A COMPACT 100-WATT BANDSWITCHING HAM TRANSMITTER

Front panel view of the home-built 100-watt bandswitching transmitter. Controls are identified and correspond to the schematic. The transmitter covers 80, 40, 20, 15, and 10 meters.

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Complete construction details on a TVI-proof transmitter which uses standard components and covers five ham bands.

A CONSIDERABLE number of amateurs are interested in a transmitter in the 100-watt class, provided that such a transmitter is compact as well as versatile and includes modern design features. This interest is particularly evident in the terrific sales popularity of the currently available manufactured units and transmitter kits in this power range. This article will discuss a somewhat similar transmitter which meets these specifications, yet is suitable for home construction without the need for complicated sheet metal work or for special components.

This transmitter was designed for maximum flexibility in keeping with its compactness. Four modern tubes are used in the r.f. section, four tubes are devoted to the high-level plate modulator, while three rectifiers and a voltage regulator complete the tube line-up. The transmitter covers five bands in the range from 3.5 to 30 mc., yet is completely bandswitching without plug-in coils. Only three tuning controls require attention when shifting frequency. A continuous tuning pi network is used for the final. All controls as well as the oscillator crystal are accessible from the front panel, eliminating the need for "digging" into the rig when operating. The oscillator also functions as a buffer amplifier for external v.f.o. operation. All power supplies are integral parts of the unit, with a bias pack to supply fixed bias to permit excitation keying. Naturally, AM as well as c.w. output is available, and all stages are completely metered. The entire transmitter mounts on a 13" x 17" x 3" chassis with an 8¾" rack panel.

Modern transmitter design is being influenced by a number of factors, which, in the light of present day circumstances, are making construction practices of a few years ago somewhat obsolete and undesirable. Perhaps the most important factor to be considered can be attributed to the rapid expansion of commercial television broadcasting, which has compelled amateurs to consider the reduction of TVI caused by their transmitters. The generally accepted methods of combating TVI involve complete shielding and filtering of the rig. Sometimes these measures are a bit difficult to adapt to existing equipment, but, by considering the problems involved at the onset of design, can be incorporated in a new transmitter without undue trouble.

This attention to TVI reduction and its associated problems led to several of the design features of this rig. Because of its marked superiority in reducing undesired harmonic output, a pi-network was selected for the final output coupling. The *E. F. Johnson Company* has made available to amateur circles, a line of components for pi-network construction. Their 229-201 rotary inductor allows the network to be tuned from 3.5 through 30 mc. without coil changing, and thus is perfectly suited to a bandswitching transmitter.

It was reasoned that if the r.f. components mounted above the chassis in this transmitter could be assembled in their own small shield box, the problems of complete transmitter shielding would be greatly simplified. To avoid the necessity of fabricating such a shield box at home, some shopping around was done to locate a unit of commercial manufacture which could be used. Fortunately, the *Bud* "Minibox" series met the requirements and a 10" x 6" x 3½" unit, CU-3010, was selected as the correct size to house the pi-network components and the final amplifier tubes.

The proper choice of output tubes for the transmitter was given careful consideration. Beam power and screen grid type tubes are gaining in popularity over triodes for use in ham gear. Undeniably, the higher power sensitivity of such tubes permits the use of low driving power, and the fact that they can operate without neutralization helps to simplify circuitry. On the other hand, many hams recall without relish, the parasitic tendencies and unstable operation sometimes experienced with tubes such as the 807. However, recent tube developments have resulted in a new button-stem construction with short internal leads and multiple base connections for cathode and suppressor to permit better r.f. grounding, as well as internal base shielding. This construction is used in the efficient 2E26, and in the 6146 beam power amplifier tube. This compact 6146 has an ICAS rating of 90 watts input per tube up to 60 mc., so a pair connected in parallel, as used in this transmitter, is easily capable of 100 watts r.f. output.

Separation of the grid and plate circuits of the final amplifier was readily accomplished since the 6146 is provided with a top plate cap. Assembling the plate components in the previously-mentioned "Minibox" shield allows the grid circuitry to be completely isolated simply by mounting these parts under the chassis. This has resulted in an amplifier which is completely stable in operation.

Only two additional stages are used to complete the r.f. section of this

transmitter. This makes for compact construction, and has the advantage of minimizing the number of stages requiring attention when changing frequency. After some thought, it was decided to avoid the use of broadband circuits; instead, tuned plate loads were selected for their increased efficiency. Several trial constructions were made to investigate various tube combinations and circuits. Finally, the nine-pin miniature 5763 tube was chosen for both the oscillator and multiplier stages, and has proven to be suitable for both applications.

The first stage is connected as a Colpitts harmonic oscillator, which is modified so as to allow operation as a buffer-multiplier as well, with excitation then coming from an external v.f.o. A double-pole, double-throw wafer switch, S_1, in the grid-cathode circuit of this stage permits this changeover. The screen of this tube is supplied with a well regulated 150 volts, controlled by an 0A2 VR tube.

The second 5763, V_2, operates as a buffer-multiplier to drive the final to full output on all bands. Approximately 45 volts of negative bias from the bias pack keeps this stage below cutoff without excitation, with additional operating bias developed across the grid leak by the driving signal. A variable screen voltage control functions as an excitation control to adjust the drive supplied to the final grids. The 5763 cathode and suppressor are tied directly to the chassis at the socket, to produce effective r.f. grounding.

The two 5763 stages are made band-switching, covering five ham bands without plug-in coils, namely 80, 40, 20, 15, and 10 meters. On 80 meters, a 3.5 mc. crystal is used, with the rig operating straight through in all stages. Either 3.5 or 7 mc. crystals may be used for 40 meter operation since the oscillator plate is then tuned to 7 mc., with the buffer and final again running straight through. On the 20 meter band, the oscillator tank is tuned to 7 mc.; however, the buffer stage now acts as a doubler to supply 14 mc. signal to the final grids. To reach 15 meters, the 7 mc. output of the oscillator is tripled to drive the final on 21 mc. Finally, to reach the 10 meter band, the 7 mc. crystal frequency is doubled in the oscillator tank, and again doubled in the multiplier to reach 28 mc. for the final grid. The final stage, it will be noted, functions as a straight amplifier on all bands.

A three-stage audio amplifier is included in the rig, for high level plate modulation of the final amplifier. A 6BA6 is used as the first speech amplifier, intended for use with a crystal microphone of average output. Contact bias is used to develop the slight bias voltage required by this stage, so that the cathode can be returned directly to ground in the interests of minimizing hum pickup at this input stage. An r.f. filter is provided in the grid and heavy decoupling is used in the plate feed. An audio gain control appears at the grid of the following 6AG5 amplifier, which is used as a driver for the modulator tubes. Inverse-feedback is added to the first two stages, and while the gain control is included in the loop, this feedback is desirable in improving the regulation of the driver. A transformer with a 1.5:1 turns ratio is used to couple the driver to the grids of the modulator tubes, which are conventional 807's in push-pull, operating with 30 volts fixed bias and 300 volts on the screens.

While economical in the number of stages, this audio section has been found more than adequate, and fully modulates the final with the gain control less than half open, when used with an *Astatic* T-3 mike. It is unusually hum free, and the components have been selected to give a restricted frequency response to produce clean crisp quality so necessary for ham work.

To facilitate an accurate check on the operation of the transmitter, a complete metering system is used. A rather tricky metering method, as used in the *Johnson* "Viking," has been adapted to this rig. For an effective r.f. ground, the 6146 cathodes are grounded directly, and yet with this metering technique, it is possible to measure the final cathode current. This is accomplished by inserting a milliammeter in the high voltage supply negative return lead, a 500 ma. movement being adequate in this case. Notice that the modulator cathodes are returned to the transformer center tap, rather than ground, to prevent their current from flowing through the meter.

An additional 0-50 ma. meter is used to measure the grid and plate currents of the exciter by switching the meter across small resistors provided for this purpose in the desired leads. In addition, this meter is switched into the 807 cathodes, with a suitable shunt to increase the range to 250 ma., for checking the modulator cathode current. Both meters and leads involved are carefully r.f. bypassed.

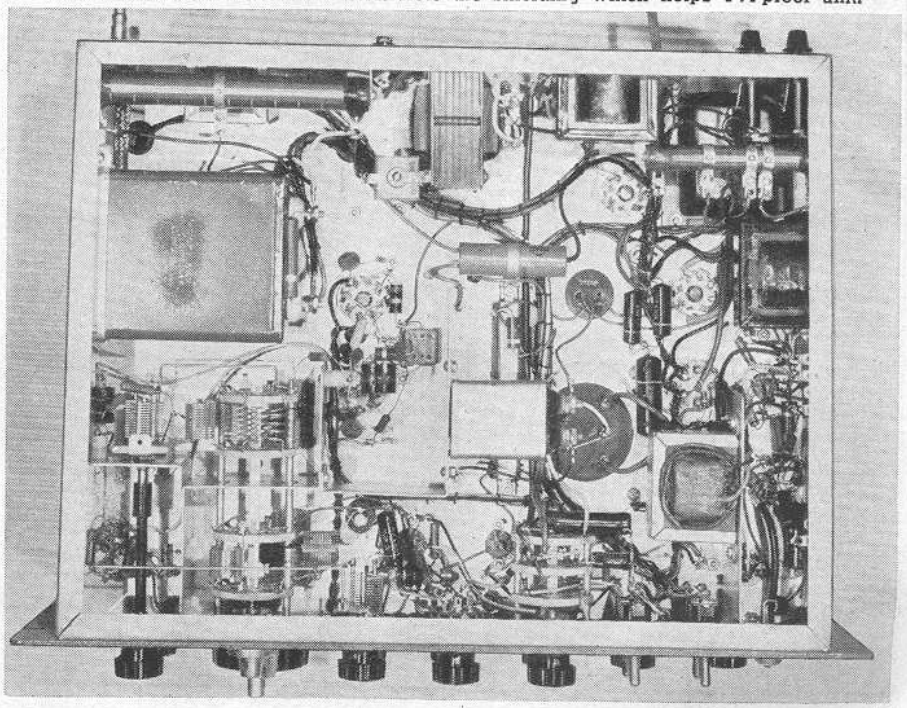
A three-deck ceramic wafer switch with 90 degree indexing is used to change the rig from c.w. to phone operation. One deck is used in the oscillator cathode, to switch the cathode return from the key jack to the high voltage panel switch for phone standby. The other decks control the final screen and modulation transformer changeover.

A high voltage power supply furnishes slightly over 600 volts under full load to the final and modulator stages, using a choke input filter to smooth out ripple. A high wattage bleeder is tapped at 300 volts to supply the modulator screens during phone operation, and through a dropping resistor, feeds well regulated voltage to the final amplifier when operating c.w. Under phone conditions, both screen and plate circuits of the class C stage are modulated to secure 100% modulation. An additional resistor with a shorting switch is added to the r.f. screen circuit to reduce power output for tuning.

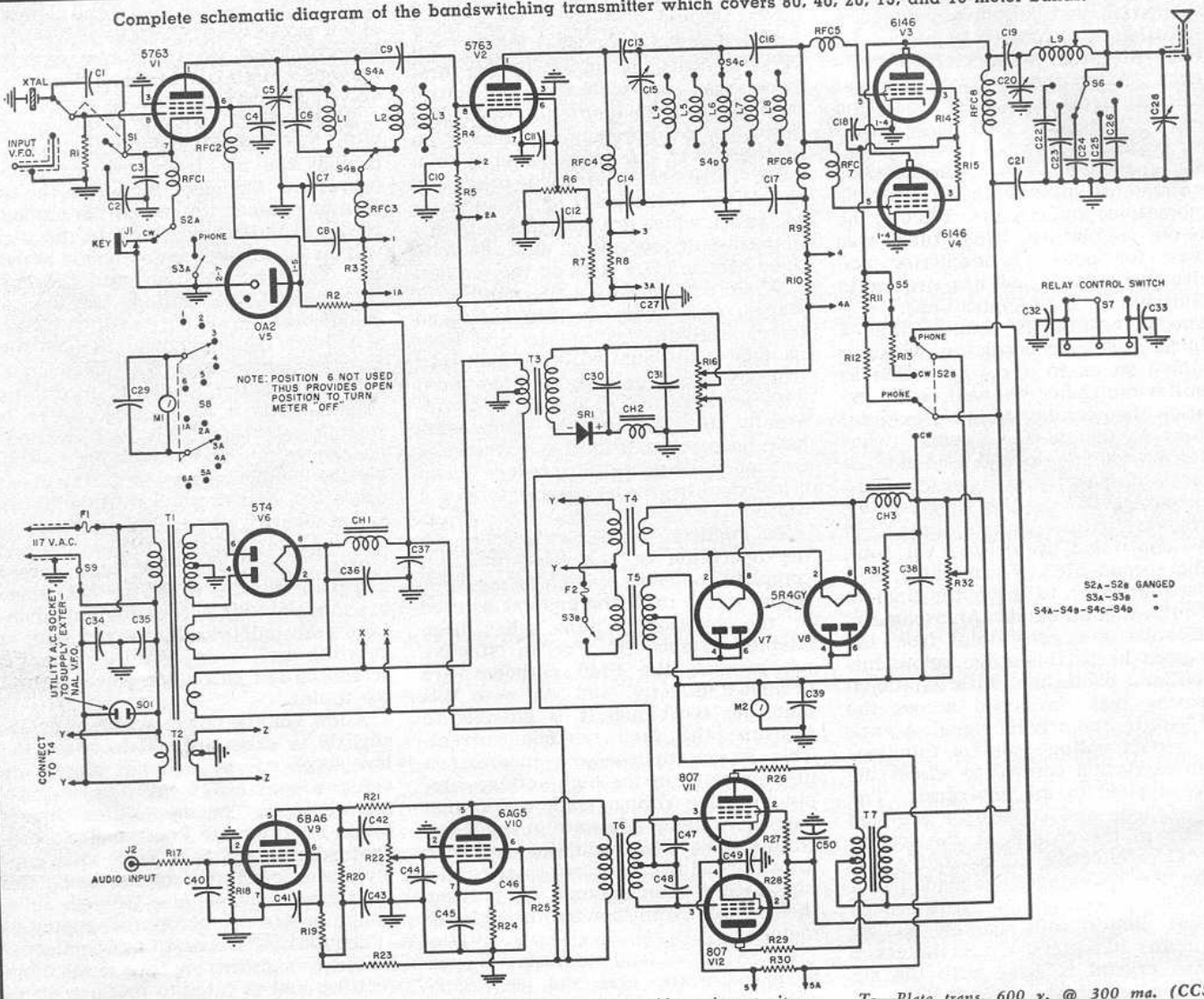
A low voltage power supply provides slightly in excess of 300 volts for the low level r.f. and audio stages, by using a metal 5T4 rectifier and pi-section filter. The input filter capacitor is intentionally kept small to prevent soaring voltages from this supply under conditions of no load. The excitation control also serves as a minimum bleeder across this supply.

The bias pack uses a back-connected filament transformer, into a selenium rectifier and pi filter to produce up to 100 volts bias. The final requires 75 volts, the buffer 45 volts, and modulator 30 volts, available from a low resistance bleeder with three sliders

Under chassis view of transmitter. Note the shielding which helps TVI-proof unit.



Complete schematic diagram of the bandswitching transmitter which covers 80, 40, 20, 15, and 10 meter bands.



R_1—100,000 ohm, ½ w. res.
R_2—25,000 ohm, 10 w. wirewound res.
R_3, R_5, R_8, R_{10}, R_{27}, R_{28}—100 ohm, ½ w. res.
R_4—68,000 ohm, ½ w. res.
R_6—25,000 ohm, 5 w. wirewound pot
R_7—2700 ohm, 2 w. res.
R_9—2200 ohm, ½ w. res.
R_{11}—20,000 ohm, 10 w. wirewound res.
R_{12}—20,000 ohm, 25 w. wirewound res.
R_{18}—2500 ohm, 10 w. wirewound res.
R_{14}, R_{15}—47 ohm, 2 w. res.
R_{16}—3000 ohm, 50 w. wirewound res. with 3 sliders
R_{17}—47,000 ohm, ½ w. res.
R_{18}—2.2 megohm, ½ w. res.
R_{19}—1 megohm, ½ w. res.
R_{20}—250,000 ohm, ½ w. res.
R_{21}—1.8 megohm, 1 w. res.
R_{22}—500,000 ohm pot.
R_{23}—27,000 ohm, 2 w. res.
R_{24}—270 ohm, 1 w. res.
R_{25}—2700 ohm, 1 w. res.
R_{26}, R_{29}—120 ohm, ½ w. res.
R_{30}—.8 ohm meter multiplier shunt (to increase 50 ma. meter to 250 ma.)
R_{31}—2.2 megohm, 2 w. res.
R_{32}—15,000 ohm, 100 w. wirewound res. with 1 slider
C_1—15 μμfd. ceramic capacitor
C_2, C_4, C_8, C_{10}, C_{11}, C_{12}, C_{14}, C_{17}, C_{27}, C_{29}, C_{32}, C_{33}, C_{39}, C_{40}, C_{47}, C_{48}, C_{49}—1000 μμfd. ceramic capacitor
C_3, C_9, C_{13}, C_{16}—100 μμfd. ceramic capacitor
C_5, C_{15}—100 μμfd. midget var. capacitor
C_6—40 μμfd. silver mica capacitor
C_7—.02 μfd. mica capacitor
C_{18}—.003 μfd., 1500 v. mica capacitor
C_{19}—.002 μfd., 2500 v. mica capacitor
C_{20}, C_{28}—350 μμfd. var. capacitor (Johnson 350E20)
C_{21}—.005 μfd., 2500 v. mica capacitor
C_{22}—1250 μμfd., 1000 v. midget mica capacitor
C_{23}—1000 μμfd., 1000 v. midget mica capacitor
C_{24}—750 μμfd., 1500 v. midget mica capacitor
C_{25}—500 μμfd., 1500 v. midget mica capacitor
C_{26}—250 μμfd., 3000 v. midget mica capacitor (two 500 μμfd., 1500 v. in series)
C_{30}, C_{31}—30/30 μfd., 150 v. elec. capacitor
C_{34}, C_{35}, C_{41}, C_{46}—.05 μfd. bypass capacitor
C_{36}—1 μfd., 1000 v. oil-filled capacitor
C_{37}, C_{43}—40/40 μfd., 450 v. elec. capacitor
C_{38}—10 μfd., 1000 v. oil-filled capacitor
C_{42}—.005 μfd. coupling capacitor
C_{44}—250 μμfd. ceramic capacitor
C_{45}—10 μfd., 50 v. elec. capacitor
C_{50}—.1 μfd. bypass capacitor
RFC_1, RFC_2, RFC_3, RFC_4, RFC_6—2.5 mhy., 150 ma. r.f. choke
RFC_5, RFC_7—.8 μhy., 1000 ma. r.f. choke (Ohmite Z-235)
RFC_8—2.5 mhy., 500 ma. r.f. choke (Millen)
CH_1—6 hy., 150 ma. filter choke
CH_2—30 hy., 60 ma. filter choke
CH_3—10 hy., 300 ma. filter choke (Thordarson T-20C56)
L_1, L_4—80 m.—48 t. B & W "Miniductor" #3012
L_2, L_5—40 m.—20 t. B & W "Miniductor" #3012
L_3, L_6—20 m.—13 t. B & W "Miniductor" #3011
L_7—15 m.—6 t. B & W "Miniductor" #3006
L_8—10 m.—4 t. #14 bus, ⅝" dia., ⅞" long
L_9—Rotary pi-network inductor (Johnson #229-201)
T_1—Power trans. 350-0-350 v. @ 150 ma.; 5 v. @ 3 amps.; 6.3 v. @ 6.5 amps. (Merit P-3173 or equiv. Author used a now-obsolete trans.)
T_2, T_3—Fil. trans. 6. 3 v. @ 3 amps.
T_4—Fil. trans. 5 v.c.t. @ 6 amps. (Stancor P-3062)
T_5—Plate trans. 600 v. @ 300 ma. (CCS) (Stancor P-8042)
T_6—Driver trans. 1.5 to 1 single plate to push-pull grids (Stancor A-4752)
T_7—Mod. trans. 1.6 to 1, 807's class AB to paralleled 807's r.f. suitable, 75 w. or more audio capacity
M_1—0-50 ma. milliammeter (Simpson type 127)
M_2—0-500 ma. milliammeter (Simpson type 127)
S_1—D.p.d.t. ceramic wafer switch
S_{2A}, S_{2B}—3-pole, 2-pos. switch made from Centralab 90 degree index assembly and 3 ceramic wafers ("C.W.-Phone Switch")
S_{3A}, S_{3B}—D.p.s.t. bat-handle toggle switch
S_{4A}, S_{4B}, S_{4C}, S_{4D}—4-pole, 11-pos. exciter band-switch made from Centralab 30 degree index assembly and 4 ceramic "Y" sections. (Only 5 pos. required, see text on modifications)
S_5—S.p.s.t. bat-handle toggle switch ("Tune-Up Voltage Control")
S_6—S.p. 6-pos. switch (5-pos. required)
S_7—S.p.d.t. bat-handle toggle switch ("Relay Control")
S_8—D.p. 6-pos. non-shorting meter switch
S_9—S.p.s.t. bat-handle toggle switch ("A.C. Line Switch")
J_1—Closed circuit key jack
J_2—Shielded shorting-type audio input connector
SR_1—75 ma. selenium rectifier
Xtal.—See text
F_1, F_2—5 amp. fuse
SO_1—117 volt utility socket
V_1, V_2—5763 tube
V_3, V_4—6146 tube
V_5—0A2 tube
V_6—5T4 tube
V_7, V_8—5R4GY tube
V_9—6BA6 tube
V_{10}—6AG5 tube
V_{11}, V_{12}—807 tube

which is connected across this pack.

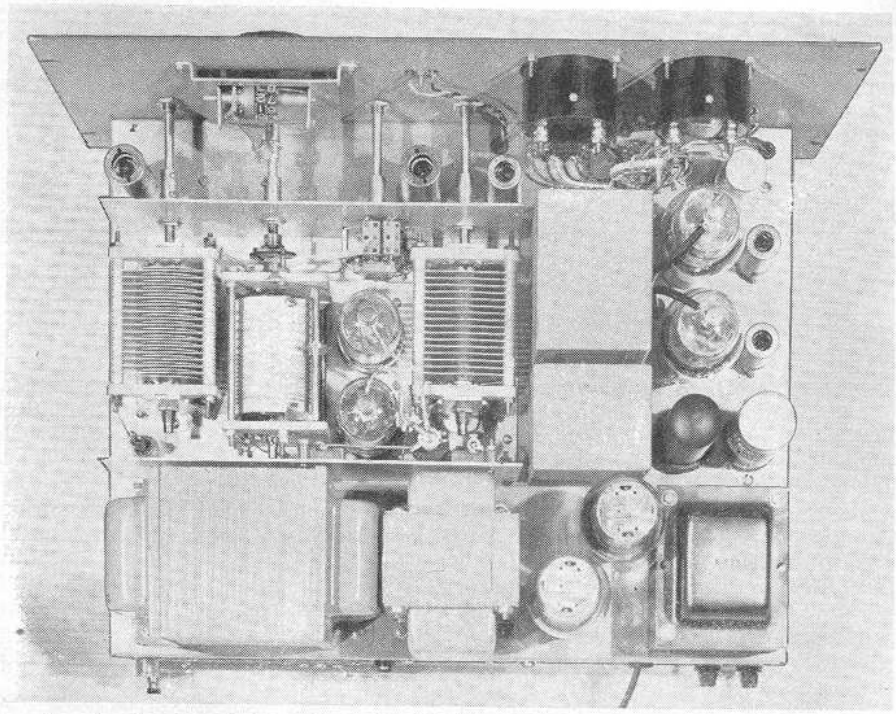
Because of the compactness of this transmitter, the layout is determined, to a great extent, by the sizes and shapes of major components. For this reason, it is suggested that those persons who may be interested in duplicating the rig obtain *all* parts before commencing work on the chassis. Needless to say, electrical equivalents will be satisfactory providing they are of comparable size.

Construction was inaugurated by fitting the plate components into the "Minibox," and reference to the photographs will aid in this layout. All mounting holes should be drilled in the "Minibox," and then transferred to the main chassis which should be drilled before any assembly is started. Tube sockets for the 6146's are mounted in the main chassis, with larger clearance holes cut in this "Minibox," but all other components are mounted through both chassis and "Minibox."

The "Minibox" should be placed on the main 13" x 17" x 3" aluminum chassis while the high and low voltage power supply and audio amplifier components are arranged as shown in the photographs. It should be noted that the high voltage transformer and filter choke mount near the rear left corner of the chassis with the "Minibox" closely against them, to provide space on the front top of the chassis for the exciter and VR tubes. The counter-dial, *Johnson* 116-208-4, requires some space behind the panel, which should be considered in spacing out the tubes. Shaft bearings in both "Minibox" and front panel permit brass shaft extensions to protrude to the front panel. The pi-network layout which was best able to utilize the available space, and still result in a neat front panel layout, is evident in the photos. The plate tuning capacitor is to the right of the tubes, with the fixed loading capacitors and switch directly in front of the tubes. The variable coil is immediately to the left, with the variable loading capacitors in the remaining space, with a coaxial cable output lead to the rear.

The two 5R4GY high-voltage rectifiers and the low-voltage power transformer occupy the rest of the back chassis top surface, with the 5T4, filter components, and the audio tubes with modulation transformer taking the space immediately to the right of the "Minibox." The space directly behind the front panel is required for the meters and meter switch, as well as audio and excitation pots.

Viewing the panel from the front the seven controls from left to right stretched across the center section of the panel, are as follows: the audio gain control (R_{22}), six position meter switch (S_8), excitation control (R_6), plate tuning capacitor (C_{20}), fixed loading switch (S_6), variable inductor tuning dial (L_9), and variable loading capacitor (C_{28}). The meters are mounted to the front panel side by side, with the crystal socket located between them and the tuning dial. The



Top chassis view of transmitter with shield cover removed to show parts location.

remaining controls are under the chassis, accessible from the front panel. The key jack and mike input connector (shorting type) are to the extreme left. The four toggle switches are grouped together, and control a.c. input (S_9), high voltage (S_3), reduced voltage tune-up (S_5), and an additional switch for relay control purposes (S_7), intended for antenna changeover, v.f.o. standby, etc. Next comes the c.w.-phone switch (S_2), followed by the crystal-v.f.o. switch (S_1), the oscillator tuning capacitor (C_5), exciter bandswitch (S_4), and tuning capacitor (C_{15}).

Two fuses, shielded line cord, v.f.o. input jack, v.f.o. a.c. utility outlet, relay switch terminal strip, ground binding post, and the coaxial antenna connector are on the rear chassis edge.

The photograph of the under side of the chassis shows the layout of remaining parts, including bleeders, filament transformers, bias supply, and filter capacitors. A few comments on various phases of construction may be of assistance to builders of the transmitter.

The bandswitch is assembled from four 11-position ceramic switch wafers, *Centralab* "Y" sections, and a 30 degree indexing unit. The switch is assembled on a "Z" shaped aluminum bracket, approximately 3 inches on a side with a 3/8" mounting lip along the lower edge. The coils are attached to the switch before mounting to the chassis. Only five of the switch contacts are used per deck, in addition to the wiper, so the r.f. insulation was improved by carefully drilling out the rivet and removing every other contact, with increased spacing and resultant 60 degree coil indexing. The coils are assembled to the wafers so that the 10 meter coil is nearest the wiper, to obtain short r.f. leads on this band.

A small aluminum bracket fastens between the bandswitch shield and the chassis lip to support the multiplier

(*Continued on page* 155)

Partial view of the top of the chassis with "Minibox" subchassis cover in place.