coils as an example, when C_1 is at about half scale there should be a definite increase in noise, and in the strength of the signals which no doubt by this time have already been heard. Continue on past this point until a second peak is reached on C_1; at this peak the input circuit is tuned to the frequency which represents an image in normal reception. The oscillator in the receiver is designed to work on the high-frequency side of the incoming signal, so that C_1 always should be tuned to the peak which occurs with most capacity. On the higher-frequency bands the two peaks will be closer together on C_1 because of the greater tuning range; the reverse is true on the lower frequencies, and on 160 meters the two peaks will be found at opposite ends of the tuning range.

After the signal peak on C_1 has been identified, tune C_3 over its whole range, following with C_1 to keep the mixer circuit in tune, to see how the band fits the dial. With C_2 properly set, the band edges should fall the same number of main dial divisions from 0 and 100; if the band runs off the low-frequency edge, less capacity is needed at C_2, while the converse is true if the band runs off the high edge. Once the band is properly centered on the dial, the panel may be marked at the appropriate point so that C_2 may be reset readily when changing bands. Incidentally, if the type of knob shown in the photograph is used it will be helpful to scratch a thin line on the edge of the knob opposite the pointer arrow so that the scratch may be lined up with the mark on the panel. The scratch may be filled in with white ink or paint for easy visibility.

MIXER REGENERATION

At this point it is time to become familiar with the operation of the mixer when regeneration is introduced. Tune in a signal and adjust C_1 for maximum response. Advance R_2 slowly, simultaneously swinging C_1 back and forth through resonance. As regeneration is increased signals and noise both will become louder and C_1 will tune more sharply, until finally the mixer circuit will break into oscillation when, with C_1 right at resonance, a loud carrier will be heard, since the oscillations generated will go through the receiver in exactly the same way as a signal. Always work the mixer somewhat below the critical regeneration point and never permit it to oscillate in practical operation.

The procedure described above should be followed through for all coil sets. Barring mistakes in wiring or changes in circuit constants, particularly coil dimensions and tuning capacities, the only feature likely to give trouble is the regeneration. If the antenna happens to be nearly resonant in the band, it may not be possible to make the mixer oscillate; on the other hand if the antenna loading is negligible the circuit may oscillate continuously regardless of the setting of the regeneration control. The former condition can be cured by reducing the capacity of C_4 or by increasing the number of turns on L_3. If the mixer oscillates continuously, the opposite remedies are required. The latter condition easily can be recognized by a series of beats and chirps as C_1 is tuned over its range. Normally, only signals tuned in by the oscillator circuit will be heard, with C_1 having no effect except to control volume. Since the antenna loading changes with frequency, there may be cases where the mixer will go into oscillation at frequencies somewhat removed from the actual signal frequency, but operate normally at the latter. In general, it is not necessary to "push" the regeneration for the sake of signal strength. It is there chiefly to increase the signal-to-image ratio, which it does by the process of building up the desired signal. Peak regeneration is needed only when a desired signal is being QRM'd by an image, which happens a surprisingly small number of times in practice.

It is a good plan to spend some time operating the set without attempting to add regeneration to the i.f. stage, in order to attain complete familiarity with the method of handling mixer tuning and regeneration. As a straight super the receiver is, of course, considerably more selective than a t.r.f. receiver, especially to strong off-channel signals. Learn to keep C_1 always at resonance or on the low-frequency side of resonance with the incoming signal. Keeping exactly in line naturally requires "two-handed" tuning, but in practice it will be found that C_1 need not be touched when tuning over the portion of the band normally covered near the transmitter frequency. This condenser may, in fact, be used as a volume control, in which case it is advisable to keep it on the high-capacity side of resonance so that it will be as far as possible from resonance with the image frequency. Its tuning will not be too critical so long as the regeneration is kept to a moderate value; at peak regeneration, however, the tuning is quite sharp. For operating convenience, be sure to pick out an easy-running condenser for C_1—there's no band-spread on this circuit.

The oscillator-mixer coupling condenser, C_5, should be adjusted so that pulling of the oscillator frequency at 14 Mc. is negligible as C_1 is tuned through resonance with the incoming signal. The setting generally will be with the plates rather far apart. There will always be considerable pulling if C_1 is tuned to the *oscillator* frequency, even on the low-frequency bands. This, however, does not represent an actual operating condition. On 7 Mc. and lower there should be no detectable change in beat note as C_1 goes through the *signal* peak. A few hundred cycles change is typical of 14 Mc.

I.F. REGENERATION

When the operation of the receiver is completely familiar, the i.f. regeneration may be added. The method has already been mentioned; it remains only to describe the operation. The amount of feed-back will be determined by the length of wire inserted in the can containing T_2. Optimum selectivity usually will be secured when the regenerative coupling is adjusted so that the 6K7 goes into oscillation with the gain control, R_4, fairly well "down"—far enough so that it is well below maximum gain and in the region where, without regeneration, its effect on gain is not great. There are two reasons for operation in this way rather than with the feed-back adjusted so that oscillation takes place when the gain is near maximum. In the first place, the normal tube gain is not needed—the volume will be too great with both regeneration and high tube gain. Second, the selectivity will be considerably greater if the signals are kept at a low level and built up to a peak almost solely through the use of regeneration. Aim to balance gain and regeneration so that the average signal level, at resonance with peak regeneration, is about the same as with normal i.f. gain without regeneration. The off-resonance signals will then be rather far down, giving greater effective selectivity. With the conditions recommended, the i.f. regeneration gives a voltage gain of about 40 on a moderately strong signal; that is, the signal is 40 times as strong with regeneration as without it at the same i.f. gain-control setting.

For single-signal c.w. reception, set the beat oscillator so that when R_4 is advanced to make the i.f. just go into oscillation the resulting tone is the desired beat-note frequency. Then back off on R_4 to give the desired selectivity. Maximum selectivity, of course, will be secured with the i.f. just below the oscillating point; noise and miscellaneous clicks and impulses will make a "ringing" sound at this point and the signal must be tuned carefully to be set right on the peak. At the peak the signal strength will build up to a large value as compared with a frequency slightly off resonance. With regeneration reduced slightly the ringing will disappear and the signal peak will not be quite so marked, although the selectivity still will be high. The "other side of zero beat" will be very much weaker than the desired side. A typical measurement, using a 1000-cycle beat note, gave a ratio of 35 db between the desired signal and the a.f. image, or 1000-cycle beat note on the "other side." The ratio will depend somewhat on the accuracy of i.f. tuning; the best method found is to peak all i.f. circuits as accurately as possible without regeneration, then to introduce the regeneration without further adjustment of the i.f. trimmers.

Since the i.f. amplifier works out of the mixer, it is to be expected that the latter will have some effect on the i.f. regeneration, and such is the case if the regeneration is worked too near the critical point. For example, if C_1 is slightly on the low-frequency side of resonance and R_4 is advanced to critical regeneration, tuning the mixer input to the high-frequency side may cause the i.f. amplifier just to go into oscillation. To overcome this, R_4 may be set so that the i.f. does not oscillate at any setting of C_1; this will give somewhat less than maximum selectivity, but there is still plenty. Another method is to detune slightly the i.f. circuit in the plate of the 6L7, which will "decouple" the circuits sufficiently to make the i.f. regeneration independent of the setting of C_1. This, however, has an adverse effect on the selectivity because of the staggered tuning.

A regenerative i.f. stage has a quite sharp peak when operated as outlined above. Although the attenuation at frequencies several kilocycles from resonance is not as good as with a crystal filter, the overall selectivity, plus the peak, gives a highly satisfactory single-signal effect—certainly one decidedly worth while not only for c.w. but also for 'phone work. On 'phone, the sidebands are drastically cut of course, but it becomes possible to copy signals which otherwise would be completely drowned out by near-by carriers.

The operating characteristics of the receiver have been given detailed attention because in any receiver involving regeneration the success of the outfit is chiefly attributable to the skill of the operator. It takes a little time to learn how to get the most out of such a set, but the results are there to be had if a little patience is expended in finding out how to get them. Do one thing at a time and find out all about it before going on to the next. You'll be surprised at what can be done. And incidentally, in a speaker-blasting contest, this outfit will shout just as loudly as anything else having a pentode output stage.

A Six-Band Kilowatt Transmitter

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frequency range will be because of too-high minimum capacity. Also, the condensers should have at least the spacing indicated in Fig. 1, because the r.f. voltage across each circuit is high.

Proper placement of by-pass condensers is of utmost importance. Remember this transmitter is capacitively-coupled to the final amplifier, which makes the plate coil of each stage of the exciter the "grid" coil of the final amplifier, so that by-pass condensers of each stage must terminate at the filament circuit of the final amplifier.

Experience with this transmitter and others leads us to believe that very few push-pull amplifiers are properly balanced with regard to grid current. Few, if any, difficulties have been experienced in obtaining balance in the plate circuit, but the grid circuit is another story. The assumption that the mechanical center-tap of the grid coil or grid circuit is the electrical center-tap is far from the truth. A simple method of checking the balance of a push-pull amplifier is to take one tube out of the socket and then, with the plate lead disconnected, check the grid current to the remaining tube. Remove the tube from the socket and place the same tube on the other side of the circuit. Again check the grid current. Adjust the center tap connection a quarter inch at a time until balance is found. The same procedure should be applied to each stage of the exciter unit. Sometimes the filament by-pass return from the grid circuit must be adjusted for exact electrical symmetry between the two tubes. The grid leads can be made mechanically symmetrical around the center of the coil.

The exciter is capable of supplying to the final tubes a grid current of at least 100 ma. through a 2000-ohm grid leak. The bias voltage and grid current are more than adequate for plate modulation of the final. If some fixed bias voltage is desired in order to key one of the lower powered stages, it is recommended that the smallest bias which will give plate-current cut-off with no excitation be employed. Contrary to popular belief, a large amount of fixed bias is not a safety