More About the Three-Control Six-Band 813 Transmitter

Supplementary Data on the 500-Watt Rig

BY C. VERNON CHAMBERS,* W1JEQ

• The 813 transmitter described originally in *QST* for January, 1954, and carried in subsequent editions of the ARRL *Handbook*, still continues to enjoy widespread popularity. Answering several hundred inquiries during the past 2½ years has given us an opportunity to find out the things that most often bother the ham in duplicating the performance of the original. This article covers these problems and also the matters of coupling to an antenna system and the installation of a differential keying system.

Most of those who have had previous experience in building a multistage transmitter have had little difficulty in duplicating the 813 rig described in *QST* for January, 1954.[1] However, many who have made this their first major attempt at construction have run into various stumbling blocks or have been uncertain about specific points. There are others who have asked about such things as a simple method of installing a differential keying system and a suitable antenna tuner. We will try to cover the points brought up most frequently.

Some of those who have written in more recently have apparently overlooked the second article which dealt with some of the problems. If you missed it, look in *QST* for June, 1955.[2]

* Technical Assistant, *QST*.

[1] Chambers, "Three-Control Six-Band 813 Transmitter," *QST*, January, 1954. Also *The Radio Amateur's Handbook*, 31st–33rd editions.

[2] Chambers, "Supplementary Data on the Three-Control 813 Transmitter," *QST*, June, 1954.

Drive to the 813

The most common difficulty reported is inadequate drive for the final at the higher frequencies, especially 28 Mc. Fear that the driver is incapa-

Fig. 1 — This front view of the 813 transmitter identifies the decal markings for the meters and the tuning controls. Dials for the amplifier plate capacitor and the excitation control are National types AM-3 and P, respectively. The latter is no longer manufactured. The grid, plate, v.f.o. and antenna-coupler capacitors located at the bottom of the panel are equipped with National type HRS-5 (black) knobs. Type HRS-4 knobs are used with the three rotary switches.

ble of delivering ample excitation for the 813 should be dispelled. The tube lineup is entirely adequate for proper drive to the final, and a large majority of those who have built the unit have had no trouble. Most of the difficulty arises in adjustment of the slug-tuned coil L_2, and insufficient voltage from the exciter power supply. The circuit, including L_2, has a wide tuning range — approximately 3.5 to 5 Mc. When adjusted for constant input to the grid of V_4 as originally outlined, the coil will resonate somewhere around 4.5 Mc. and the grid voltage across the 22K grid resistor (the one connected in series with L_2) will be −18 volts or so as indicated by a v.t.v.m. If, in the attempt to regulate the drive for V_4, it is necessary to tune L_2 above 4.5 Mc., the grid voltage for V_4 will drop too far below −18 volts to assure adequate drive for the tube.

Practical experience with the transmitter has proved that flat input to the buffer is less important than previously anticipated. Therefore, L_2 may be tuned for maximum drive to V_4 at 3.6 Mc. (approximately −25 volts). This results in increased excitation all along the line, and provides a considerable boost in the 28-Mc. excitation to the 813. Naturally, the amplifier excitation is also increased at the lower frequencies, but this is of no consequence because any excessive drive can be handled by means of the excitation control.

It is difficult to check the resonant frequency of L_2 (with the coil wired into the transmitter) because of the swamping effect of the 4.7K cathode resistor for V_3. If you want to grid-dip the inductor, it is suggested that the cathode resistance be temporarily increased to 50K or more. The plate voltage should be off.

It is important that V_1, V_3, V_4 and V_5 operate with a plate potential of 300 volts. The 6146, V_6, requires a full 400 volts for the plate. When checking plate voltage for these tubes, remember that the plate current for V_5 and V_6 increases as the operating frequency is raised. Therefore, make certain that the exciter supply delivers 400 volts under 28-Mc. load conditions.

The varying load caused by band changing in the multiplier stage may cause the plate voltage for V_1, V_3, V_4 and V_5 to drop below 300 volts in some cases. If this happens, the existing dropping resistor (1000 ohms fixed) should be replaced with a slider-type, 20-watt unit. Adjust the resistance so that these tubes receive 300 volts when the rig is tuned to 28 Mc. Fig. 4 shows a suitable mounting position for the resistor.

The accompanying current-voltage chart shows operating conditions for 3.5 through 28 Mc. in the original transmitter. Voltage readings were

Voltage-Current Chart for the 813 Transmitter

Tube	*Band (Mc.)*	*Grid 1 (volts)*	*Grid 1 (ma.)*	*Grid 2 (volts)*	*Grid 2 (ma.)*	*Cathode (volts)*	*Plate (volts)*	*Plate (ma.)*
V_1	3.5	−16	—	150	—	0.6	300	—
V_3	3.5	—	—	—	—	39	300	—
V_4	3.5	−18	—	190	—	19	300	35
V_5	3.5	−64	—	115	—	27.5	300	5.5
V_5	7	−61	—	115	—	27.5	300	5.5
V_5	14	−58	—	170	—	34	300	8.5
V_6	3.5	−75	*	170	—	—	400	55
V_6	7	−76	*	170	—	—	400	63
V_6	14	−80	*	185	—	—	400	87
V_6	21	−80	*	195	—	—	400	90
V_6	28	−75	*	175	—	—	400	105
V_7	3.5	−165	17	400	40	—	2000	220
V_7	7	−185	18	400	40	—	2000	220
V_7	14	−190	19	400	35	—	2000	220
V_7	21	−190	20	400	35	—	2000	220
V_7	28	−190	19	400	40	—	2000	220

* Approximately 2 ma. Depends on setting of excitation control.

made with a v.t.v.m. (except for the 813 plate voltage) and the output voltages of the exciter and the amplifier plate supplies were 400 and 2000 volts, respectively, with the rig fully loaded at 28 Mc. Grid voltage for V_3 is not listed because this tube operates Class A.

In their anxiety to do a thorough job, some of the boys carried the TVI preventive procedure a bit too far by using shielded wire for some of the r.f. leads, particularly the leads from the tanks to the control grids of the 6146 and the 813. The capacitance of shielded wire, of course, detunes the multiband circuits and a good portion of the excitation may be lost.

Inasmuch as two rigs are seldom completely identical as to stray capacitance, it is understandable that the original values of inductance for the multiband tanks — especially those at the grid and the plate sides of V_6 — may require slight modification. If the tuning range of these tanks has been affected by a new order of minimum capacitance, it may be impossible to resonate the exciter for maximum output at 28 Mc. The proper

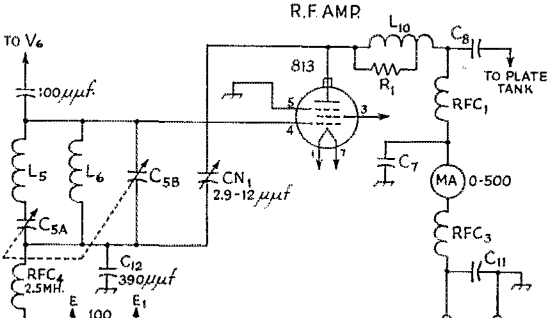

Fig. 2 — Capacitive-bridge neutralizing circuit for the 813 power-amplifier stage. This same method of stabilizing an amplifier may be used with the 6146 at 3.5 Mc. C_{12} and RFC_4 (not labeled in the original circuit) now have values of 390 $\mu\mu$f. and 2.5 mh., respectively.

CN_1 — 2.9–12-$\mu\mu$f. neutralizing capacitor (E. F. Johnson N-250).

C_{12} — 390-$\mu\mu$f. tubular ceramic.

L_{10} — Parasitic choke: 6 turns No. 16 tinned wire, 1¼ inches long, ¼-inch diameter.

R_1 — Five 470-ohm 1-watt carbon resistors in parallel, tapped across 3 turns of L_{10}.

adjustment of multiband tanks has been covered in previous articles.[3]

Output Impedance, Antenna Couplers and Antennas

These three subjects are grouped under a common heading because of their close relationship. And let's start out by clearing up the fairly prevalent opinion that there is something tricky about the output-coupling circuit ($L_8C_{10}S_2$). Except for a simple switching arrangement which shorts out the unused part of the link winding, it is identical to the series-tuned arrangement commonly used for coupling amplifiers to 50-ohm coaxial lines. Anyone interested in the circuit will find the required reading under "Output Coupling Systems" in Chapter 6 of *The Radio Amateur's Handbook.*

Several constructors who encountered difficulty loading the 813 transmitter discovered that they had improperly wired the $C_{10}L_8S_2$ combination. To prevent others from making the same mistake, we offer the following:

A tap on L_8 — the one that goes to C_{10} and S_{2B} — effectively divides the inductor into two sections. The 8-turn section is used for coupling to the LO-BAND plate inductor, L_7, and the 1-turn link is used for coupling to L_9 at 14 through 28 Mc. There are two precautions to observe when installing this tapped coil. First, make certain that the small link is adjacent to L_9. This, in turn, will place the 8-turn section next to L_7. Second, carefully study the transmitter diagram before wiring L_8 to S_2. It is very easy to end up with the wrong link shorted when the switch is thrown to either the LO- or HI-BAND positions. The circuit of the transmitter shows the switch in the 3.5–7-Mc. position.

The transmitter output circuit is designed to feed a 50-ohm resistive load. This doesn't mean feeding a 50-ohm coax line with any old antenna connected at the other end. Unless the antenna is matched to the line, it will introduce reactance in the output coupling circuit and cause the amplifier plate capacitor, C_9, and the output capacitor, C_{10}, to resonate at dial settings that do not coincide with those previously listed.[1] To operators having no prior working acquaintance with coaxial output systems, we recommend "Matching the Load to the Line," Chapter 13, *The Radio Amateur's Handbook,* as a complete source of information on any adjustments which may be necessary to match the antenna to the transmission line.

If the antenna to be used with the transmitter is fed with an open-wire line or is a high-input-impedance affair, it is advisable to use a coax-coupled matching circuit between the transmitter output and the antenna or feedline. The 500-watt antenna coupler described in the "Coupler or Matching-Circuit Construction" section of Chapter 13 (*Handbook*) is ideal for coupling most of the popular all-band antennas to the 813 rig. Another section of Chapter 13, "Coupling the Transmitter to the Line," explains how the an-

[3] Johnson, "Multiband Tuning Circuits," *QST*, July, 1954.
Chambers, "Single-Ended Multiband Tuners," *QST*, July, 1954.

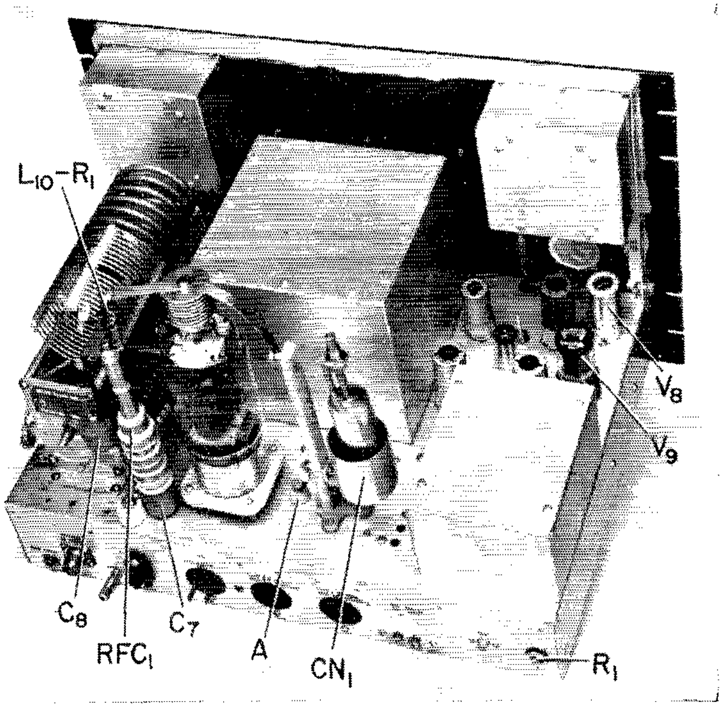

Fig. 3 — Rear view of the modified 813 transmitter. The type R-175A choke is mounted on C_7 (original component) to the left of the tube. The parasitic trap, $L_{10}R_1$, is at the top of the choke and the neutralizing capacitor, CN_1, is to the right of the 813. Keyer tubes are to the right of the buffer and the multiplier tubes in the upper right-hand corner of the chassis.

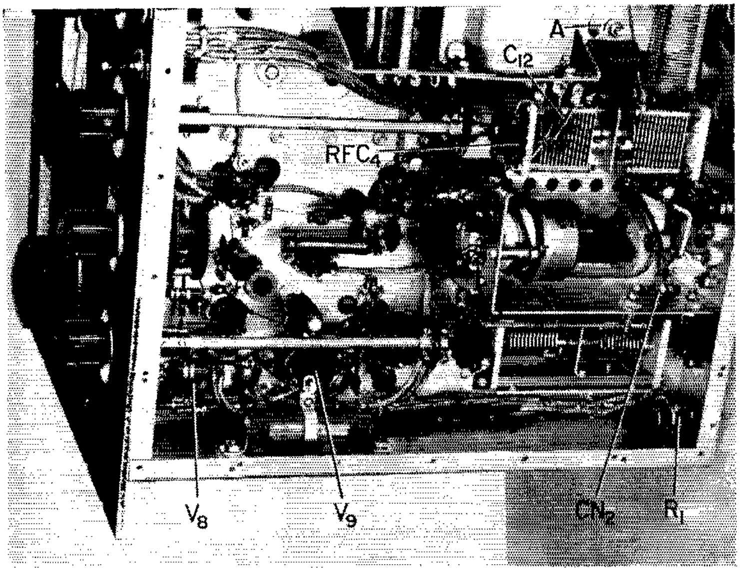

Fig. 4 — In this view, the potentiometer for the keyer control-tube, V_{8A}, is mounted on the wall at the bottom right-hand corner of the chassis as seen in this view. The neutralizing capacitor for the 6146, CN_2, is supported by National TPB through-point bushings. Sockets for the keyer tubes are in the lower left-hand section of the unit and the 20-watt adjustable resistor is mounted on the bottom wall.

tenna-coupler adjustments may be speeded up and checked with the aid of an s.w.r. bridge.

Neutralization, Parasitics, and R.F. Feed-Through

The second article on the 813 transmitter [2] explained why some duplicates of the rig might require neutralization and suggested the *Handbook* capacitive-bridge system as a cure for instability. This bit of information has prompted a number of inquiries. Some reported the need for neutralization and questioned the effectiveness of the recommended neutralizing circuit. Others asked if a neutralizing circuit would clean up certain erratic current readings observed while tuning the final. And still others referred to r.f. feed-through (from grid to plate of the amplifier when operated without plate and screen voltage) detected by one means or another.

The first step toward the cure for instability is the grounding of the beam-forming plates (Pin 5) of the 813 as recommended earlier.[2] Following the usual practice at that time, the transmitter diagram did not show this connection.

If instability is encountered in a rig having Pin 5 grounded, attempt to determine the frequency of oscillation. Three common types of oscillation may take place in an amplifier. Since different measures must be taken to suppress each type, it is important that the type be identified before it can be treated intelligently. V.h.f.- and low-frequency parasitic oscillations are difficulties that may or may not pop up in a duplicate transmitter and either one can cause erratic meter readings. The methods of testing, and the remedies for these types of oscillation are thoroughly treated in "Stabilizing Amplifiers," Chapter 6 of the *Handbook*.

Should the oscillation be at the fundamental frequency, it may quit when a load is coupled to the amplifier. When loading fails to stabilize the output stage, check the performance of each exciter tube — one of them may be oscillating hard enough to drive the final during key-up periods. The *Handbook* section referred to above explains how the tests should be made.

When the need for neutralization has become an established fact, consider use of the capacitive-bridge system previously referred to.[2] Fig. 2 shows this circuit applied to the original 813 amplifier. As far as neutralization is concerned, CN_1 is the only addition to the amplifier. However, it was necessary to reduce the value of C_{12} (originally 0.001 μμf. and not labeled) to 390 μμf. to make the ratio of CN_1 to C_{12} equal the ratio of the tube grid-plate capacitance to the input capacitance (see *Handbook*). The value of RFC_4 (not labeled on the transmitter circuit diagram) has been increased to 2.5 mh., and L_{10} and R_1 have been added to suppress low-frequency and v.h.f. parasitics that developed after the amplifier had been modified for neutralization, and the National type R-175A plate choke had been substituted. More about the choke later on.

The neutralizing capacitor is mounted on the chassis as shown in Fig. 3. A feed-through bushing, A, to the left of CN_1 permits connection between the stator side of the capacitor and the grid circuit. Strips of ⅜-inch-wide flashing copper are used for above-chassis leads to the capacitor. A heat-radiating plate cap for the 813 serves its intended purpose and also provides a convenient means of terminating the copper leads running to CN_1 and the parasitic trap. Fig. 4 shows the positions of the feed-through bushing, A, C_{12} and RFC_4 as viewed from the bottom.

Neutralizing adjustments are also described in Chapter 6 of the *Handbook*. The section about this subject should also be reviewed for information about r.f. feed-through (mentioned earlier). Note in particular that feed-through cannot always be reduced to zero but that the correct adjustment should give a *minimum* reading on the r.f. indicator. The sensitivity of the indicator will frequently determine whether or not the reading can be reduced to zero.

The 6146, when operated straight through, is probably the only driver tube that may require neutralization. We were able to *make* the stage oscillate weakly and intermittently, but only after increasing plate and screen voltage, removing excitation and adjusting the grid and plate controls to settings not normally used. All of this was done so that the capacitive neutralizing system could be tried in this stage. The system did work and required neutralizing and grid bypass capacitances of approximately 1.5 and 500 $\mu\mu$f., respectively. This means that the 0.001-$\mu\mu$f. capacitor formerly used between C_4 and ground must be replaced with the 500-$\mu\mu$f. unit. The neutralizing capacitor, labeled in Fig. 4 as CN_2, may be a pair of 3-$\mu\mu$f. ceramic tubulars connected in series. Incidentally, several makes of TV-type tubular trimmers broke down when tried in the neutralizing circuit.

A low-frequency parasitic that turned up in the multiplier-driver stage after neutralizing components had been installed was killed by replacing the 1-mh. grid choke with a 2.5-mh. job. This oscillation occurred only when the plate voltage for V_6 was increased to 450 volts or above.

Keying

Although the 813 transmitter employs straight cathode keying of the oscillator, we have received very few unfavorable reports concerning chirp, clicks, etc. However, many perfectionists have requested dope on a differential keyer circuit that could be added to the rig. A few hours of lab work proved that the system described by Puckett [4] could be easily included as an integral part of the rig. All that is required in the way of operating voltage for the keyer will be found right there in the r.f. unit.

The keying circuit uses a type 12AU7 control tube and a type 6BL7GT vacuum-tube keyer, as shown in Fig. 5. This circuit also shows the modifications which have been made to the transmitter so that the keyer could be included. The bottom end of the 47K oscillator grid resistor has been lifted from ground and then returned to Pin 1 of V_8. The original key jack, J_1, has been moved over to Pin 7 of V_8, and the bottom end of the oscillator cathode choke is now grounded. Cathode bias for the multiplier stage, previously developed across a 220-ohm resistor, has been eliminated and the cathode of V_5 is returned to the plates of the 6BL7GT.

Undoubtedly, some individuals will question the advisability of keying the multiplier stage in preference to keying the following multiplier-driver. Actually, we would have preferred to key the 6146, but we felt that the voltage drop caused by the 6BL7GT (the tube may be regarded as a cathode resistor of about 1000 ohms) would adversely affect the output capability of the tube.

Installation of the keyer components is illustrated in Figs. 3 and 4. Heater voltage for V_8 and V_9 may be obtained by tapping onto the heater line for the r.f. tubes. Negative control voltage for the keyer tubes may be taken from the 6146 bias supply by connecting in at the junction of the 1.2K and 10K resistors. Plate voltage for V_{8B} can come from the 300-volt line for $V_1 - V_5$.

Adjustment of the keying circuit and the keying characteristics are explained in Puckett's article. The only other comment about keying that we have to offer concerns bias for the final amplifier. The "beyond cut-off" bias for the original rig tended to introduce clicks *after* the keyed stage and, as a result, the fixed bias for the 813 was reduced to approximately −65 volts. This was accomplished by substituting a 4700-ohm, 2-watt resistor for the 470-ohm filter resistor used in the bias pack.

General Information — Electrical

Yes, a National type R-175A r.f. choke may be used as RFC_1 in the 813 plate circuit. However, use of this choke as a replacement for the original homemade affair did affect the tuning range of the plate tank and made necessary the removal of 1 turn from L_7. The turn was removed from the C_8 end of the coil. Fig. 3 shows the R-175A mounted on C_7 at the rear of the chassis.

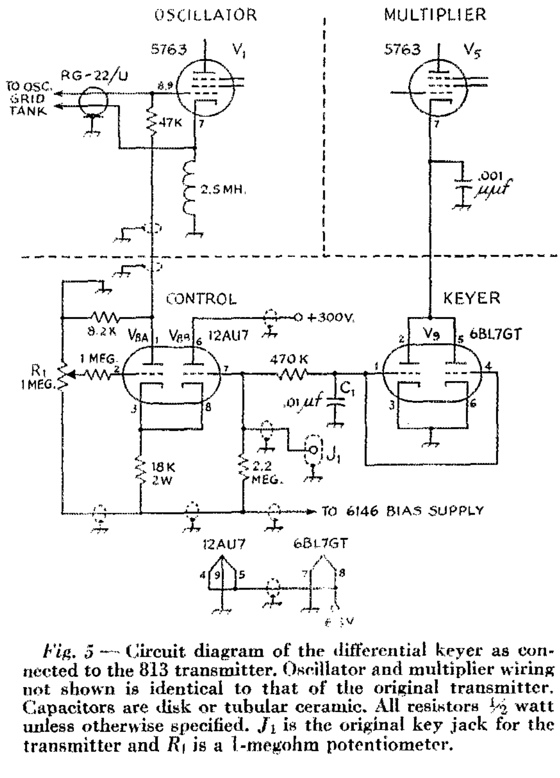

Fig. 5 — Circuit diagram of the differential keyer as connected to the 813 transmitter. Oscillator and multiplier wiring not shown is identical to that of the original transmitter. Capacitors are disk or tubular ceramic. All resistors ½ watt unless otherwise specified. J_1 is the original key jack for the transmitter and R_1 is a 1-megohm potentiometer.

[4] Puckett, "De Luxe Keying without Relays," *QST*, September, 1953.

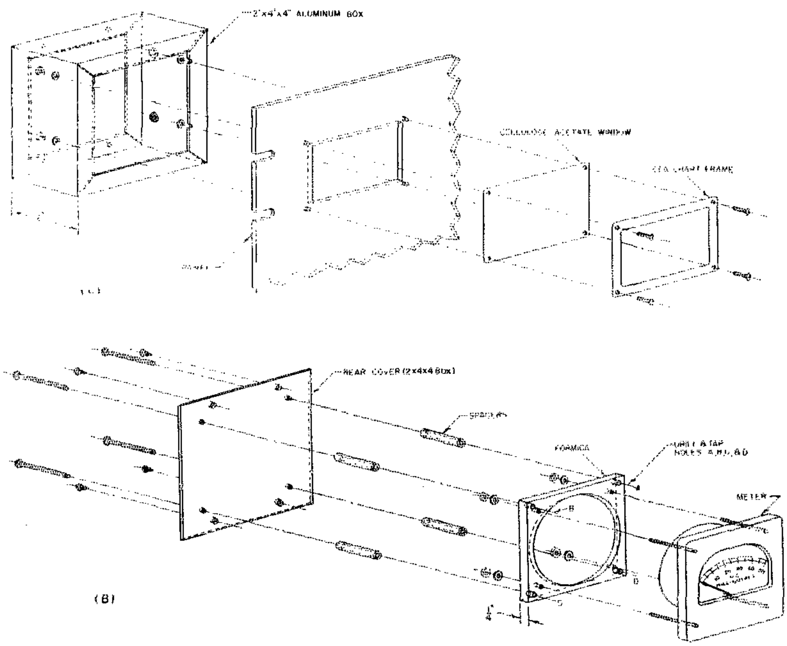

Fig. 6 — The chart frame, the panel and the aluminum box are held together, as shown in A, by the hardware supplied with the CFA. B shows a meter (Triplett Model 327-T), its insulated mounting ring, and the rear cover of the box. The meter assembly is slipped into the metal box after the latter has been attached to the rear of the panel. Shielded meter leads enter the bottom of the box through a rubber grommet. The shield braid should be bonded to the outside of the aluminum case at the point of entry.

The 100-ohm shunt in the screen lead to the 813 has been replaced with a 1-ohm, 1-watt resistor. This increases the full-scale reading of the 50-ma. meter to 100 ma. and prevents pinning of the pointer by high screen current drawn during tuning adjustments.

The parallel-tuned circuit formed by C_7, C_{11} and RFC_3 (approximately 250 $\mu\mu$f. in parallel with 2 μh.) has a natural resonance somewhere around 7 Mc. which may cause heating of the choke, harmonic output, or TVI difficulties. A check with a grid-dip meter will let you know if the resonant frequency needs moving. Raising or lowering the value of any one of the three components involved will do the trick.

Although we don't particularly recommend it, crystal control can be added to the transmitter provided you are prepared for some rather difficult mechanical problems. The oscillator revision may be patterned after the circuitry used in the remotely-tuned v.f.o. described elsewhere.[5] However, a great deal of care went into the mechanical design of the v.f.o. for the 813 rig, and it is difficult to visualize any switching or plug-in arrangement permitting crystal-v.f.o. operation that will not affect the stability of the v.f.o.

General Information — Mechanical

Procurement of a National type ACD-1 right-angle drive has been impossible for many constructors. Production of the unit was stopped shortly after the transmitter was completed. However, the National type RAD drive, now available, fits the application very nicely.

The meter boxes were improperly identified in *QST* for June, 1954. They are ICA type 29840 — not type 29804 as listed.

A new sketch of the mounting and the shielding of the meters is presented herewith as Fig. 6. Section A of the drawing shows the assembly formed by the chart frame and its cellulose-acetate window, the panel and an aluminum box. The front cover for the box is not used.

Section B of Fig. 6 shows the support for a meter. The distance from the face of the meter to the rear cover should not exceed 1⅞ inches. Reduce the length of the threaded meter terminals if necessary.

W1STX has just informed us that the full-scale drilling template for the transmitter is still available. See the Ham-ad on page 147, *QST*, July, 1955, for further information.

We are able to furnish 8 × 10-inch glossy prints of any or all of the photographs illustrating the articles (including the shots shown in this issue), at $1.00 per print, postpaid.

As is Headquarters' policy, each future inquiry about the transmitter will receive individual attention. However, we believe that the preceding articles [1,2] and this current write-up present just about every bit of constructional and operational data that there is to offer.

[5] Mix, "Simple Remote Tuning for the V.F.O.," *QST*, January, 1953. Also *The Radio Amateur's Handbook*, 31st–33rd editions.