A Tramplifier for 432 MHz

Table-top aid to access of Oscar 7, Mode B — a quiet gray box.

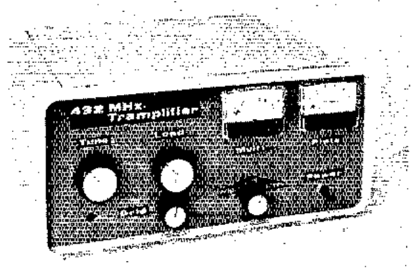
By Thomas McMullen,* W1SL and Clarke Greene,** WA1JLD

Let's roll the ball on 432 MHz! If you've been putting off building a medium-power amplifier for lack of an easy design to follow, this article is for you. You don't have to be an Oscar-7 enthusiast to appreciate this design, but if you are using Oscar in Mode B (432.15-MHz input/145.95-MHz output), you may need a bit more power to do the job effectively. The Tramplifier is probably just what you've been waiting to build.

Perhaps you're interested in conventional communications modes on 432, and don't have enough power available to compete with the chaps and gals who are running up big scores in contests and states-worked totals. If this description fits you, read on! Finally, you may be a person who finds new ideas interesting, but building homemade equipment isn't your preferred pastime. Should this be your outlook in amateur radio, keep reading. There are some novel ideas presented here.

*Assistant Technical Editor, *QST*.
**ARRL Laboratory Assistant.

[1] This and all subsequent footnotes can be found at the end of the article.



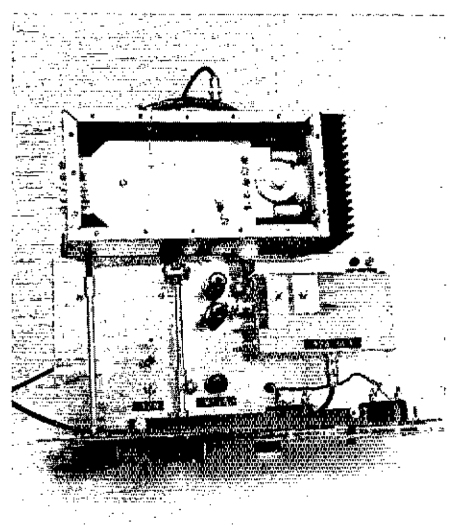
Equipment for 432 MHz varies in style, size, complexity, and ancestry. Some stations use converted uhf-fm transmitters that once saw duty in taxicabs or the like. Others have been able to build up-converters using tubes such as the 6939.[1] Others have pressed their 144-MHz equipment into service by employing an active frequency tripler.[2,3]

With most of these systems, there seems to be a plateau with an almost vertical wall between the two power levels. The simple or low-power systems needed too much antenna to reach the required radiated power for good use of the satellite, while the next step-up in power employed the 4X150/4CX250 family of tubes with the required noisy blower for cooling the anode.

A Quiet Alternative

The design criteria for a desirable amplifier were simple — a table-top conduction-cooled (quiet) unit that would deliver 100-watts output at a drive level of less than 10 watts. The table-top configuration would be more attractive to many station owners than would the old reliable rack-and-panel system of days gone by. The conduction-cooling requirement was to get away from the blower/air-hose/insulated-box problems that follow the usual external-anode design. At the 100-watt output level, some transmission-line loss could be tolerated and still allow the use of a modest antenna for satellite access.

Some of the new conduction-cooled triodes seemed attractive, but drive requirements were a bit above the capabilities of many present exciters. Transistors provide an interesting approach, but linear devices at the 100-watt level are difficult to obtain; the inclusion of linear mode for ssb operation was a must. A little-known member of the 4X150 family — the 8560A, seemed ideal. In appearance it resembles a 4CX250 that didn't get the cooling fins



The amplifier chassis is mounted parallel to the front panel. A varactor-diode tripler is mounted on the subchassis, at the right. This view of the amplifier shows the ceramic insulators that provide pressure to hold the tube anode against the thermal link and the heat-sink assembly. A half-wavelength plate line occupies most of the length of the chassis, with a flapper type of tuning capacitor mounted on the left wall. The two VR tubes, center, are regulators for the screen voltage. Insulated shafts extend into the plate compartment, under the plate line, where they rotate eccentric disks to provide tuning control. Two tip jacks at the extreme right allow a cooling fan to be connected, if needed for higher power operation.

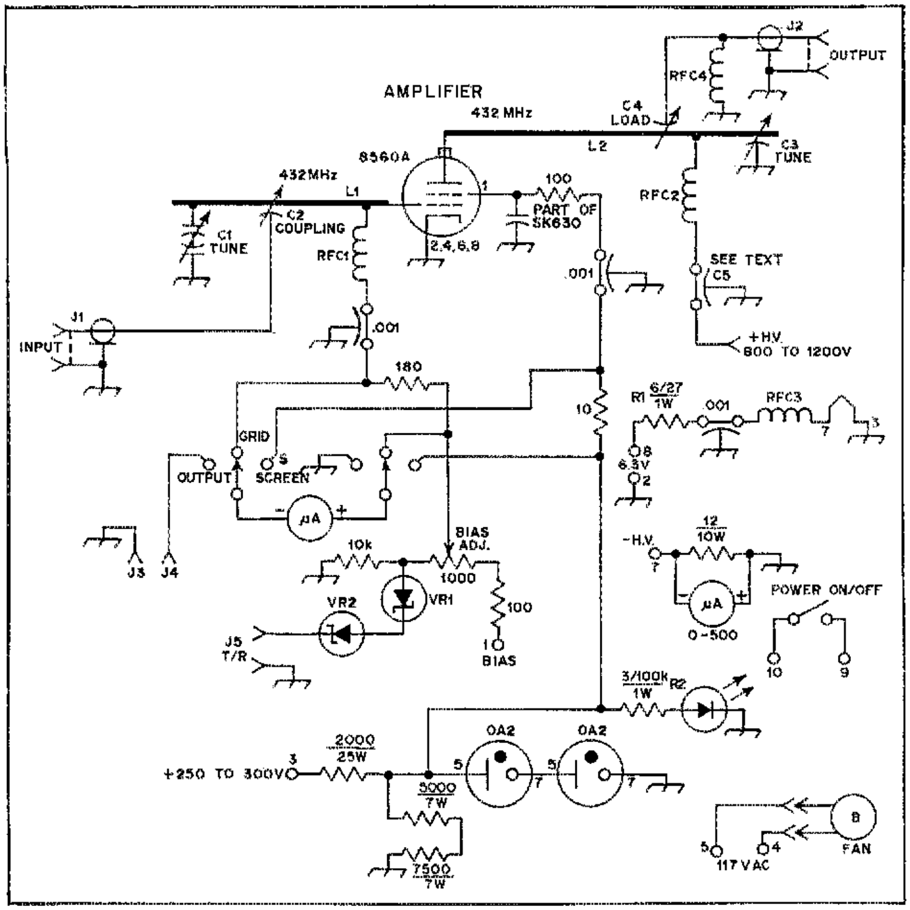


Fig. 1 — Schematic diagram of the 432-MHz amplifier.

C1 — 1.8- to 5.1-pF air variable, E. F. Johnson 160-0205-001. Mount on phenolic bracket.

C2 — 1/2-inch dia disk on center conductor of coaxial extension. See text and photograph.

C3,C4 — Spring-brass flapper type tuning capacitors. See text and Fig. 2.

C5 — 2-1/2 X 4-inch pc board, single-sided, with .01-inch thick Teflon sheet for insulation to chassis. Copper-foil side mounted toward the chassis wall.

CR1 — 1/4-inch dia LED.

J1 — BNC chassis-mount connector with threads filed to fit inside brass sleeve.

J2 — Type "N" coaxial connector.

J3,J4 — Tip jacks or binding posts.

J5 — Phono type connector. External relay contacts should be wired to short J5 for "carrier-on" condition.

J6 — High-voltage connector, James Millen 37001.

L1 — 1-3/4 X 4-inch double-sided pc board, spaced 7/8-inch from chassis.

L2 — 3-1/2 X 6-1/4-inch double-sided pc board or aluminum strip. Length from tip of line to tube center is 7-1/8 inches. See Fig. 2.

Heat Sink — Astrodyne No. 3216-0500-A0000, 5 X 5 inches. Can be painted flat black or anodized for better dissipation.

R1 — 27 ohm, 1-W resistor, 6 in parallel.

R2 — 100-kΩ 1-W resistor 3 in parallel.

attached to the anode, but rather has a solid block in place. Other than that, the characteristics of the two are almost identical. Drive requirements are low, and the tube can be cooled by clamping the anode to a heat sink through a thermal link.

Amplifier Circuitry

The amplifier draws heavily upon previous designs that utilized the air-cooled, external-anode tubes,[4,5] as shown in Fig. 1 and in the photographs. A half-wave grid line is fabricated from double-sided pc-board material. The input-coupling method departs slightly from previous examples, but only in the mechanics of adjustment. The plate line is similar to published information, with slight variations in the method of tuning.

Input coupling to the amplifier is by means of a capacitive probe to the grid line. A small tab of copper is soldered to the grid line and forms one side of the capacitor. A disk on the center conducter of a coaxial section is the movable portion of the coupling. This coaxial section is fabricated from pieces of brass tubing that will slide together, telescope fashion. A BNC chassis-mount fitting with the threads filed down is soldered into the inner, movable, piece of tubing to allow ease of connection from the exciter. A piece of copper wire and a couple of Teflon disks extend the center conducter for attachment of the capacitor plate inside the grid compartment Once adjusted, the sliding portion is held in place by means of a small compression clamp.

The plate line is the familiar half-wavelength variety, with capacitive tuning provided by movable vanes or "flappers." In earlier versions using this tuning scheme, the flappers were moved by means of string that was allowed to wind or unwind around a shaft, providing front-panel control. After a few instances of loss of control, caused by the nylon fishing line melting or becoming untied, the writers decided that there had to be a better way. Accordingly, the cam-on-a-rod method was tried and found satisfactory. Both plate -tuning and output-coupling flappers are adjusted in this manner (Fig. 2).

Cooling It

Several tests were performed to check the effectiveness of the thermal-link/heat-sink cooling system. With the aid of Temprobes,[6] it was determined that the tube would stay within maximum temperature ratings while dissipating 100 to 200 watts of dc. A liberal coating of thermal-conducting grease was used to aid heat transfer. More on this subject later.

Early tests with only dc applied, and later ones with the full dc and rf voltages present, confirmed that at the 100-watt output level no forced-air cooling was required. At higher output levels of 175 to 200 watts, the temperatures on the anode and heat sink were still below the maximum allowed by the manufacturer, but high enough that it was felt prudent to add a quiet "whisper" fan for safety. Operational tests proved that the added background noise was not distracting to the operator.

Construction

There are several configurations possible for the package, and the constructor should feel free to mold them to fit his idea of how things should be assembled. An LMB cabinet (CO-1) was selected for an enclosure because it matches many of the "gray boxes" found in a lot of shacks. Rather than mount the heat

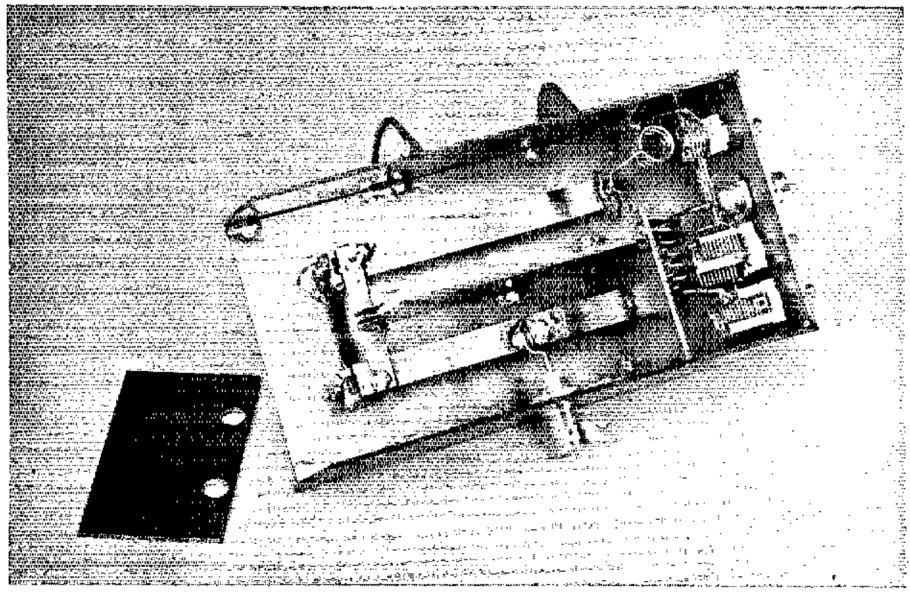
Table I
Operating Conditions

144-MHz drive power watts	*432-MHz drive power watts*	*432-MHz output power watts*
4	2	30
8	4	50
10	5	80
15	7	100
18	9	140

Ep — 1000 V.
Ip — 60 mA, zero signal.
Ip 300 mA, single tone (cw), 140 W output.

sink through an unsightly hole in the rear panel of the cabinet, it was decided to mount the amplifier parallel to the front panel. This places the heat sink inside, but there is adequate ventilation through the box to allow proper cooling. This mounting scheme also permits a fan to be mounted inside, so that there are no awkward protuberances to worry about behind the cabinet. A standard size chassis is used to fill the gap between the panel and the amplifier proper, and incidentally to provide a mounting space for peripheral electronics. As long as the parts placement within the amplifier grid and plate compartments is not changed from the design given here, it will not matter what is done externally.

The grid compartment is a 5 X 7 X 2-inch aluminum chassis with captive nuts in the bottom lip to permit securing the bottom plate. For the plate compartment a 5 X 10 X 3-inch aluminum chassis was modified to provide better mounting surfaces for the heat sink and to allow the plate-tuning flapper to be mounted on the end wall of the compartment. One end of the chassis was removed and pieces of aluminum angle stock were fastened around the open end. These pieces were drilled to accept No. 8-32 screws that thread into tapped holes in the heat sink. Tapped holes in the top surface of the heat sink and captive nuts in the top lips of the chassis permit a perforated top plate to be fastened securely for minimum rf leakage. Total dimensions are given in Fig. 2.



The varactor tripler is assembled in a box made from double-sided pc board. Construction of the tripler is described in Chapter 7 of the *Handbook.*

Tube Placement

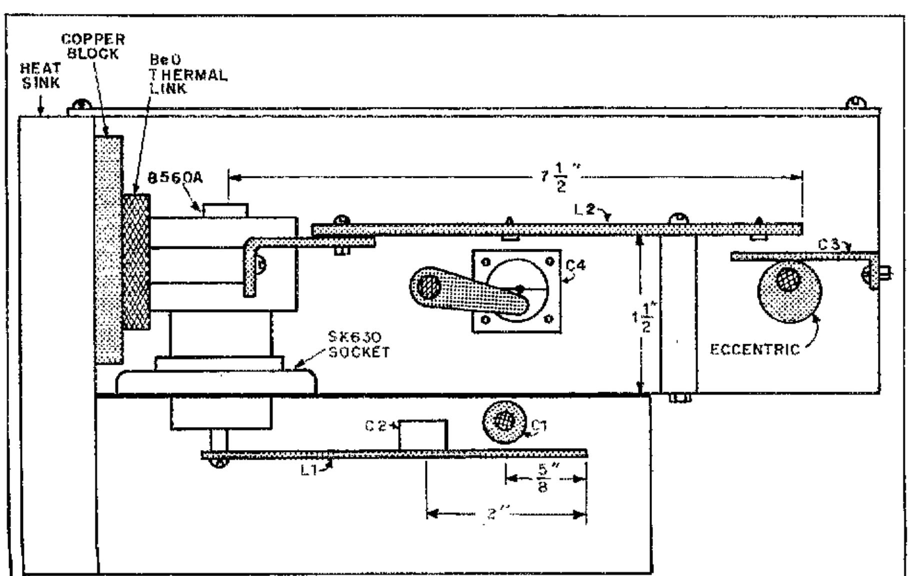
An Eimac SK-630 socket and SK-1920 thermal link are used in mounting the tube and conducting the heat away from the anode. The thermal link is made of toxic beryllium oxide (BeO). The manufacturer's caution against abrasion, fractures, or disposal should be heeded. Parts placement in the anode-block area is critical if efficient heat transfer and minimum strain on the tube are to be obtained. The tube socket must have sufficient clearance in its mounting hole that some lateral movement toward or away from the heat sink is allowed. The socket is secured to the chassis with the usual toe clamps supplied. Because of the rim formed on the socket by the integral screen-bypass capacitor, a spacer is needed between the thermal link and the heat sink. A piece of copper, 1/4-inch thick and 2-3/4 X 4-1/2-inches square, serves as the spacer, as well as providing excellent heat transfer to the inner face of the heat sink. This copper spacer and the BeO thermal link are both held in place between the tube anode and the heat sink by the pressure applied by the ceramic pillars. The anode end of the plate line is bent up to form a surface that will permit screws to thread into the insulators. In the early version of the amplifier this shaped and bent piece of aluminum was only long enough to provide some mounting surface to which the plate line (double-sided pc board in this instance) was fastened by means of five No. 6-32 screws and nuts with lock washers. The photograph shows this particular scheme in the top view. A later version had the pc board replaced with an aluminum strip of the same size. A still later test was made with the anode-clamp/plate line all constructed from one piece of aluminum. No difference in plate-circuit performance could be noticed, which was the reason for the tests of different materials.

A moderate coating of thermal-conducting grease should be applied between the copper plate, the heat sink, the thermal link, and the anode block. Don't overdo it, however. In one test a glob of the material found its way down to the screen ring, and the combination of rf and dc voltages between the screen and plate caused the material to break down

The Tripler

In case you haven't guessed, the tripler is responsible for the "Tr" part of the name, an appendage that was ap-

Fig. 2 — Cutaway drawing from the side of the grid and plate compartments. The plate line may be made of two pieces, as shown here, or of one single piece of aluminum strip. C4 is shown from the end-on view. The arm that moves C4 and the eccentric that moves C3 are fastened to their insulated shafts by epoxy cement. Small Teflon buttons prevent accidental shorts between the capacitors and the plate line.



plied to the combination while W1SL had his back turned. It seemed appropriate, so no great effort was expended to remove it.

The frequency tripler, using a varactor diode, is essentially a duplicate of the one described in other ARRL publications.[7] A slight change was made to permit easier adjustment; a 1000-ohm resistor was added in series with the normal bias resistor across the diode. This permits the diode current to be monitored during the tune-up procedure. A rough approximation of correct adjustment can be obtained by tuning the input circuitry for maximum voltage across the 1000-ohm resistor, and then adjusting the idler circuit and the output circuits for a dip in this reading. These adjustments should be made with the varactor output connected to a suitable 50-ohm load; reactive loads will cause the readings to be erratic and confusing. Final adjustments should be made with the aid of SWR meters and a sensitive wavemeter or other spectral-output indicating system. Once the tripler is adjusted for proper operation into a dummy load, *dont touch it.* Further adjustments should be done at the tube grid-input circuit.

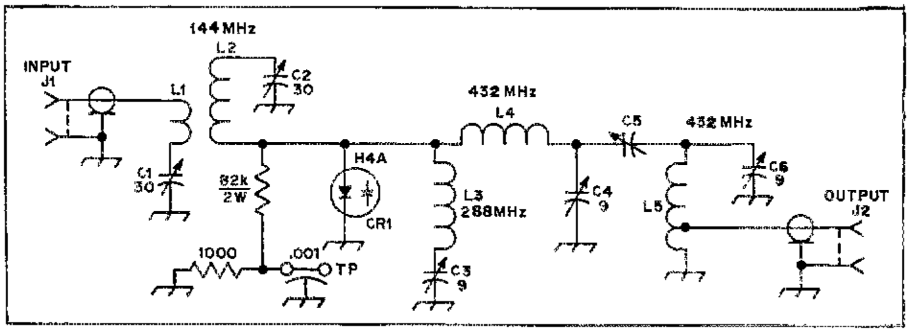
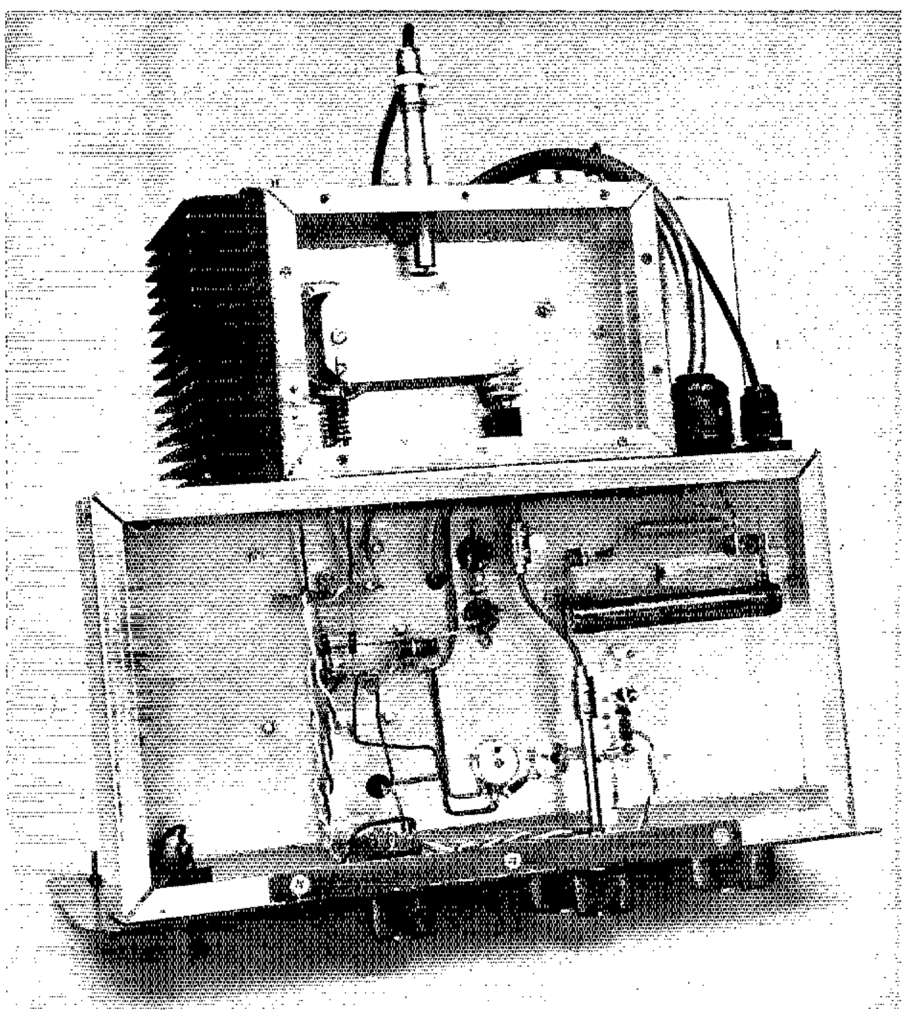


Fig. 3 — Schematic diagram of the varactor tripler. See footnote 2 and 3.

Because the tripler construction and the peripheral-electronics chassis layout were not carefully coordinated, there is a distressing lack of space to adjust the tripler input circuits while in place (as can be seen in the photograph). However, if the builder will move the location of the voltage regulator tubes an inch or two to the left, there should be no problem. The tripler is fastened to the chassis by means of spade lugs extending from the vertical members of the tripler box.



A look at the bottom of the amplifier reveals the grid compartment, top center, and the ac and dc connection cables from the power supply. A grid line is tuned by means of a butterfly type of capacitor, mounted on phenolic so that the total capacitance is reduced. A small disk on the end of a coaxial section provides capacitive input coupling to the grid circuit. The flexible coupling shown here has since been replaced by two universal-joint type of connectors, to remove some annoying backlash in the tuning control. A high-wattage dropping resistor, part of the screen supply circuitry, is shown at the right.

Power Supply

Most of the earlier testing of this unit was performed while using the Heath HP-23A to supply all voltages. The amplifier can be operated at the 80- to 100-watt output level without unduly taxing the capability of this supply. Accordingly, the wiring and plug connections were made up with this feature in mind. When a larger supply was constructed for tests at the 200-watt level, connections were made compatible with those on the Heath supply as far as practicable. When using the HP-23A, provision must be made to drop the filament potential to the nominal 6.0 V required by the 8560A heater. A voltage-dropping resistor for this purpose is located under the support chassis. Heater voltage should be measured *at the tube socket,* not at the power supply. The newer power supply, HP-23B, can be used if the series resistance added is sufficient to drop the potential from 12 to 6 V as needed by the tube.

Adjustment and Operation

Initial testing should be performed while operating the amplifier at reduced plate and screen voltages, if possible. Output coupling should be at maximum, and the input-coupling probe should be near maximum. Again, do not adjust the tripler circuits to make up for misadjustment of the amplifier. Drive power should be adjusted by increasing or decreasing the 144-MHz excitation to the tripler. An output power indicator should be used as an aid to adjustment of the amplifier. Provisions were made in the wiring to the multimeter switch to display a sample of rf energy, such as might be obtained from a directional coupler.[8] The input-probe spacing and the grid-line tuning should be adjusted for maximum drive to the tube; this should be concurrent with minimum SWR as seen by the tripler. Move the coupling probe in small increments – the proper position will tend to be somewhat difficult to find. Output coupling and plate tuning should be adjusted for maximum output. The reason for starting with maximum coupling is that with minimum coupling and reactive loads, the amplifier could be unstable. Loading should be decreased until there is a smooth, but not sharp, dip in plate current. A reading in the vicinity of 250 to 300 mA at resonance is about right, at a plate potential of 800 V. As with most tubes in this family, maximum output is seldom achieved at minimum plate current. Use the output power as an indication of proper operation, but be sure that the screen is not abused – *small* amounts of *negative* screen current are no cause for alarm. In all cases, do not exceed the power dissipation rating of the tube element concerned.

It is not practical to operate this tube in this configuration at more than 1200-V plate potential. Tests were made at 1500 V, with disastrous results. At that dc level, with the added rf voltage, the stress across the BeO thermal link caused it to become very "unhappy." This caused it to produce frying sounds, which made the authors unhappy. The condition also caused a reduction of plate-circuit efficiency and much unwanted heating of nearby metal parts. Investigation of the phenomena showed that the high Q of the circuit caused the fault. Rather than do a complete redesign of the plate circuit, and because the initial goal was a 100-watt unit, the decision was made to leave well enough alone and recommend a 1200-volt limit.

Variations

It should be obvious that there are other possibilities for providing drive to the amplifier. A transmitting mixer that will provide 432-MHz output can be used in any desired mode – the bias of the amplifier can be adjusted for either Class C or linear operation. An existing exciter or low-powered transmitter at 432 MHz will also work well. See Table I for suitable drive levels.

And for those readers that have a "bargain" surplus blower that they absolutely must get some use of, the 8560-A can be exchanged with a 4X150 or 4CX250; simply replace the heat sink with a metal plate and an air fitting for the blower. Since there will be no thermal link to contend with, these tubes may be operated at higher plate voltage and higher output power. However, some slight lengthening of the plate line may be necessary to compensate for the reduced capacitance at the tube end.

Panel Lettering

One of the simpler details of a large construction project is the application of lettering to the front panel. There are many products on the market to fill this need. Hand lettering with a pen on masking tape is probably the easiest way to accomplish the task but, needless to say, lends the least professional finish. At the opposite end of the scale, one can fabricate black anodized aluminum name plates for each control, as shown in the photographs. Supplies for this process are available from Kepro, 3630 Scarlet Oak Boulevard, St. Louis, MO 63122. The materials used here cost less than $20 and there is plenty of aluminum, etching powder, and developer left over for several more projects. The process is similar to the production of pc boards. Complete step-by-step instructions are provided by Kepro and need not be repeated here. *A word of caution:* one of the materials, sodium hydroxide, should be handled with care. Prolonged contact with the skin could cause burns and, accordingly, rubber gloves are recommended.

Acknowledgements

The authors would like to thank Bill Orr, W6SAI, for aid in parts procurement, and Bob Sutherland, W6PO, for help in analyzing the "unhappiness" of the BeO thermal link.

Footnotes

1 Moretti, "A Heterodyne Exciter for 432 MHz," *QST*, November, 1973, (also see Feedback, *QST*, March, 1974, page 83).
2 *Radio Amateur's Handbook*, ARRL, 52nd Edition, Chapter 7.
3 *Radio Amateur's VHF Manual* ARRL 3rd Edition, Chapter 13.
4 Knadle, "High Efficiency Parallel Kilowatt for 432 MHz," *QST*, April, 1972.
5 Knadle, "Dual-Band Stripline Amplifier-Tripler for 144 and 432 MHz," *Ham Radio*, February, 1970.
6 Temprobes® Test Kit, by Tempil®, Hamilton Blvd., South Plainfield, NJ 07080.
7 See footnote 2.
8 McMullen, "The Line Sampler," *QST*, April, 1972. Also in *FM and Repeaters for the Radio Amateur*, Chapter 10, and *The Radio Amateur's VHF Manual*, Chapter 14.

Strays

I would like to get in touch with . . .

- ☐ amateurs who are employees of Ontario Provincial Police. VE3CGU
- ☐ employees of the Fisher Scientific Co. and subsidiaries who are ham operators. K3VMS
- ☐ those interested in starting an on-the-air detective book club. WN6HND
- ☐ amateur radio operators who were former members of the Lone Scouts of America. WB2WOQ
- ☐ others wishing to join an amateur radio astronomy group recently organized. Contact Todd Ferson, East Hillcrest Dr., DesMoines, IA 50317.
- ☐ anyone interested in forming an astronomy and amateur radio net and/or club. Write Tom Frauenhofer, 170 Hilltop Rd., Rochester, NY 14616.

THE ARRL BICENTENNIAL WAS AWARD

At its January 1975 meeting, the ARRL Board of Directors authorized a special U.S. Bicentennial WAS Award for contacts made January 1-December 31, 1976.

The design is evident, with a vertical format. The actual certificate is 10 X 14 inches, with red, white and blue printing on a heavyweight tan parchment-like stock. Even if you've earned WAS previously, you're eligible for and will want to try for this one. Forms should be ready about the time this notice appears. (An s.a.s.e. will expedite yours!)

The Board included a schedule of handling charges of $2 for League members, $4 for non-members, and no charge for stations outside of Canada and the U.S. In general, standard WAS rules apply although this particular award will not be endorsed for band or mode. *CQ USA!*