amateur service newsletter
W6SAI

THE 3-400Z and 3-1000Z FOR AMATEUR SERVICE

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The EIMAC 3-400Z and 3-1000Z are zero bias triodes designed for grounded grid service in the high frequency spectrum. The tubes are rated at 400 and 1000 watts plate dissipation, respectively. No external bias supply is required over the plate potential operating range of 2000 to 3000 volts.

These tubes are especially suited for single sideband operation in the amateur service. Costly and bulky screen and bias supplies are not required. The tubes are small and rugged, and are designed to fit into modern, compact transmitter design. Best of all, the 3-400Z and the 3-1000Z provide improved linearity and a reduction of bothersome intermodulation products when operated in an approved circuit.

The 3-400Z is rated to 1000 watts PEP input, and the 3-1000Z is rated to 2000 watts PEP input. These ratings are established at moderate plate potentials, and result in third-and high-order product distortion figures better than -35 decibels below maximum output!

Preliminary operating data for these tubes is given in figure 1, and suggested circuits are shown in figures 2 and 3.

Circuitry for the 3-400Z

A simple operational circuit for the 3-400Z is shown in figure 2. The input circuit comprises a high-C tank (L1-C1), with excitation applied at a point which matches a 52 ohm driving source. The coil is bifilar wound, with the filament voltage applied to the tube via the coil. The grid of the tube is at ground potential for both d-c and r-f The plate circuit consists of a pi-network (C5-L2-C6) with the output voltage monitored by a simple diode voltmeter.

The Cathode Circuit

Capacitors C3 and C4 form part of the cathode tuned circuit and comparatively high valves of r-f current flow through them. The specified capacitors are satisfactory for the 3-400Z tube in continuous service, and will serve for the 3-1000Z in intermittent duty. These two capacitors should be grounded to a common point at the rotor of capacitor C1. Capacitor C2 carried the full excitation current and should be a transmitting type, as specified.

Although specifically designed for class B service, the 3-400Z may be operated as a class C power amplifier or oscillator or as a plate-modulated radio-frequency power amplifier. One can take advantage of the zero bias characteristic of the 3-400Z in class C amplifiers operating at plate voltages below 3000 volts by employing only grid-leak bias. If driving power fails, plate dissipation is then kept to a low value because the tube will be operating at the normal static zero bias conditions. Operating conditions are listed below:

MAXIMUM RATINGS	Class C Amp. or Osc.	Class C Plate-Modulated
D C PLATE VOLTAGE	4000 VOLTS	3000 VOLTS
D C PLATE CURRENT	350 MA	275 MA
PLATE DISSIPATION	400 WATTS	270 WATTS
GRID DISSIPATION	20 WATTS	20 WATTS
TYPICAL OPERATION		
D C Plate Voltage	3000 volts	3000 volts
D C Plate Current	333 m A	245 m A
D C Grid Voltage	-75 volts	-90 volts
D C Grid Current	130 m A	100 m A
Grid Driving Power	25 watts	18 watts
Plate Output Power	730 watts	550 watts

Air Sockets and Chimneys for the 3-400Z and 3-1000Z

In order to properly cool the seals and envelope of the 3-400Z and 3-1000Z, use of the EIMAC Air System socket is recommended. The SK-400 and SK-500 sockets are satisfactory; however, the new series SK-410 and SK-510 sockets are recommended for new equipments. These modernized sockets feature low cost, lighter weight design and simplified mounting. Low lead inductance insures proper tube operation.

The SK-410 socket may be used with the 3-400Z, 4-250A, 4-400A series tubes, in conjunction with the SK-416 chimney (for the 3-400Z) or the SK-406 chimney (for the 4-250A or 4-400A). The SK-510 socket may be used with the 3-1000Z (with the SK-516 chimney) or the 4-1000A (with the SK-506 chimney). See tube data sheet for air flow and full cooling information.

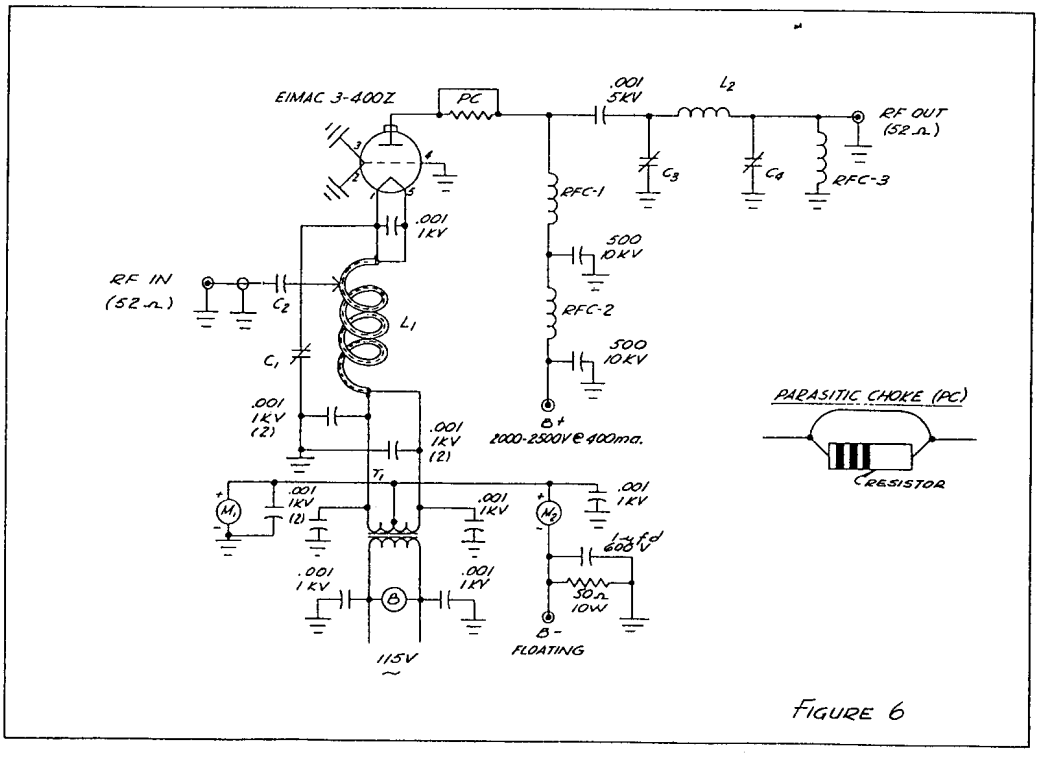


FIGURE 6

Using the 3-400Z on 50 MHz

The 3-400Z is rated for maximum service to over 100 MHz and makes an excellent grounded grid linear tube for 6 meter band. A suitable circuit for this service is shown in Figure 6. Neutralization is not required and the amplifier is stable and free of parasitics. A standard tuned cathode input and pi-network output circuit are used, with the grid and plate current meters placed in the d-c ground return. The power supply shown in Figure 3 can be used with this amplifier.

The amplifier may be built on a 10" x 14" x 3" aluminum chassis-box. Cathode circuit components are mounted within the box, with the plate circuit components placed atop the box. A complete cabinet, or enclosure should be built atop the chassis using perforated aluminum sheet. This will contain the various harmonics and reduce coupling between input and output circuits. The three grid pins of the 3-400Z socket (EIMAC type SK-410) are grounded directly to the chassis by means of wide copper straps passing through the adjacent socket slots. The straps (cut from flashing copper) are soldered to the socket pins, then bolted to the chassis directly next to the socket. Tuned cathode circuit L1/C1 is mounted close to the socket to insure short leads. The "cold" end of the bifilar filament coil (L1) is bypassed with two ceramic capacitors in parallel on each lead to bypass any r-f current flowing at this point. Input tuning capacitor C1 is mounted to the chassis in close proximity to the tube socket. All leads should be short and direct. Coupling capacitor C2 is placed near the tuned circuit and the lead from C2 to the input connector may be a length of 52 ohm coaxial cable.

The blower is mounted to the chassis, forcing air into the box which escapes via the tube socket and chimney.

FIGURE 1
Operating Data For
EIMAC 3-400Z and 3-1000Z

3-400Z

Filament: 5 volts @ 14.5 amperes

Socket: EIMAC SK-400 Air System Socket

Cooling: Radiation and forced air

Maximum Operating Temperatures: Base, 200° C; Plate seal, 225° C

Typical Operation for minimum distortion products with 1 kw PEP input

DC Plate Voltage	2500 volts
Zero Signal Plate Current	73 mA
Single Tone d-c Plate Current	400 mA
Single Tone d-c Grid Current	142 mA
Two Tone d-c Plate Current	274 mA
Two Tone d-c Grid Current	82 mA
Useful Power Output (PEP)	560 watts
Resonant Load Resistance	3450 ohms
Intermodulation Products	Typically more than -35 decibels below PEP level

Filament: 7.5 volts @ 21.3 amperes

Socket: EIMAC SK-500 Air System Socket

Cooling: Radiation and forced air

Maximum Operating Temperatures: Base, 200° C; Plate Seal, 225° C

Typical Operation for minimum distortion products with 2 kw PEP input

DC Plate Voltage	2500 volts
Zero Signal d-c Plate Current	162 mA
Single Tone d-c Plate Current	800 mA
Single Tone d-c Grid Current	254 mA
Two Tone d-c Plate Current	550 mA
Two Tone d-c Grid Current	147 mA
Useful Power Output (PEP)	1050 watts
Resonant Load Resistance	1700 ohms
Intermodulation Products	Typically more than -35 decibels below PEP level

Figure 2: Grounded grid circuitry eliminates expensive bias and screen supplies required with grid driven circuitry. Good tube linearity, plus use of tuned cathode circuit results in low distortion, high power sideband amplifier.

Parts List:

C1 -- 1000 pF (Three gang b-c variable, with sections connected in parallel. J.W. Miller #2113).

C2 -- .01 µF, mica. 1200 volt. Aerovox type 1446.

C3 -- .01 µF, mica. 500 volt. Aerovox type CM-30B-103.

C4 -- same as C3.

C5 -- 3500 volt rating. Effective tuning capacity; 2.5 pF per meter.

C6 -- 500 volt rating. Effective tuning capacity; 25 pF per meter.

L1 -- See text. Resonates to operating frequency with C1 setting of approximately 13 pF per meter. Approximate dimensions are: 80 meters, 10 turns, 1-5/8" i.d., 3-1/4" long, tap 6 turns from ground. 40 meters, 6 turns, as above, 2" long, tap 3-1/2 turns from ground. 20 meters, 4 turns, as above, 1-1/4" long, tap 2 turns from ground. 15 meters, 3 turns, as above, 1" long, tap 2 turns from ground. 10 meters, 1 turn, as above, tap 1/2 turn from ground. Make of 1/4-inch copper tubing, threaded with #12 insulated wire.

L2 -- Make of 1/4-inch copper tubing, 3" i.d. To resonate to frequency with settings of C5 and C6 as specified above.

M1 -- 0-750 mA M2 -- 0-1 mA M3 -- 0-1 mA

R1 -- Internal resistance of meter M3 plus R1 totals 550 ohms. Meter reads 0-500 mA, full scale.

T1 -- 5 volts at 14.5 amperes. Chicago type F-516.

RFC1 -- HF choke. B & W type 800.

RFC2 -- VHF choke. Ohmite Z-144.

PC -- Three 100 ohm, 2 watt composition resistors in parallel; shunt coil is 3 turns, 1" diameter, length of resistors.

B -- 115 volt blower. Minimum of 15 cubic feet per minute. Ripley #82.

FIGURE 3

T1 - 2900-0-2900 volts @ 500 mA CCS. 115-230 volt primary. 1600 VA capacity. Chicago #P-2126.

T2 - For 866A tubes: 2.5 volts @ 10 amp. 9 kV insulation. Chicago #F-210H.
For 872A tubes: 5 volts @ 15 amp. 10 kV insulation. Chicago #F-520HB.

CH1 - 10 Henries @ 500 mA. Resistance 40 ohms. Chicago #R-105

RYL - DPST relay. Potter & Brumfield PR7AY, with 115 volt a-c coil.

Note: 866A rectifier tubes may be used with 3-400Z. Use 872A rectifier tubes for 3-1000Z. Xenon type 3B28 may be substituted for 866A, and 4B32 for 872A.

FIGURE 4

Pi-network circuit for 3-1000Z

C1 - 1250 volt, transmitting-type mica capacitor. Aerovox type 1446 or 1651-L. Two capacitors may be connected in parallel to obtain odd values of capacitance.

80 meters:	1000 pF	15 meters:	150 pF
40 meters:	450 pF	10 meters:	100 pF
20 meters:	220 pF		

C2 - Same as C1. Capacitance as follows:

80 meters:	900 pF	15 meters:	90 pF
40 meters:	375 pF	10 meters:	30 pF
20 meters:	150 pF		

C3 - Same as C1. 0.02 μF

L1 - May be made of B & W Miniductor coil stock, as follows:

80 meters: 2.5 µH 15 turns, 1" diameter, 8 turns per inch. (B & W #3014).
40 meters: 1.1 µH 8 turns, same as above.
20 meters: 0.55 µH 7 turns, 3/4" diameter, 8 turns per inch. (B & W #3010).
15 meters: 0.37 µH 6 turns, same as above.
10 meters: 0.3 µH 6 turns, 1/2" diameter, 8 turns per inch. (B & W #3002).

Network may be adjusted by shorting capacitor C2 and trimming coil L1 until L1-C1 resonates to center of band of operation, or by making C2 variable and adjusting for maximum grid drive.

B - 115 volt, 60 cycle blower. Ripley #81. 45 cubic feet per minute.

RFC1 - 30 ampere bifilar filament choke. Barker & Williamson FC-30

Note: An alternative arrangement is to eliminate the bifilar filament choke and substitute a low-capacity filament transformer. (7.5 volts at 21.3 amperes). A suitable transformer is made by Transformer Technicians, Inc., 2608 No. Cicero Avenue, Chicago, Ill. (Type #TTI-4173).

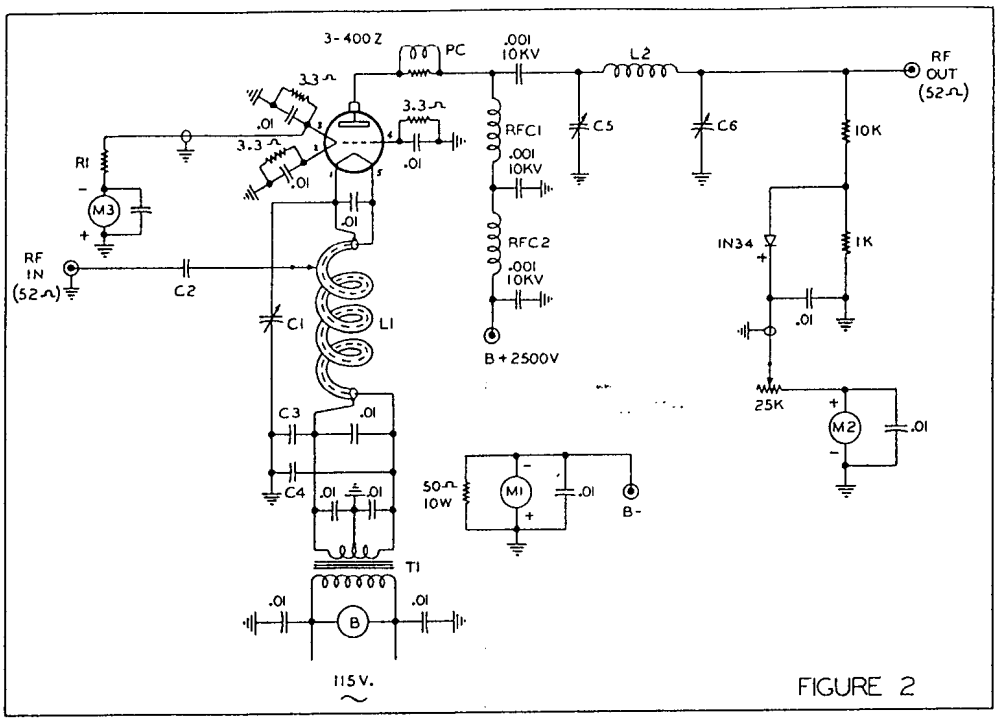


FIGURE 2

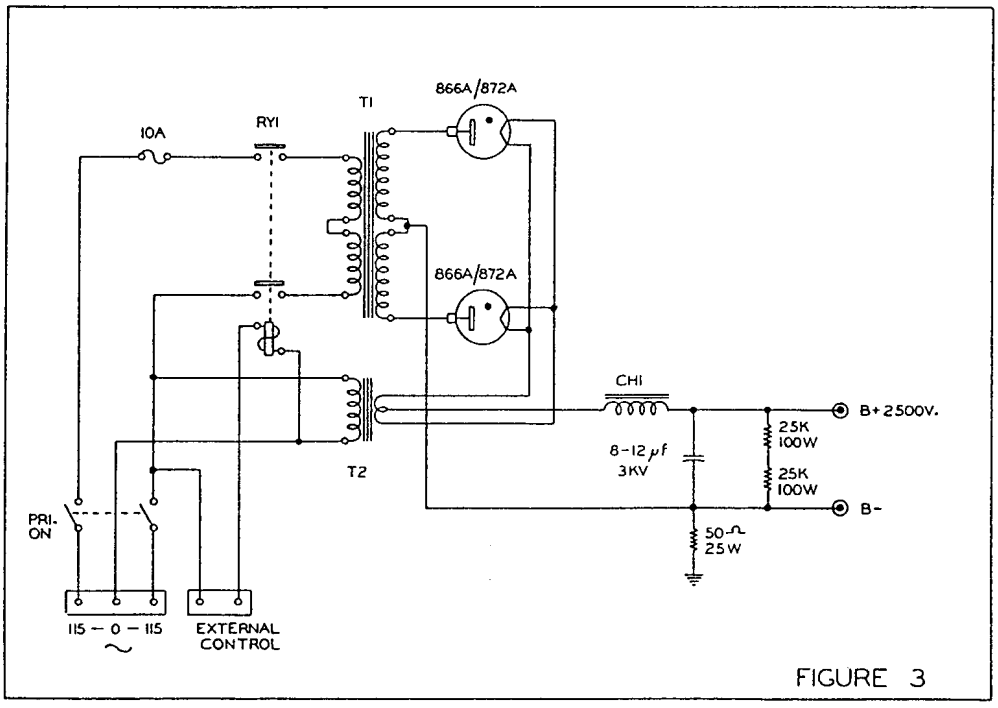


FIGURE 3

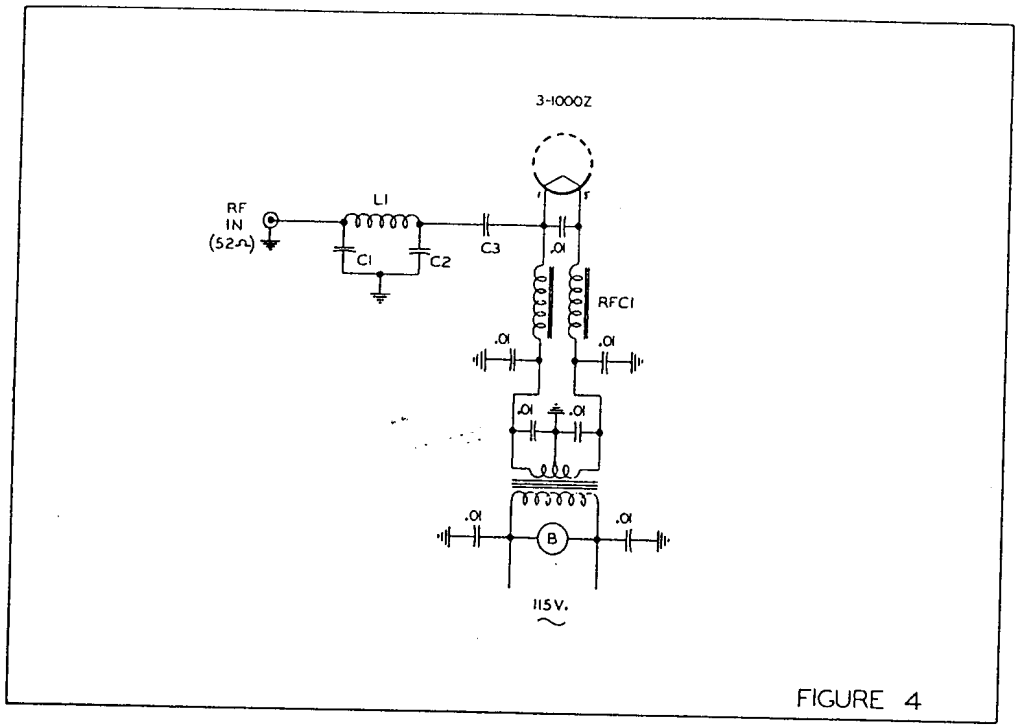
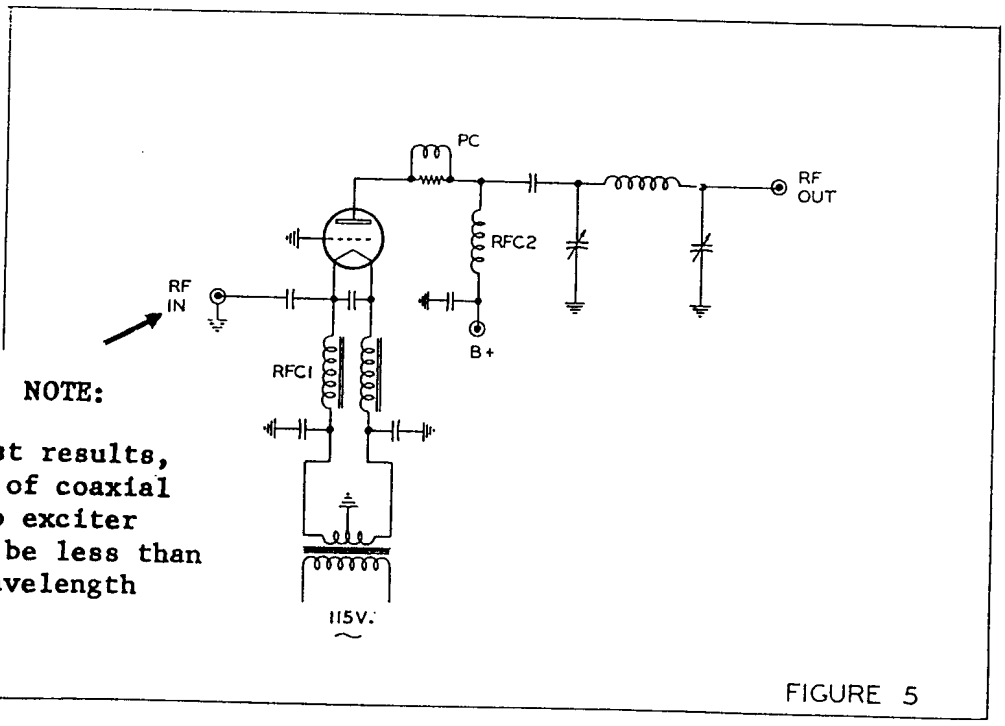


FIGURE 4



NOTE:

For best results, length of coaxial line to exciter should be less than 1/10 wavelength

FIGURE 5

The Untuned Cathode Circuit

Shown in figure 5 is a simple grounded grid amplifier circuit employing r-f chokes in the cathode in place of a tuned circuit. This circuit is very popular, and may be employed with the 3-400Z or 3-1000Z provided the limitations of the circuit are understood by the user.

Any single-ended Class B stage (regardless of the tube used) draws grid and plate current over only a portion of the operating cycle (approximately 180°). The input impedance of such a stage, therefore, does not represent a constant load. The waveform delivered by the exciter to the grounded grid stage is greatly distorted over the portion of the cycle that the amplifier draws grid and plate current. Although published "input impedance" values may look attractive, they actually represent only the fundamental component of input impedance (useful for tank circuit "Q" calculation). Since the input load impedance of the class B grounded grid stage is not a constant value, it is necessary to transform it to a constant impedance which will resemble 50 ohms over the complete operating cycle. This is best done by a high C tuned circuit placed directly at the cathode of the grounded grid stage.

The 3-400Z and 3-1000Z are not unique in requiring a tuned cathode circuit. Good engineering practice requires it for any grounded grid amplifier to achieve best linearity unless the amplifier is operating class A. In short, grounded grid amplifiers may be built without the cathode tank circuit, but the fullest capabilities of the equipment will not be realized. Power output will be sacrificed, and poorer values of odd-order product distortion will be observed when the cathode tank circuit is omitted. The degree of degradation will vary with the particular driver/amplifier combination used, and with the length of interconnecting coaxial line. Typical measurements made with a class A driver stage (well swamped) and a short length of interconnecting coaxial line between the driver and a grounded grid amplifier showed that when the amplifier cathode tank was removed, the power output of the amplifier stage dropped about 5%, the third order products increased approximately 3-5 decibels, and the fifth order products increased 5-7 decibels. The higher order products also rose accordingly. It is possible that with an exciter having poorer output circuit Q, and with other lengths of interconnecting coaxial line that a greater degradation might have been noticed in performance when the tuned tank was removed.

The tuned cathode tank can be thought of as a refinement necessary for best performance of a grounded grid class B linear amplifier. Its use is highly recommended.

Filament coil L1 is made of a section of ¼-inch diameter copper tubing with a length of #12 insulated wire passed through the center hole. Heavy conductors are soldered to each end of the coil to serve as filament circuit leads. After the correct position of the excitation tap has been found, it may be soldered in position.

It is necessary to use some form of tuned circuit at this point and to resist the temptation to substitute untuned filament chokes. Use of the latter by themselves will result in degradation of linearity to a marked degree, and will make the amplifier more difficult to drive properly.

Circuit Details

Plate meter M1 is placed in the B-minus lead to the amplifier in order to register plate current instead of cathode current (a combination of grid and plate current). The negative return of the power supply, therefore, should be "floating" as shown in figure 3.

Since a great deal of power is produced in a small package, an EIMAC air system socket and blower are recommended for use with these tubes in order to maintain the envelope and seals at a low temperature. An alternative arrangement may be two separate blowers, one directed at the envelope of the tube, and the other at the bottom of the tube socket.

Amplifier Construction and Adjustment

In order to complement the excellent internal shielding of the grounded grid tubes it is necessary to isolate the input and output circuits. The cathode circuit should be placed below the metal chassis, enclosed in a metal box. Plate circuit components should be mounted above the chassis. As a TVI preventive measure, the complete amplifier should be enclosed within a metal shield made of perforated material. The grid terminals are bypassed to ground by means of three .01 μF ceramic capacitors mounted (one at each socket terminal) by the shortest possible leads. Also placed at each grid terminal is a 3.3 ohm, 1-watt composition resistor. These resistors "de-Q" the capacitors and provide a short, direct ground return for the r-f and d-c currents in the grid circuit. Meter M3 measures the slight voltage drop across the resistors and is calibrated in terms of grid current for tuning purposes.

Before the amplifier is adjusted, the filament voltage at the tube socket should be checked to ensure that excessive voltage drop does not exist in the tuned circuit. Approximate setting for the tap of L1 is given in figure 2. The exact point may be found by loading the amplifier to full input and varying tap placement until maximum grid current is obtained at the same setting of capacitor C1 that provides minimum SWR on the exciter coaxial line. At incorrect tap settings, minimum SWR figure and maximum grid current settings of capacitor C1 do not coincide.

When properly loaded and tuned, grid current runs about 1/3 the value of plate current. Plate loading and tuning and the excitation level adjustments should be conducted to adhere closely to this ratio of grid/plate current. After the amplifier is loaded to maximum input in this fashion, the pi-network should then be overcoupled (C6 reduced in capacitance) slightly until the r-f output measured on M2 drops about 3%. This will approximate a condition of maximum linearity. Do not apply full excitation to the tube without plate voltage and proper loading as grid dissipation will be exceeded.

In sideband service, for voice waveforms, the indicated plate current measured on M1 will be approximately one-half the peak d-c plate current. One kilowatt PEP input to the 3-400Z, for example, may be achieved on voice by plate current meter peaks of 200 milliamperes at a plate potential of 2500 volts.

Notes on the 3-1000Z tube

The circuit of figure 2 may be used for the 3-1000Z. However, the higher filament current of this tube requires that a heavier bifilar coil be used having a length of #10 insulated wire for the center conductor. Also, as the input impedance of this tube is close to 52 ohms, the filament tap point for C2 occurs near to the top (filament end) of the coil. Adjustment of the tap point may not be required.

It may be somewhat easier from a mechanical point of view to substitute a pi-network input circuit for the parallel L-C circuit, as shown in figure 4. Untuned filament chokes are used to supply filament voltage to the tube, and a simple fixed tuned pi-network circuit is employed to couple the exciter to the filament circuit of the 3-1000Z. The transformation ratio of the network is 1:1, matching the line to the tube, yet providing the "Q" necessary for proper circuit operation. The pi-network circuit and filament choke may be used for the 3-400Z tube, if desired.

To assist in proper adjustment of the amplifier, an output tuning device should be placed in the coaxial lead to the antenna. A SWR power meter or r-f ammeter may be used. The amplifier is adjusted for maximum power output at the proper plate and grid current values. Carrier injection may be used for the tuning process, and antenna loading and grid drive adjusted to provide the current data given in figure 1 for 3-400Z.

FIGURE 6

50 MHz Linear Amplifier for 3-400Z

C1 - 100 pF. Bud MC-1855 (double bearing)

C2 - .001 mica capacitor

C3 - 15 pF. 3 kV (.075" spacing). Johnson 155-8 capacitor may be used, with every other rotor plate removed.

C4 - 200 pF. Bud MC-1858 (double bearing)

L1 - 2 turns of 1/4-inch copper tubing, 1 inch inside diameter, 1-1/2 inches long. Pass #12 insulated wire through center before winding coil. Tap for C2 placed at center of coil. Connections between L1 and C1 should be made with 1/8-inch copper strap.

L2 - 3-1/2 turns of 1/4 inch copper tubing, 2 inch inside diameter, 3 inches long. Mount between stator terminals of C3 and C4 with short leads.

PC - Plate lead to 3-400Z is made of 1/4-inch copper strap. The parasitic choke (PC) is made of a section of this lead with three 47 ohm, 2 watt resistors in parallel placed across the lead, as shown in Figure 6. Resistors are mounted side by side.

RFC1 - 8.3 μH. Space-wound on 1/2-inch diameter ceramic insulator, 2-1/2 inches long (Birnbach 447). Wind #28 double silk covered wire spacewound about wire diameter. Winding 1-3/4 inches long. Teflon rod may be used. (Avoid polystyrene as it may melt or deform from heat of tube).

RFC-2,3 - VHF choke. Ohmite Z-50.

M1 - 0-200 mA (grid current)

M2 - 0-500 mA (plate current)

B - 115 volt blower. Minimum of 15 cubic feet per minute. Ripley #82 or Dayton 2C782

T1 - 5 volts at 14.5 amperes. Chicago-Standard F-516

Socket: EIMAC SK-410 Chimney: EIMAC SK-616

Note: 500 pF, 10 kV capacitors are TV "door-knob" type. Aluminum chassis box 10" x 14" x 3" is used.