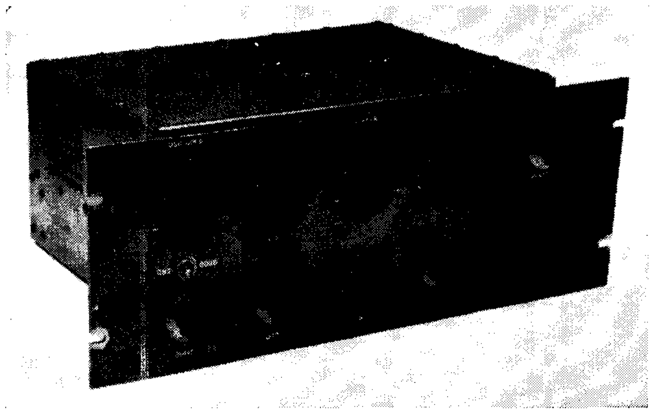

Fig. 1—This 500-watt transmitter packs a punch on 50 Mc.! It is completely enclosed in an aluminum box to reduce TVI problems. The top and bottom are made of perforated aluminum and the holes on the left side of the enclosure are for air intake to the blower. Lower controls are (l. to r.): drive (R_1), oscillator (C_1), doubler (C_2), amplifier grid (C_3), and loading (C_5). Plate tuning (C_4) is at the upper right.

A Compact 500-Watt Transmitter for 50 Mc.

BY WILLIAM I. ORR,* W6SAI AND RAYMOND F. RINAUDO,* W6KEV

Six meters is here to stay. Regardless of the ups and downs of the sunspot cycle, this band remains popular and has heavy usage in most parts of the United States. Many six-meter operators have expressed a desire to build a simple, foolproof, high-power transmitter exclusively for 50-Mc. operation. The design shown herewith has been in service for over two years, has proved to be a steady and dependable performer and is recommended to those six-meter operators who wish to "step up to the very best!"

It has been found from the writers' experience that power levels up to 500 watts or so are readily achieved at 50 Mc. with physically small equipment and reasonable power supplies. Above this power level, however, the cost and difficulty of assembling high-power gear seems to rise as the square of the power input! In particular, the amount of expensive "iron" required in power-supply and audio equipment seems to be entirely disproportionate to the 3-decibel power gain achieved when going from 500 watts to a kilowatt. The extra 3 decibels can more easily be achieved in the antenna.

Circuit Description

The transmitter is a three-stage crystal-controlled unit capable of running 625 watts input c.w. or 300 watts a.m. phone on the 50-Mc. band. Provision is made for v.f.o. control. Only three transmitter stages are required and precautions have been taken to prevent radiation of undesired harmonics or spurious emissions that might cause TVI or BCI.

The tube line-up, Fig. 2, is: 6AG7 oscillator multiplier, 6V6GT frequency doubler, and a 4CX300A power amplifier. The crystal oscillator is a modified Pierce circuit, with a crystal connected between the grid and screen of the pentode tube, and the plate circuit tuned to the third harmonic of the 8-Mc. crystal. If desired, 6-Mc. crystals may be substituted without circuit changes, the plate circuit then being tuned to the fourth harmonic of the fundamental frequency. Maximum frequency stability is achieved by a combination of low crystal current and oscillator screen voltage regulation. A 0A2 regulator tube holds screen voltage at 150 on the oscillator stage. The 25-Mc. harmonic output is capacity-coupled to the following doubler stage.

The doubler uses a 6V6GT in a conventional circuit. Its screen voltage is adjustable at the front panel by R_1. This control determines the drive level to the final amplifier. The 50-Mc. output of the doubler stage is applied to the grid circuit of the 4CX300A amplifier stage by link coupling through a short length of coaxial line. Inductive coupling through two tuned circuits helps to minimize the coupling of 25- and 75-Mc. energy and higher harmonics to the final-amplifier grid.

The 4CX300A final-amplifier stage uses a simple pi-network plate circuit. The tube is neutralized by a capacitive bridge circuit composed of the various internal capacitances of the 4CX300A, the neutralizing capacitor, C_7, and the 300-pf. silver mica bypass capacitor in the ground leg of the tuned grid circuit. The 4CX300A is mounted in an Eimac SK-710 socket containing a low-inductance screen bypass capacitor, C_8, especially

* Eitel-McCullough, Inc., San Carlos, Calif.

1 Reprinted from QST Magazine.

2 A 4CX250B or 4X150A may be used in this circuit with socket substitution.

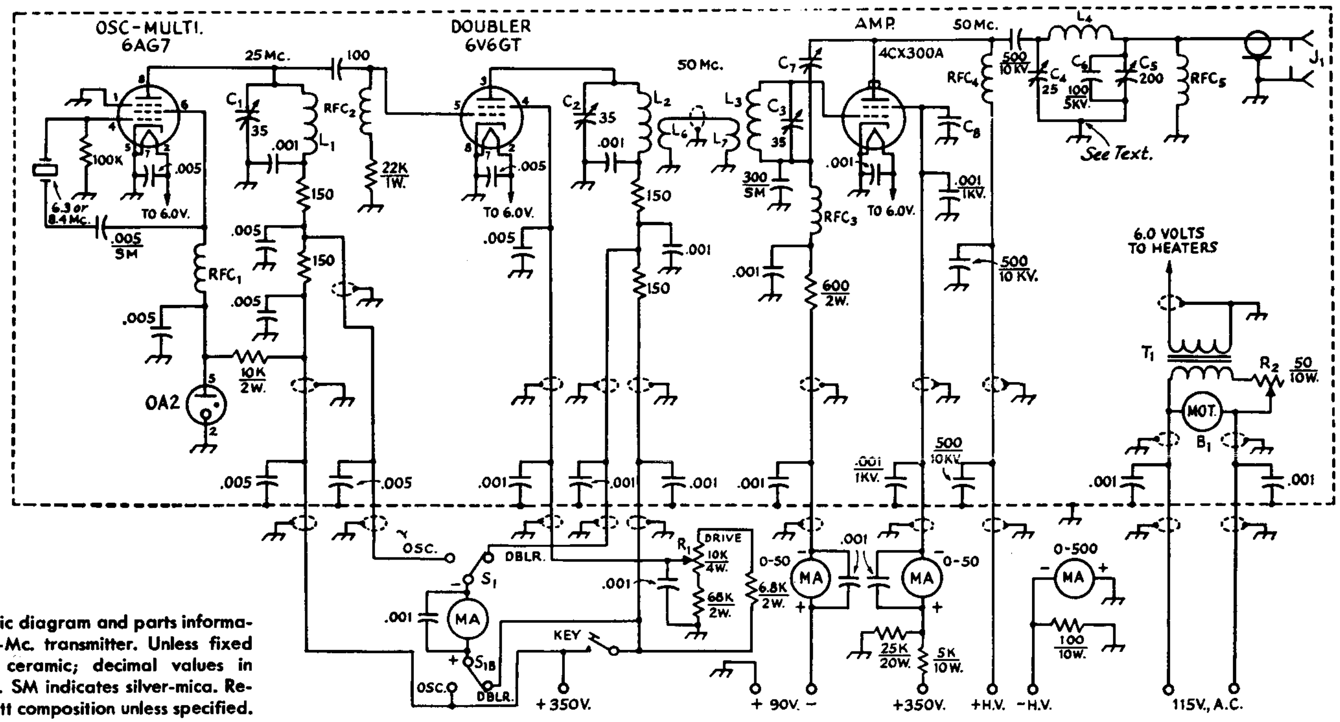

Fig. 2—Schematic diagram and parts information for the 50-Mc. transmitter. Unless fixed capacitors are ceramic; decimal values in μf., others in pf. SM indicates silver-mica. Resistors are ½-watt composition unless specified.

B_1—Phonograph motor to drive blower; see text. Blower should deliver 10 c.f.m. or more.

C_1, C_2, C_3—35-pf. variable (Johnson 149-2 or 35R12).

C_4—25-pf. variable, 0.075-inch spacing (part used was surplus; suggested replacement Johnson 154-11).

C_5—200-pf. variable, .02-inch spacing (surplus, from BC-375 tuner. Johnson 155-6 suitable).

C_6—100-pf. 5000-v. (Centralab 850S-100N).

C_7—Neutralizing capacitor; see text and Fig. 4.

C_8—Screen bypass, built into socket.

J_1—Coaxial receptacle.

L_1—12 turns No. 16 tinned, ½-inch diam., 16 t.p.i. (Air-Dux 416T).

L_2—7 turns No. 16 tinned, ½-inch diam., 8 t.p.i. (Air-Dux 408T).

L_3—4 turns like L_2.

L_4—4 turns ⅛-inch copper tubing, 1-inch diam., ¾ inch long.

L_5—3 turns No. 16 tinned, wound on 50-ohm 1-watt resistor.

L_6, L_7—Links of insulated wire around cold ends of L_2 and L_3, 1 turn each. Can be made from ends of connecting 50-ohm coax, with outer conductor removed.

R_1—10,000-ohm 4-watt control.

R_2—50-ohm 10-watt slide type.

RFC_1—2.5-mh. r.f. choke (National R-100).

RFC_2—44-μh. r.f. choke (Ohmite Z-14).

RFC_3—7-μh. r.f. choke (Ohmite Z-50).

RFC_4—3-μh. r.f. choke. 48 turns like L_1.

S_1—D.p.d.t. toggle.

T_1—6.3 volts, 4 amp. Adjust R_1 for 6.0 volts at heater terminals.

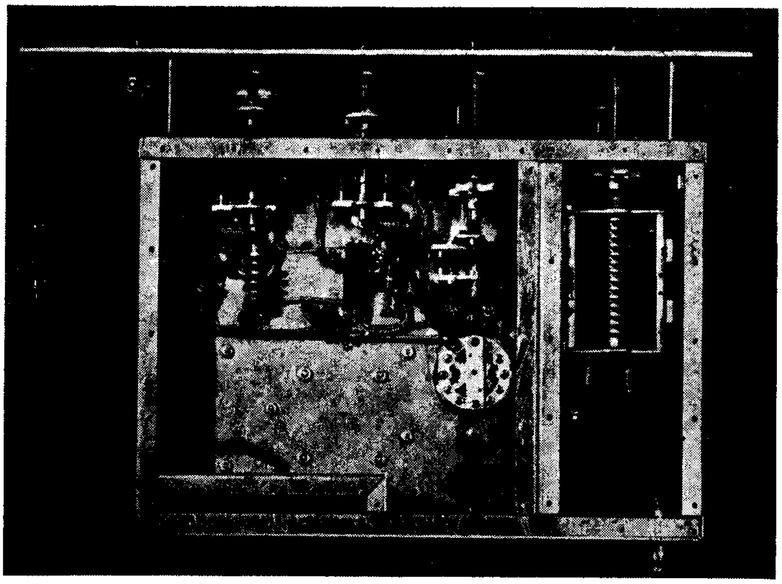

Fig. 3—Under-chassis view of the transmitter. The blower exhaust port is at the lower left, just above the terminal strip shield. All power leads are run in shield braid, with the center conductor bypassed to the braid at each end. The right-hand compartment houses the final-amplifier tank circuit. The 4CX300A socket is at the center of the chassis, behind the grid-tuning capacitor, C_3. Under-chassis area is pressurized by a solid plate, removed for photography.

designed for v.h.f. operation. In addition, the socket screen terminal is bypassed with a 0.001-μf. disk ceramic capacitor.

Four panel-mounted meters are used to indicate the currents drawn by the various stages. The left meter measures the plate current of either the oscillator or doubler. A double-pole double-throw switch, S_1, connects the meter across the appropriate 150-ohm shunt. Individual meters are used in the grid, screen and plate circuits of the final amplifier. The plate-current meter, right, is placed in the negative lead from the high-voltage supply, requiring that the negative lead not be connected to ground at any point in the supply.

The oscillator and doubler stages are operated from a 350-volt 150-ma. power supply which also provides the screen voltage for the amplifier stage. C.w. keying is best accomplished by breaking the plate and screen voltage of the doubler stage at the keying point indicated in the schematic, allowing the oscillator to run continuously. A suitable *LC* filter must be used at this point to suppress key clicks, and the use of a keying relay is recommended to remove high voltage from the key. This is preferred to keying the cathode of the 6V6GT.

Transmitter Construction

Reliability is the watchword in the design of this transmitter, and the construction technique used is the tried-and-true relay-rack style, designed to remove as much thermal heat from the equipment as possible. Nearly 200 watts is dissipated by the transmitter when running "wide open," so special pains are taken to insure that all components run cool, and well within their ratings. As the complete transmitter has to be shielded to reduce unwanted radiation, the problem of heat radiation is an important one.

The transmitter is enclosed in a home-made aluminum box 14 inches wide, 10 inches deep, and 6½ inches high. The enclosure is supported behind a standard 7 by 19-inch rack panel by means of four 2-inch metal pillars, thus providing space for the various switches and meters to be mounted behind the panel and out of the strong r.f. field. The top of the enclosure and the small portion of the bottom directly below the final tuning capacitors are covered by perforated aluminum sheet. The chassis portion of the enclosure has a solid aluminum sheet bottom plate, making possible chassis pressurization by the blower, the air escaping through the SK-710 socket and the SK-606 chimney and cooling the 4CX300A anode. A small aluminum shield (lower left corner, Fig. 3) was placed in one corner of the underchassis area to prevent the radiation of harmonics via the terminal-strip connections. Shielded wire is used for all power leads, and each terminal of the barrier strip is bypassed.

The blower used to cool the 4CX300A is a "home-brew" device. A squirrel-cage blower is driven by a phonograph motor which turns at about 3300 r.p.m. The unit moves enough air to cool the tube adequately up to about 150 watts plate dissipation, but would be insufficient for the full 300-watt dissipation rating. However, in neither the keyed c.w. mode (625 watts input) or the a.m. mode (300 watts input) does the average plate dissipation exceed 125 watts, so full dissipation is not required. Although the blower is rated at 10 cubic feet per minute, chassis back-pressure reduces the air flow to less than 4 c.f.m.

The neutralizing capacitor, C_7, is formed by placing a ½-inch square aluminum plate adjacent to the anode of the tube, the separation being about ⅜ inch. This capacitor may be seen in the top-view photograph, Fig. 4, appearing as a small bracket between the 4CX300A and the front panel. The plate is mounted on the top of a ceramic feed-through insulator, which brings the neutralization lead from beneath the chassis.

Component Layout and Wiring

Parts layout is not especially critical. The stages are placed so that the tuning controls are evenly spaced across the front panel, even though the chassis is offset slightly from the center line of the panel (see under-chassis photograph). The blower and motor are placed in a corner of the chassis, with the blower exhaust duct passing through the deck of the chassis. All under-chassis power and filament wiring is done with shielded wire, and r.f. leads are made short and direct. The interstage link circuit is made of a short length of RG-58/U, 52-ohm coaxial line, with the outer shield of the line grounded at both ends. Flexible couplings and panel bushings are used on the tuning-capacitor shafts to insure that the controls turn evenly and smoothly. Capacitors C_1 and C_2 are grounded to the chassis, but capacitor C_3 is mounted on an insulating block, as its rotor is above ground.

The plate circuit of the 4CX300A employed a home-made choke, RFC_4, air-wound over a ½-inch-diameter form. After a period of time, it was found that the choke had a tendency to sag a bit, so a section of Air-Dux coil was substituted for the home-brew choke (see parts list).

The pi-network capacitors, C_4 and C_5, are mounted by their front frames to a ¼-inch Plexiglas or phenolic sheet measuring 3½ by 4½ inches which, in turn, is supported from the front wall of the enclosure by one-inch metal bolts and pillars. The capacitors are driven by insulated couplings and thus the rotor shafts are floating above ground. The rear frame of each capacitor is then grounded to the chassis by means of a ½ inch wide copper strap running from the frame to the side of the chassis box via the shortest possible route. Ground loops are thus avoided, and the 6-meter pi-circuit tunes in a normal manner, "just like on the d.c. bands!"

The amplifier plate coil, L_4, is supported on two one-inch ceramic insulators bolted to the rear frame of the tuning capacitors, and connections to the coil, capacitors, and plate blocking capacitor are made with ½-inch copper strap. The auxiliary loading capacitor, C_6, and grounding choke, RFC_5, are mounted on the rear of the variable loading capacitor, C_5. A short length of RG-58/U 52-ohm coaxial line connects the loading capacitor to the coaxial receptacle mounted on the rear wall of the enclosure. The outer braid of the line is grounded at the receptacle and also at the common point on the chassis wall to which the tuning capacitors are grounded.

Transmitter Operation

Once the transmitter has been completed, the wiring should be checked for possible errors before the equipment is given the "smoke test." A filament supply of 6.0 volts at about 4 amperes is required. It is important to note that the filament voltage of the 4CX300A is *6.0 volts, not 6.3 volts*, and the voltage should be held within plus or minus 5 per cent of the design voltage if best tube life is to be obtained. Borrow a good, one-per-cent laboratory-type voltmeter to check your filament voltage and adjust it to 6.0 volts, or a little under. The 6AG7 and 6V6GT will work well at this slightly-lower-than-normal filament voltage. The blower should be turned on with the filament voltage to make sure that the stem of the 4CX300A remains cool, and the bottom plate should be in position to pressurize the chassis.

For initial tune up, the screen and plate voltages are removed from the 4CX300A. Remember that screen voltage should not be applied to the amplifier stage unless plate and bias voltages are also on the tube. It is permissible to apply or remove all voltages simultaneously, but screen voltage should never be applied *before* grid bias voltage and plate voltage are on, or screen current and dissipation will be excessive. This sequence of operation applies to all tetrode tubes, including small receiving tubes.

The 90-volt bias supply for the 4CX300A must be capable of withstanding about 30 ma. of grid current without serious loss of voltage regulation. A simple 50-ma. supply with a VR90 regulator tube will do the job. Adjust the series resistor to pass maximum current (40 ma.) when the supply is disconnected from the transmitter.

After the tuned circuits have been set to their approximate resonant frequencies with the aid of a grid-dip oscillator, an appropriate crystal is placed in the panel socket and high voltage applied to the oscillator and doubler stages, and bias to the 4CX300A. The drive potentiometer, R_1, is set for minimum screen voltage on the 6V6GT and the tuned circuits are resonated for an indication of grid current on the 4CX300A grid meter. The drive control is adjusted for about 5 ma. amplifier grid current.

The 4CX300A stage is next neutralized in the normal manner, the neutralizing capacitor being adjusted so

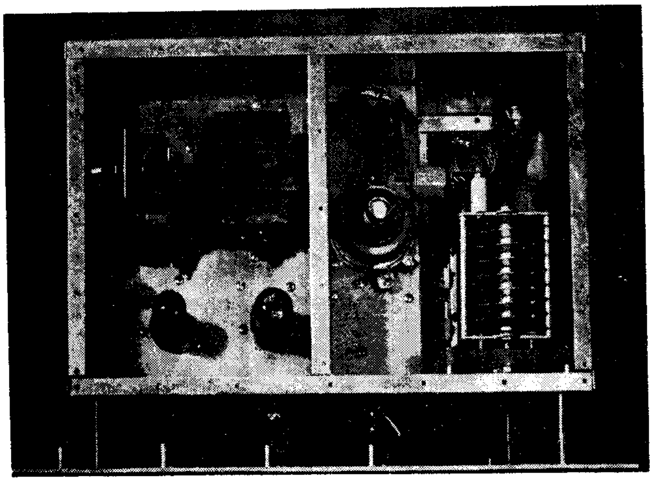

Fig. 4—In this view the blower and filament transformer are seen in the left-hand compartment near the rear of the chassis. Chassis plate, side pieces and shields are made from flat aluminum with flanges folded in a metal brake. In the left compartment are 0A2 regulator, 6AG7 oscillator, and 6V6GT doubler. The 4CX300A amplifier is on the edge of the chassis in the right-hand compartment, along with the plate-circuit components.

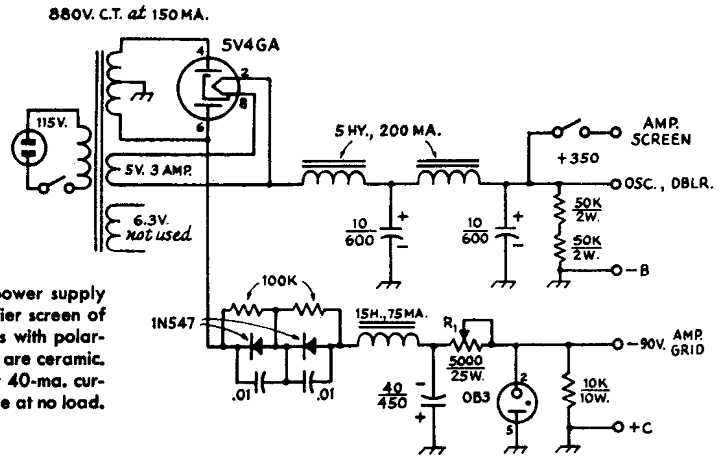

Fig. 5—Circuit diagram of the power supply for the exciter stages and amplifier screen of the 50-Mc. transmitter. Capacitors with polarity marked are electrolytic, others are ceramic. The slider on R_1 should be set for 40-ma. current flow through the regulator tube at no load.

that a minimum of grid current variation is noted when the plate tuning capacitor, C_4, is tuned through resonance (loading capacitor C_5 is set at maximum for this adjustment). Alternatively, a small pilot lamp or other r.f. indicator may be coupled to the coaxial antenna jack and the neutralizing capacitor adjusted for minimum feed-through power. Once the stage is properly neutralized, little or no change on the grid meter will be noted as the amplifier plate circuit is tuned through resonance.

When all is working properly, the transmitter may be connected to the antenna feed line or to a dummy load, and grid drive, screen and plate voltage applied to the amplifier stage. Start with the drive control set near minimum. Increase the drive slightly and establish resonance in the plate tank circuit. Drive and loading are now increased until the typical operating conditions indicated in the table are achieved. The amplifier stage should never be operated in a lightly-loaded condition unless the drive level is reduced. With a little practice, you'll soon observe that grid, screen and plate currents are a function of both grid drive and antenna loading. If loading is too light, grid and screen current will be high. If the loading is too heavy, grid and screen current will tend to be low. Screen current, it should be noted, is an extremely sensitive indication of proper balance between drive and loading. In fact, under conditions of heavy loading, the screen current of a tetrode may reverse. This phenomenon, common to tetrode tubes, makes it dangerous to rely upon a screen-dropping resistor or a series regulator to supply the screen voltage unless a bleeder is connected from screen to cathode. The bleeder should draw at least 15 milliamperes. Resistor R_2 in the screen circuit of the 4CX300A fulfills this requirement. Since it is placed before the screen meter, the bleeder current does not register.

TABLE I

Typical Operating Conditions for the 4CX300A

Circuit	*Class C* Telegraphy	*Class C* Telephony	*Class AB_1* Linear, S.S.B.
Plate Voltage	2500	1500	2500
Screen Voltage	250	250	350
Grid Voltage	−90	−100*	−55
Plate Current, ma.	250	200	100–250
Screen Current, ma.	16	20	4
Grid Current, ma.	25	14	—
Driving Power, watts	2.8	1.7	—
Plate Input, watts	625	300	625
Power Output, watts	500	235	400

* −90 volts fixed, plus 10 volts rectified bias.

For complete operating data, see information accompanying the tube, or write the authors.

Modulating the Transmitter

For a.m. phone, the final amplifier may be plate modulated. Plate potential is reduced to 1500 or 1000 volts. A pair of 811As, operating at the same voltage, will make a satisfactory modulator. As with other tetrodes, it is necessary to provide some modulating voltage to the screen element of the 4CX300A. A choke of 10 henrys (50-ma. rating) in series with the screen supply circuit, between R_2 and the meter, will provide adequate screen modulation so that 100-per-cent plate modulation may be achieved.

Using an External V.F.O.

An external v.f.o. may be used with this transmitter by changing the 6AG7 oscillator stage to a frequency multiplier and injecting a 6- or 8-Mc. frequency into the panel crystal socket. To do this, it is only necessary to ground the crystal socket pin connected to the 0.005-μf. screen-blocking capacitor. The output of the v.f.o. may now be injected into the crystal socket via a short length of coaxial cable. The inner conductor of the cable is terminated to the socket pin attached to the 6AG7 grid terminal, and the shield of the cable is attached to the grounded socket pin. An old FT-243 crystal holder may be used for the plug on the end of the cable. If one of the 4-40 bolts holding the crystal socket to the panel is reversed and allowed to project beyond the panel, a small clip on the shield of the cable may be used to ground both the shield and the proper socket pin by clipping it to the projecting bolt. Other methods of connecting a v.f.o. are shown in July 1963 *QST*, page 16.