TRIODE LINEAR AMPLIFIERS

The LAZY LINEAR Amplifier was one of the most popular circuits published in G-E HAM NEWS during the 1940's, since it "arrived" just about the time that single sideband first appeared on the amateur bands. The low-cost, easy-to-drive GL-811-A zero bias triode tube made possible an efficient, reliable and practically foolproof linear amplifier design which could be driven by the 20-watt peak output SSB exciters then being used by many amateurs who pioneered this new mode of communication.

Records show that several hundred "Chinese" copies of the Lazy Linear Amplifier, and literally hundreds of additional amplifiers using the Lazy Linear circuit in different mechanical arrangements, were constructed by radio amateurs.

The original Lazy Linear Amplifier article is being repeated here. The original plug-in coil type grid and plate tank circuits are easily modified into bandswitching type circuits through the availability of modern ceramic-insulated tap switches, and ready-wound coil material.

LAZY LINEAR AMPLIFIER

Final Amplifier for AM, NBFM, CW or SSB

With Push-Pull GL-811-A Triodes

From July-August, 1949

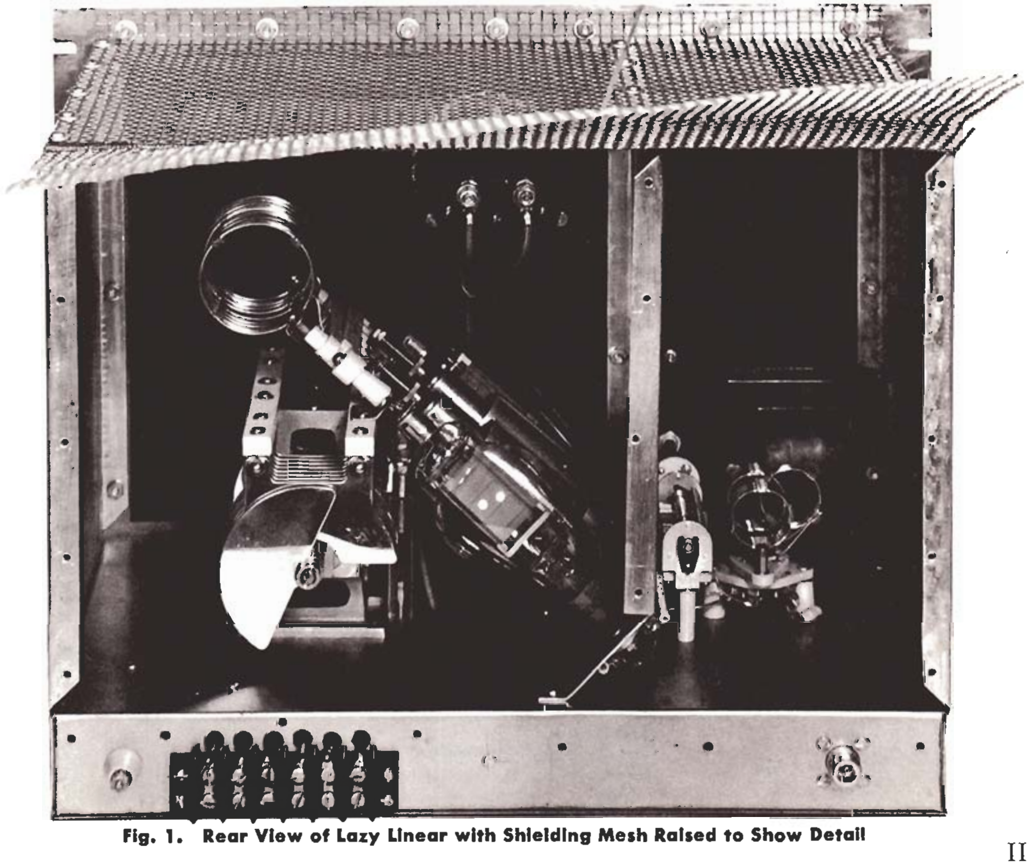


Fig. 1. Rear View of Lazy Linear with Shielding Mesh Raised to Show Detail

Why Use a Linear Amplifier?

High power linear amplifiers are very rarely used in amateur stations, although the average amateur uses linear amplifiers all the time, and may not realize it fully. All distortion-free audio amplifiers, as well as RF and IF amplifiers, in superheterodyne receivers are linear amplifiers (the limiter in an FM receiver is an exception).

Perhaps the amateur has kept away from high-power linear amplifiers because of their reputation for poor efficiency. This reputation is perhaps deserved only when AM signals are considered, as a check of Fig. 12 will show. However, a linear amplifier is ideally suited for single-sideband transmission where the peak efficiency is about 70 percent. The Lazy Linear was designed with this type of operation in mind, although data is given for operation on AM phone, NBFM phone, and CW.

The Lazy Linear is a final amplifier capable of 400 watts peak output on SSB, 400 watts peak output using a keyed carrier (CW), 180 watts peak output on NBFM phone, and 180 watts peak output (45 watts carrier power output) on AM phone. A complete comparison of these various types of emission is given in Fig. 12. In addition, the Lazy Linear has been designed to be practically TVI-proof. Complete shielding and filtering of power leads is employed in the Lazy Linear.

GENERAL LINEAR CONSIDERATIONS

linear amplifier is by definition an amplifier in which the output signal is directly proportional to the input signal. Since this is the case, the input and output signals are very much interdependent upon one another. This is emphasized because the average amateur is familiar with Class C amplifiers, and his experience with this type of amplifier will have to be forgotten temporarily when adjusting linear amplifiers. The adjustment is not difficult but the amateur must remember that the grid current, driving power, plate current dip, etc., as applied to his experience with Class C amplifiers may mean something entirely different when working with linear amplifiers.

A linear amplifier has several very important advantages over Class C amplifiers. Because the driving power is materially lower with linear amplifiers there is far less probability of generating and radiating harmonics. This means that television interference caused by harmonics of the intended signal is much less likely. Further, the harmonic output of a linear amplifier of a given output rating is lower than is experienced with Class C amplifiers. This cuts down the amount of trouble that can be caused by harmonics and makes TVI elimination a simpler job.

For single-sideband transmission a linear amplifier is practically essential. The practical efficiency in this type of service is in the order of 70 percent on peaks. NBFM transmission could well employ a linear amplifier to take advantage of the low driving power requirements and the reduced harmonic output as compared with "Class C" amplifier operation.

In CW use, a linear amplifier opens the way to the solution of key-click elimination and bandwidth reduction. As before, of course, the driving power requirements are very low and the harmonic distortion is low. For CW work the keying and shaping may be done at a low power level point in the exciter without amplifier distortion undoing the job done at the low level point.

It is recommended that the prospective builder or user of the Lazy Linear read and digest the article "Linear R.F. Amplifiers" by S. G. Reque, which appeared in the May, 1949 QST. This article reviews the high points in the design and adjustment of linear amplifiers and will furnish good background material on the subject.

ELECTRICAL CIRCUIT

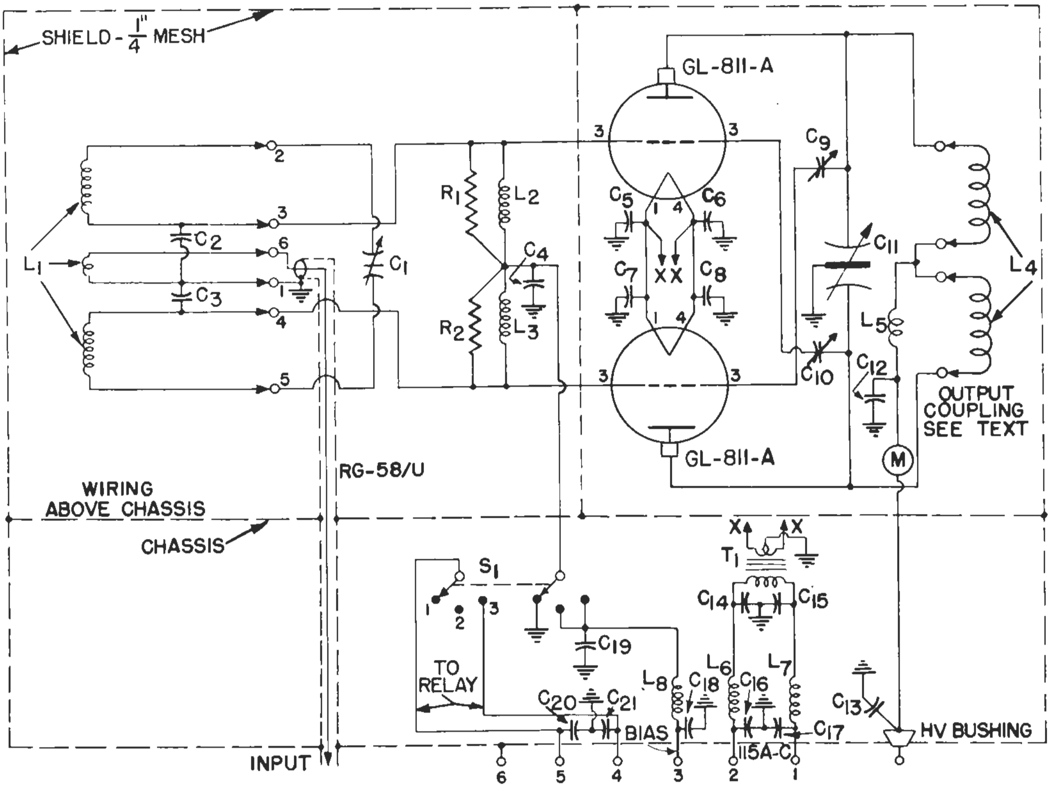


Fig. 2. Circuit Diagram of Lazy Linear

Design and Construction—Lazy Linear

ELECTRICAL DETAILS—GRID CIRCUIT

Fig. 1 will explain one reason for the name Lazy Linear. The name also applies because the tubes seem to loaf along when providing 400 watts of peak power output on SSB.

The circuit diagram for the Lazy Linear is given in Fig. 2. It will be seen that the diagram is that of the usual push-pull final with the exception of the grid circuit. In linear amplifier circuits the grid circuit is extremely important because it is necessary to provide a signal of good regulation to the tube grids. The choice of the GL-811-A tube simplifies the grid circuit design. Incidentally, the GL-811 tube will also work in the Lazy Linear, but the newer tube with its greater plate dissipation will permit a larger factor of safety in operation. The GL-811-A tubes are inexpensive and lend themselves readily to the requirements of linear amplifier operation at a power output level that is surprisingly high.

The input circuit is a combination transformer/resonant circuit/pi-matching network. Referring to the special grid circuit schematic in Fig. 3, the driving signal is coupled by means of an adjustable swinging link into a resonant circuit comprising L_{1A}, L_{1B}, C_{1A}, C_{1B}, C_2 and C_3. If the inductance of L_{1A} and L_{1B} in series be considered as having a value of L_T, and the capacity of the four condensers C_{1A}, C_{1B}, C_2 and C_3 in series be considered as having a resultant value of C_T, resonance will be achieved when the inductive reactance of L_T equals the capacitive reactance of C_T. Further, if C_{1A} is equal to C_{1B} and C_2 equals C_3, this relationship may be expressed in the formula:

$$C_T = \frac{C_{1A}C_2}{2(C_{1A}+C_2)}$$

Also, since C_2 will be equal to C_{1A} times a constant, K, we find that the resultant capacitance will then be expressed in the formula:

$$C_T = \frac{1}{2}K\frac{C_{1A}}{(1+K)}$$

In the design of the Lazy Linear K is equal to approximately 2.5, which calculates out to give the answer that C_2 (which is equal to C_3) equals 7 times C_T. It will be seen therefore that the choice of a coil fixes the values of the four condensers for any given frequency. Since C_{1A} and C_{1B} are variable (but equal) the ratio K will change somewhat over any given amateur band. Center-band frequencies were used in the calculations.

The foregoing information on the design of the grid circuit has been given mainly for one reason, and that is to point out the importance of the following statement. *It is absolutely necessary to use coils having the correct value of inductance in order to fulfill the combined requirements of tuning, coupling and matching in this circuit.*

The total operating Q of the circuit into which the exciter driving tube operates is approximately 20. This value of Q gives a reasonable amount of room for maladjustment without the danger of ending up with too low a Q for the driver. By the same token, the load on the grid circuit provided by the driver lowers the source impedance of the matching circuit and improves the voltage regulation of the driving system. Good grid circuit regulation is essential in order to provide the amplifier itself with a signal reasonably free from distortion.

It was found necessary to use a fixed source of grid bias in some cases. The amount of bias required (zero to −3 volts depending upon the plate voltage used) is most conveniently provided by a small 4½ volt battery. This battery should givc at least "shelf life" but must be in good condition if distortion is to be held to a satisfactory point. While discussing distortion it might be well to point out that, contrary to a commonly held belief, a linear amplifier must be made as r as possible for SSB work. Amplifier distortion evidences as unwanted sideband components and cross products on either side of the carrier frcquency dcspite the fact that the load into which the amplifier operates is a tuned load.

Resistors R_1 and R_2 and chokes L_2 and L_3 were not taken into account when making calculations on the grid circuit, but this approximation will not cause any serious error. The two resistors are loading or "swamping" resistors which serve to fix the source impedance and the operating Q of the grid circuit. Note, the rotor of C, is insulated from ground.

From the above discussion of the grid circuit of the Lazy Linear the average amateur may form the opinion that the unit is extremely complicated to build and adjust. The fact is that the design work has been carefully done so that, if the parts specified are used, the average amateur should not have any difficulties in building and using the Lazy Linear. The emphasis placed upon the design of the grid circuit has been deliberate in order to show why the circuit constants and the tune-up procedures should be followed exactly.

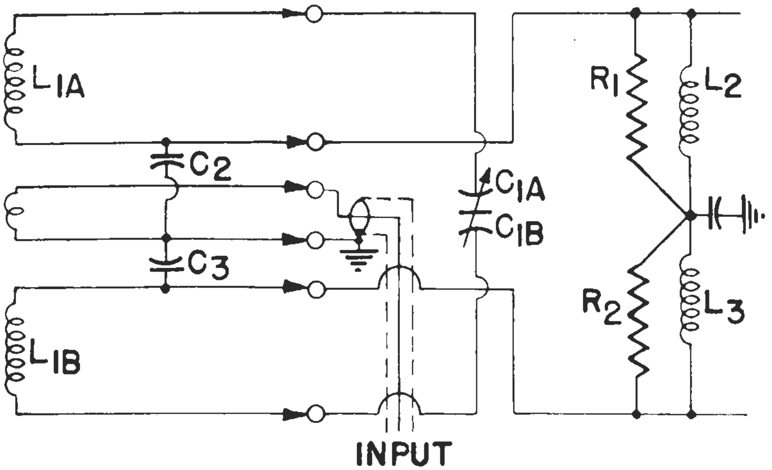


Fig. 3. Lazy Linear Grid Circuit

CIRCUIT CONSTANTS

C_1	Split-stator 140 mmf variable (Hammarlund HFD-140)
C_2, C_3	See Grid Coil Table
C_4, C_5, C_6, C_7, C_8, C_{14}, C_{15}, C_{16}, C_{17}, C_{18}, C_{20}, C_{21}	0.005 mf ceramicon or mica
C_9, C_{10}	Neutralizing condenser, 3-9 mmf, 6000 volt (Millen 15006)
C_{11}	200 mmf per section split-stator variable, 0.077 inch air-gap (Millen 14200)
C_{12}, C_{13}	0.002 mf, 2500 volt (working) mica
C_{19}	1.0 mf, 200 volt paper or oil-filled
L_1	National AR-17 swinging-link coils, modified as per text and coil table
L_2, L_3, L_8	500 microhenry r-f choke (Millen 34300-500)
L_4	Millen 44000 series "150 watt" coils, modified as per text
L_5	1.0 millihenry, 300 ma r-f choke (Millen 34107)
L_6, L_7	R-F chokes, one layer of No. 26 enamelled wire wound on new-style one watt, one megohm resistor
M	0-500 ma meter (G.E. DO-40)
R_1, R_2	1000 ohm, 10 watt non-inductive resistor (Sprague NIT)
S_1	Two-pole, three-position, non-shorting switch (Mallory 3223-J)
T_1	6.3 v, 10 ampere filament transformer (Thordarson T-21F12 or T-19F99)

ELECTRICAL DETAILS—PLATE CIRCUIT

Push-pull operation of the GL-811-A tubes requires the use of a balanced plate tank condenser. The rotor of this condenser (C_{11}) is grounded securely to the chassis to provide a good return path to the filaments. Harmonic currents must flow through the condenser back to the filaments, and they need all the encouragement, that is, low impedance, that can be provided.

The remainder of the circuit is quite usual. Note that the high voltage required should be un-modulated d-c. No attempt should be made to employ high-level plate modulation.

No output coupling arrangement will be seen in Fig. 1. This does not mean that the Lazy Linear has not been tested on the air. As a matter of fact, the Lazy Linear was thoroughly tested on the air and some of you reading this may have had a QSO with W2KUJ while the unit was undergoing tests at his shack.

Output coupling may be by means of an adjustable link arranged to swing between the two halves of the plate tank coil. Or, a balanced pi-matching network with grounded neutral may be used. In any case, provision for adjustment of the coupling (or at least the reflected load) must be made. Ample space is available for mounting a swinging link on the chassis next to the tuning condenser. If a pi-network is used this should be connected to the stator plates of the tuning condenser by means of blocking condensers of ample voltage rating (0.001 mf at 2500 volts working should be suitable).

Approximately 8000 ohms plate-to-plate loading is correct, although the exact value depends upon the plate voltage used and the class of service employed. As was true in the grid circuit, coils of the proper value of inductance are necessary in order to preserve suitable L-C ratios on each band. Plate coil specifications are as follows: The Millen 44000 series coils are used. For example, 44010 is the 10 meter coil, 44020 is the 20 meter coil, etc. These coils are used without change with the following exceptions. Coil 44080 is used for 160 meters and extra padding capacitance is required in parallel with C_{11}. Two 200 mmf condensers should be used, one in parallel with each stator section of C_{11}. These capacitors may be fixed air condensers or vacuum condensers, or even a variable condenser from the junk-box set at the proper capacitance.

Coils 44010, 44020 and 44040 will work without alteration on 10, 20 and 40 meters. Coil 44080 must be altered by removing 6 turns from each half of the coil. (This means that two 44080 coils are required, one for 80 and one for 160.)

For those who desire to make their own coils, the desired inductance for the 160—10 meter coils, respectively, is 40, 20, 10, 5 and 2 microhenrys.

MECHANICAL DETAILS

The Lazy Linear is constructed on a 11 by 17 by 2 inch *plated* chassis and uses a 19 by 14 inch front panel. The entire unit must be shielded to minimize TVI. Figs. 4, 10, and 11 show the constructional details of the metal pieces which act to support the shielding mesh and also to shield the input circuit from the plate circuit. Two pieces of galvanized quarter-inch mesh hardware cloth are cut to size to provide the top shield and the rear shield. They are best cut to size when the other metal pieces are mounted in position and properly aligned. In addition to all this shielding, a cover plate is used on the bottom of the chassis.

To make the shielding effective, remove the paint around the edges of the rear side of the front panel so that good electrical contact can be made between the front panel and the end plates, between the front panel and the quarter-inch mesh, between the front panel and the chassis, and between the front panel and the rack on which it mounts. The paint must also be removed from around the meter hole, on the rear face of the panel, so that the copper screen which covers the meter hole may be soldered to the panel. The meter itself is mounted on standoff posts to prevent breakdown between the meter and the panel. If the meter case is metal, insulated standoff posts must be used.

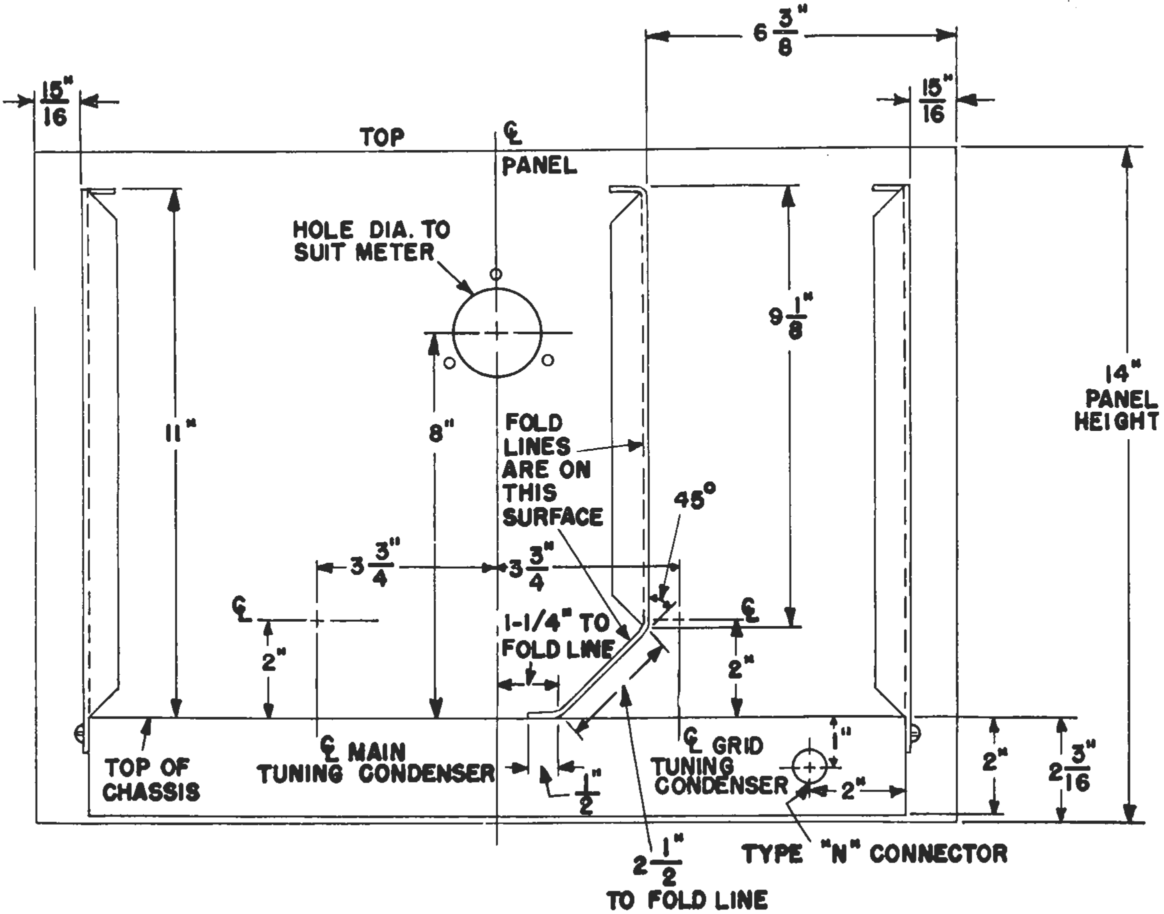


Fig. 4. Detail of Chassis and Panel Assembly (Rear View)

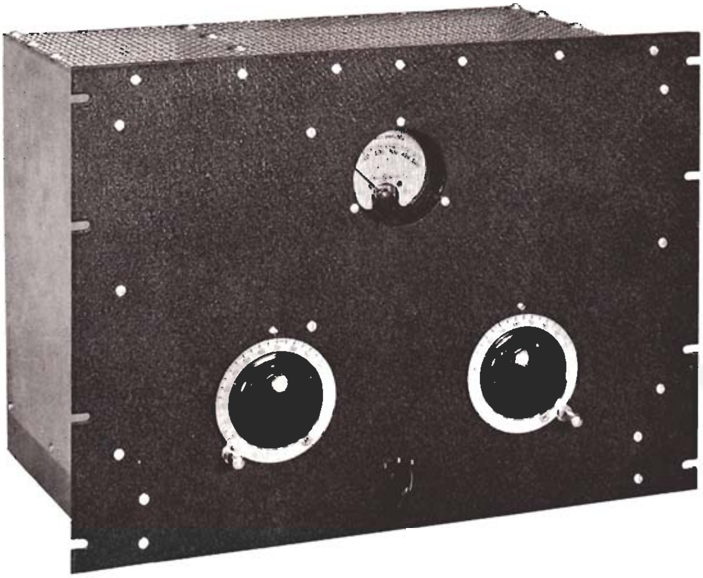


Fig. 5. Front Panel View of Lazy Linear

The rear shield of quarter-inch mesh is hinged to the top quarter-inch mesh by means of a length of flat half-inch wide copper braid. The braid should be soldered to the galvanized mesh at every point along the joint.

Detail photographs are given of the grid section and the plate section. The plate section detail, Fig. 8, shows how the Millen coil base is mounted on the Millen condenser. Two pieces of 1/16 inch brass, one inch by one inch, must be made. A half-way point fold is placed in these pieces at a 45 degree angle. When the 6–32 screw is removed from the tuning condenser in order to mount the brass plate it will be seen that the threaded area is too small to allow re-use of the same machine screw. A longer screw must be provided. However, take care that it is not too long, as it may strike the threaded rod on which the stator plates are mounted. It may be necessary to file the machine screw used to the proper length.

It will also be necessary to cut off approximately one inch of the stud which forms the top part of the neutralizing condenser so that it will fit in the space provided.

By following the photographs and the sketches, no difficulty should be encountered in the construction of the Lazy Linear. Make sure that you do a good job on the bypassing, especially where the power leads enter the rear of the chassis. Use as short leads as possible.

The dials shown in the front-panel view, Fig. 5, are Millen 10008 with Millen 10050 dial locks.

Grid coils required are the National AR-17 swinging link series. Because the input circuit is a pi network changes must be made on each of these coils. As received the coils have a center-tapped link and only one connection from the center point of the two main coils. Further, it is necessary to add C_2 and C_3 on each coil, and in the case of the 160 and 80 meter coil additional padding must be added so that it is effectively in parallel with C_1.

The changes should be made as follows: Cut the wire which connects pin 3 to the center-tap of the link about ⅜ of an inch below where it connects to the link. The two main coils are joined by a wire which is molded into the center piece of

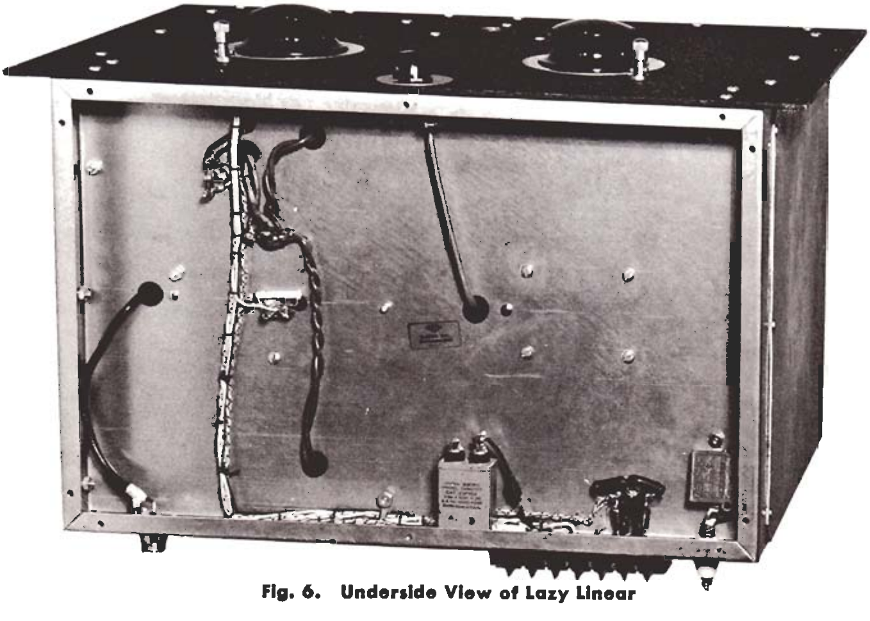


Fig. 6. Underside View of Lazy Linear

insulating material. Find the point on this wire where the connection to pin number 4 is made and cut the joining wire just below this point. The wire just cut now connects to the wire going to pin number 3. Add condensers C_2 and C_3, and the padding condenser if required, and the job is done. It will be necessary to match C_2 and C_3 within 5 percent in all cases. Repeat for all grid coils. (See Grid Coil Table for proper values to add.)

GRID COIL TABLE

160 meters: (No National AR-17 series coil was available at time of writing.) A suitable coil can be made as follows:

Each half to be 50 turns, 1 inch in diameter, 32 TPI spacing. (B & W Miniductor No. 3016 cut in half.) Space two halves one-half inch apart. Make link also 32 TPI, 1 inch in diameter, 12 turns. Pad (pin 2 to 5) with 100 mmf. C_2 equals C_3 equals 1000 mmf.

80 meters: Use National AR-17-80S. C_2 equals C_3 equals 470 mmf. Use a 20 mmf mica padding condenser from pin 2 to pin 5.

40 meters: Use National AR-17-80S and remove 8 turns from each coil half. C_2 equals C_3 equals 250 mmf. Remove 5 turns from link.

20 meters: Use National AR-17-40S. C_2 equals C_3 equals 100 mmf.

10 meters: Use National AR-17-20S. C_2 equals C_3 equals 50 mmf.

Desired inductance, for those who wish to make their own, for the 160—10 meter coils, is, respectively, 65, 32, 16, 9 and 3 microhenrys.

EXCITER REQUIREMENTS

The table of Fig. 12 indicates various modes of operation and gives information on driving power, plate operating conditions, etc. In general the driving power requirements are very low. Any exciter which ends up in an 807 or a tube of similar power should be suitable to drive the Lazy Linear for any mode of operation, provided that the exciter itself provides the proper type of emission. The exciter described by W2KUJ in the March and April 1949 CQ will provide an adequate driving signal for all types of emission (SSB, AM, NBFM).

POWER SUPPLY REQUIREMENTS

The rating table, Fig. 12, gives plate current requirements for various modes of operation, where the type of emission allows this information to be given. The voltage required will depend upon the builder's personal choice of the types of operation desired. If only AM and NBFM operation is contemplated, the power supply may be of conventional design.

For CW and SSB operation the heavy bleeder normally used to achieve good regulation may be replaced by a high resistance bleeder which will serve to discharge the filter condensers. The stand-by current drain taken by the Lazy Linear takes the place of the heavy bleeder current. Because of the intermittent current drain which typifies CW and SSB speech transmission, special care must be taken in the power supply design to avoid power supply filter resonance. A practical means of achieving this is to use a 10 to 20 mf output condenser.

TUNE-UP ADJUSTMENTS

Before attempting to get the transmitter operating properly, re-read Reque's article on linear amplifiers, as the two-tone test described therein will not be described here.

Select your band and insert the proper coils. Couple an exciter to the grid so that an un-modulated signal drives the Lazy Linear. Tune for maximum grid current (measured by an external meter in the bias supply when switch S_1 is in position 2 or 3). The filaments must be on, and the plate supply disconnected from the rear high-voltage bushing. Any grid current from 50 to 100 mils will be satisfactory now.

Neutralize the final in the usual manner. Make sure the plate tank condenser is tuned to resonance during the neutralizing process. If opportune, neutralize on the highest frequency band you intend to use.

The next step is to match the grid and plate circuits. Couple the final to a dummy load. Arrange an oscilloscope with the vertical connections connected across the dummy load so that the plate output may be observed. Apply a small input signal to the grid circuit, making sure that the grid link is loosely coupled. Now apply plate voltage (not over 1000 volts) and resonate the plate tank for maximum output as shown by the scope. The plate current should be approximately 50 to 100 mils, depending on the excitation. This may be reached by 1) making a crude adjustment of the plate loading with the dummy load, or 2) detuning the plate tank slightly to get the desired plate current. Strive for approximately 75 mils.

Under these conditions you should now match the exciter to the grid circuit. The objective here is to present the right load to the exciter so that the exciter works properly. In other words, you are familiar with the operation of your exciter, its plate current when running properly, etc. Adjust the coupling between the exciter and the grid circuit, by means of the link, (while adjusting C_1)until the exciter is working as it should. If the exciter you chose supplies sufficient power output, then there should be sufficient drive to the Lazy Linear. (See the table in Fig. 12 for approximate driving powers required.) While making these coupling adjustments by adjusting the link, work from a lightly loaded condition toward heavier loading, making sure that the grid condenser is in tune at all

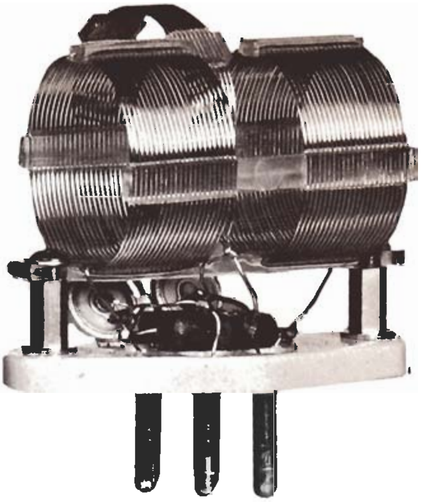


Fig. 7. Detail of Grid Coil

COIL TABLE FOR CONSTRUCTING GRID TANK CIRCUIT COILS FOR LAZY LINEAR AMPLIFIER

The following coils may be substituted for the National AR-17 series originally used in this circuit. The same padding and network capacitors, given in the grid coil table on Page 4 of the Volume 4, No. 4 issue of G-E HAM NEWS, must be used.

3.9 Mc. - Original coil was National AR-17-80S. Homemade coil - 32 uh total-make two 22 turn coils of B & W No. 3016 miniductor spaced 1/2". Link 1.7 uh, 8 turns of same material inserted in space.

7 Mc. - Original coil was National AR17-80S with 8 turns removed from each end. Homemade coil - 16 uh total - use No. 3015 miniductor - cut 2 coils each 19 turns and space 1/2 inches - link 1.7 uh - 6 turns same material in space.

14 Mc. - Original coil was National AR-17-40S. Homemade coil - 9 uh total, make 2 coils each 11 turns each of B & W No. 3015 miniductor and space 1/2". Link 0.92 uh, use 6 turns same material inserted in space.

21 and 28 Mc. - Original coil was National AR-17-20S. Homemade coil-3 uh, make 2 8-turn coils of No. 3014 miniductor with 3/4" spacing. Link 0.92 uh, use 5 turns of same material or 4 turns No. 3015.

ASSEMBLY AND BASE:

Allow 1 extra turn at each end of each coil section to form leads for connections to plug-in base. Connect as shown in circuit diagram, Fig. 2, on Page 2 of Volume 4, No. 4 issue. Make plug-in base from amphenol 86-CP6T Mica - Bakelite male 6 pin connector assembled with plate and retaining ring from amphenol 78-RS6 replacement socket. Coils mounted on 1/4 x 1/2-inch piece of polystyrene or lucite 3 inches long with 3/4-inch long spacers on fastening screws. Coils cemented to strip with low-loss coil cement.

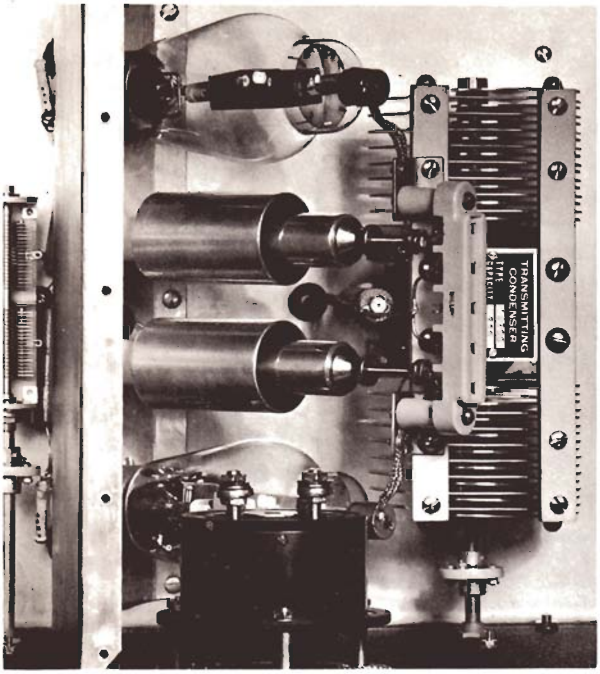


Fig. 8. Detail of Lazy Linear Plate Circuit

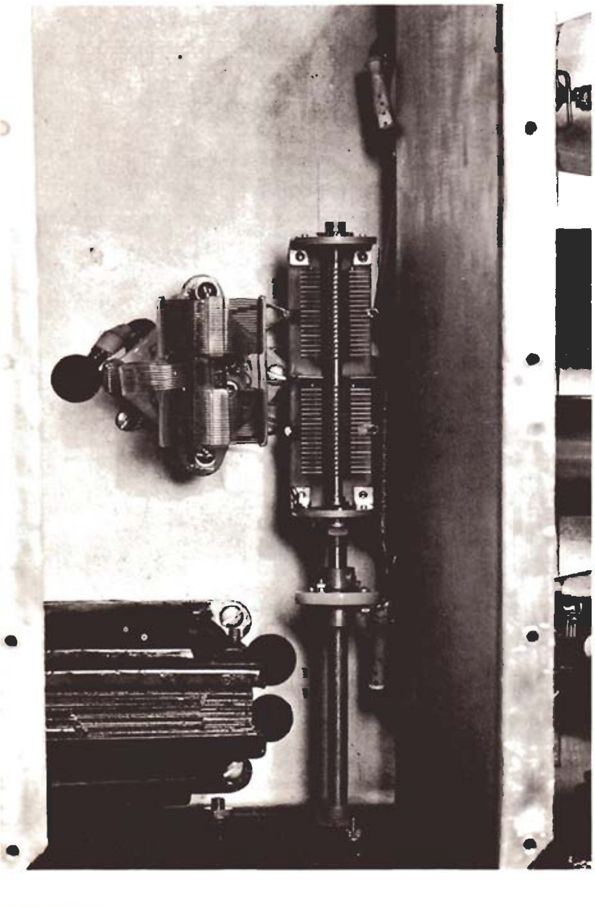


Fig. 9. Detail of Lazy Linear Grid Circuit

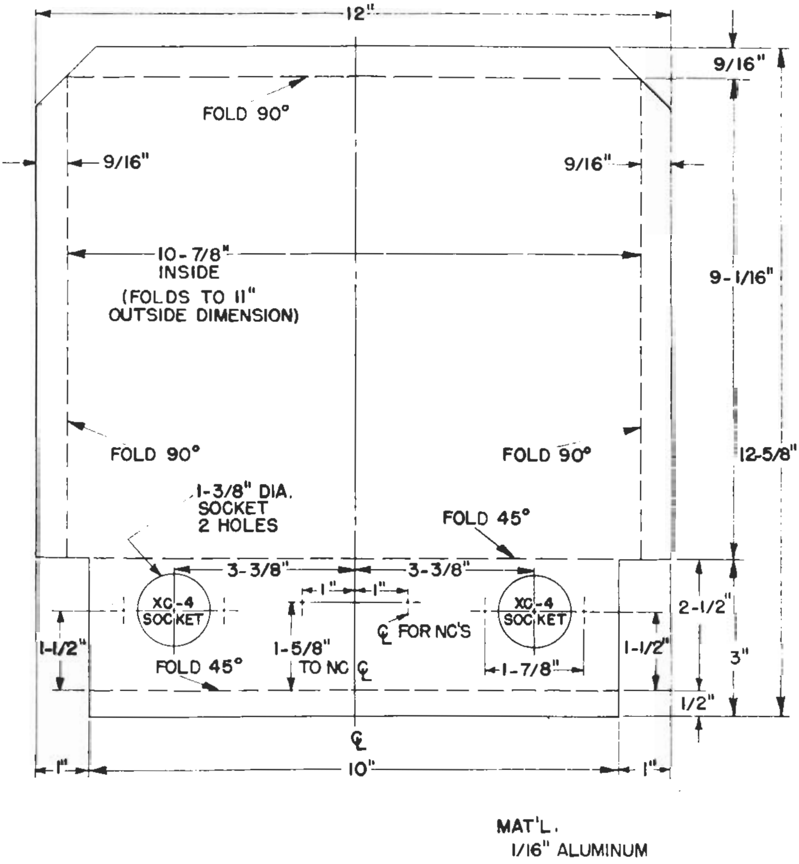


Fig. 10. Detail of Interstage Shield

times. The grid current will be significantly lower with plate voltage applied than it is with plate voltage off, so do not become concerned about the apparent loss of grid drive. An oscilloscope lightly coupled to the grid circuit can be a valuable adjustment aid.

No figure can be put on the grid current to be expected, as it may vary by a factor of perhaps five to one, depending on the plate loading, which has not yet been adjusted. However, do not exceed the maximum grid current rating of 100 mils for two tubes.

The amplifier has now been adjusted in a preliminary sort of way, and we are ready to proceed with the two-tone test as described in Reque's article, which has been referred to before. Apply a two-tone test signal to the grid circuit of the Lazy Linear. No more than 1000 volts d-c should be applied to the Lazy Linear plate circuit at this time. The envelope observed on the scope should now be as indicated in Fig. 4 of Reque's article, at least for low level inputs driving the final.

Now, with the plate load lightly coupled and C_{11} at resonance increase the input signal until the envelope flattens on peaks. The scope should be coupled to the output circuit for this test. (Note that this is *not* the distortion shown in Fig. 5 of Reque's article.) The envelope flattening may be caused by one or both of the following two conditions. 1) The driver may be improperly coupled or loaded, or it may be at the limit of its output capability, or, 2) the loading on the plate circuit may be too light, which means that the reflected load impedance is too high.

To check for point 1, couple the oscilloscope to the grid circuit of the Lazy Linear. If the envelope shows an undistorted signal (Fig. 4, Reque's article) then point 2 is causing the trouble. However, if the peaks are flattened, then the driver is supplying a distorted signal.

To check for point 2, couple the scope to the dummy load again, and watch the distorted pattern as the final tank condenser is detuned toward a higher capacity. If the plate current goes up more than 20 percent and the flattening effect seems to disappear, then the load should be coupled more tightly to the final. If this is the case, retune to resonance, couple tighter, and again check the pattern on the scope. Take care not to overload the tubes during this adjustment. Any more than a very slight indication of color in the tube anodes should be avoided.

At 1000 volts plate supply and with the two-tone signal to the grid circuit, the plate current will be in the order of 160 mils, although this value is governed by the signal strength coming from the driving stage. Optimum plate loading is that which causes a flattening of the peaks of the scope pattern as the drive is slightly increased (assuming that the driver itself is not limiting). Very little dip in plate current will be noted when tuning through resonance with the plate condenser when the amplifier is properly loaded.

With conditions as just previously described, that is, 1000 volts on the plate, two-tone test signal coming in, the average power input to the final will be 160 watts, and the peak input 1.57 times this figure or 250 watts, and the peak output will be approximately 175 watts, with a realizable 70 percent overall plate efficiency.

With the loading adjustment unchanged, the plate voltage may be increased to 1500 volts, and the bias changed to minus 3.0 volts. This is the reason that switch S_1 was incorporated in the Lazy Linear. In position 1 the grid bias is zero and the external plate voltage relay is not energized. In position 2 external bias is switched into the circuit and the plate voltage stays the same. In position 3 the external bias is unchanged but a relay may be actuated to change the voltage from 1000 to some higher voltage.

When operating with 1500 volts on the Lazy Linear several precautions must be observed. First, the two-tone test signal will cause over-heating of the final tubes if applied for more than 5 seconds at a time. Also, the 1500 volt condition can be used only when the final is driven by an exciter which puts out a single-sideband speech signal, or driven by a keyed exciter.

When testing at 1500 volts, apply a SSB signal from the exciter and talk into the mike (use no prolonged whistles or other steady tones). Increase the drive until the voice p reach a definite saturation point as seen by the scope conn across the output. Assuming that the driver itself is not limiting, then this point represents the maximum peak output signal consistent with the loading and plate supply voltage used. It will be approximately 400 watts peak output. The loading of the output circuit will be the same as used with the 1000 volt tests.

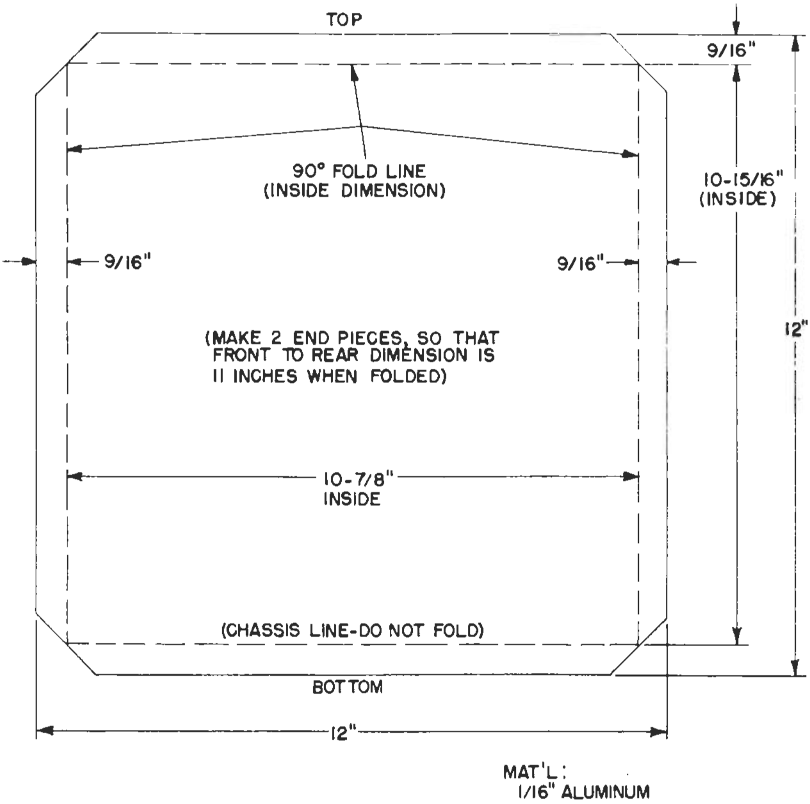


Fig. 11. Detail of Side Shields

Never attempt to operate the final beyond the saturation point just discussed. If desired, distortion may be checked by means of the two-tone test signal, when using 1500 volts, if the signal is left on for only a second or two (long enough for the plate current meter to settle down so that it may be read.) When making this test, the bias should be minus 3.0 volts and the average plate current as seen on the meter will be 240 mils, approximately. Make this test only after the tuning procedure and performance has been thoroughly checked at lower voltages. Even then, do not leave the two-tone test on for more than a second or two. This is important if you wish to use the very same tubes in the future!

After one is satisfied with the tune-up procedure, then the dummy antenna may be replaced with the radiating antenna and the coupling checked, at 1000 volts, with the two-tone test signal for a quick on-the-air test. Always monitor the output signal with an oscilloscope when you are on the air. This is the most reliable method for monitoring a phone signal.

#	EMISSION TYPE	INPUT SIGNAL REQ'D	PLATE VOLTAGE	PLATE CURRENT MA.	PLATE INPUT W.	CARR. OUT. W.	PEAK OUT. W.	NOTES
1	AM	100 % MOD. 2 WATTS	1000	CONSTANT 150	CONSTANT 150	45	180	A. PLATE TO PLATE IMPED. FOR ALL CONDITIONS IS 8000 OHMS. DETERMINE LOADING AT ONE KV. WITH TWO TONE TEST OR EQUIV.
2	NBFM	NBFM 8 WATTS	1000	CONSTANT 250	CONSTANT 250	175	180	B. CONDITIONS 1, 2, 3 AND 5 BIAS IS ZERO.
3	CW	CW 8 WATTS	1000	KEYDOWN 250	KEYDOWN 250	175	180	C. CONDITION 4 BIAS - 3 V. D. CONDITION 6 BIAS - 3 V.
4	CW	KEYED CARRIER ONLY-20 W.	1500	380	570 SEE NOTE F	400	400	E. RECOMMENDED CONDITION WHERE AM, NBFM, CW AND SSB USED INTERCHANGEABLY.
5	SSB	SSB 8 W. PEAK	1000	VARIABLE BUT STATIC PLATE CURRENT WILL BE 35 APPROX.	VARIABLE	SEE NOTE E	180	F. CONDITION 4 FOR KEYED SIGNALS ONLY. G. CONDITIONS 6 FOR SPEECH ONLY.
6	SSB	SSB 20 W. PEAK	1500			SEE NOTE G	400	

Fig. 12. Performance Table for Lazy Linear

POWER PEAKER LINEAR AMPLIFIER

A 200-Watt Output Linear Amplifier

For Single Sideband Operation

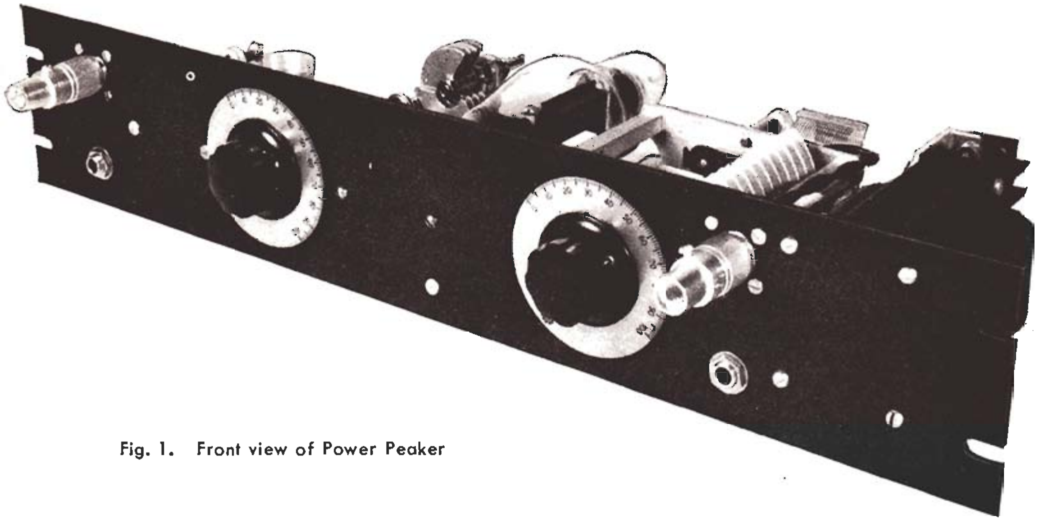


Fig. 1. Front view of Power Peaker

The Power Peaker is a complete single-tube linear amplifier featuring compact design for relay rack mounting. The r.f. driving power, for full 200-watt peak output, is less than 5 watts on any band from 80 meters to 10 meters. Thus, use of the Power Peaker driven by a single-sideband exciter, such as the SSB, JR (G-E HAM NEWS, VOL. 5 NO. 6), allows the single-sideband enthusiast to increase power by approximately 20 db. Two hundred watts of single-sideband is more than the communication equivalent of a half-kilowatt (plate input), high-level modulated AM rig operating at 80% efficiency. The Power Peaker will serve as an effective link between the 5-watt exciter and the antenna or a super-power (about 5 KW) final.

GENERAL DESCRIPTION

The Power Peaker amplifier is entirely self-contained (except for plate power supply) on a 3½ x 19 inch relay rack panel. All parts mount directly from the panel so that construction is easy and straightforward. The power amplifier tube is the rugged and dependable GL-811-A mounted horizontally near the center of the panel. Coaxial fittings are used for the r.f. input and output connections. Input and output tuning controls are accessible on the front panel as well as grid and cathode current jacks for circuit metering and tune-up. A filament transformer (T1) is mounted on the back of the panel to simplify the metering circuits and to avoid voltage drop in long filament leads.

Easily accessible plug-in coils are used for grid and plate circuits. Coupling adjustments may be made readily to match both input and output. These adjustments, once made for each band, "go with the coils" and need not be done again when changing bands. The neutralizing adjustment remains fixed from one band to another.

CIRCUIT DESIGN DETAILS

The circuit diagram of a linear amplifier is almost the same as that of a class "C" amplifier. Close inspection, however, will reveal an important difference between the Power Peaker and the conventional class "C" amplifier, that of bias. The GL-811-A is operated at zero bias and this feature makes additional swamping unnecessary. Actually this linear amplifier is self-swamped. Operating at zero bias reduces the driving power required, stabilizes the input impedance to reduce amplifier distortion, and, of course, eliminates the need for a bias supply.

The grid circuit is used as a phase inverter (accomplished with a split-stator tuning condenser) to permit grid-circuit neutralization. This arrangement reduces complexity and cost in the output circuit since it allows a single-unit plate tuning condenser to be used. The center tap of the grid coil is brought out to a grid-current jack (closed circuit type) through a 2.5 millihenry r.f. choke. The operating Q of the grid circuit is approximately 25.

The plate circuit is shunt-fed, thus reducing the insulation requirements on both the output tank coil and tuning condenser. Shock hazard is also reduced by this method. Economy of the design of the Power Peaker is exemplified by the use of small exciter-size plate tank coils. Although the amplifier will deliver a peak power output of 200 watts when loaded and driven properly, the small-size coils do not overheat. This, of course, is true because the average power of speech is small compared to peak power. The operating Q of the plate tank circuit is approximately 12 when the amplifier is loaded properly.

The over-all electrical design of the Power Peaker is aimed at economy, high efficiency (70% on peaks) and low distortion. Complete fulfillment of these design aims will not obtain, unless the coils and tuning condensers have respective inductances and capacities that are compatible with the original design. Because of the wide tuning range available, it is not sufficient just to use coils that will resonate at the desired frequency—they must resonate with the correct capacity for the frequency band in use.

It is strongly recommended that the Power Peaker be used ONLY with single-sideband suppressed carrier signals. The rating given is for this mode of operation only. More than momentary testing with continuous signals is almost certain to damage several of the components due to overheating. Keep this in mind.

CONSTRUCTIONAL DETAILS

The Power Peaker linear amplifier uses standard components throughout except for modification of the coils. This is necessary to obtain the required L/C ratios. Fig. 4 gives the layout of the 3½ x 19 inch (steel or aluminum) panel. Remember to reserve a clear space of at least one inch at each end of the panel for mounting on the rack. The plate tank condenser, C7, is spaced ½ inch from the panel by the three spacers furnished with the Hammarlund TC-220K condenser.. Before mounting this component, scrape the paint from the rear of the panel under the spacers to assure good electrical connection. The socket for the plate tank coil, L4, is mounted on the end of the plate condenser, C7, with ¾-inch spacers, and oriented so that the axis of the coil is as shown in Fig. 3. The coil socket pins 1 and 6 should be toward the top of the panel. Ground pin 6 and use pin 1 for the adjustable tap connection. It will be necessary to drill and tap the back of the plate tank condenser in order to mount the coil socket. Be certain to use fiber washers next to the ceramic socket to prevent cracking as it is tightened.

The grid tuning condenser, C1, is mounted on the rear of the front panel after the paint is removed from the area immediately around the mounting hole. In general, be certain to do this for all grounded components. The National STN neutralizing condenser, C2, is mounted on a metal bracket ½ inch by 1⅝ inch long fastened to the rear of the grid tuning condenser, C1. The rear shaft bracket of the Hammarlund MCD-100M condenser already has two tapped holes (No. 4–40 thread) which can be used to mount the bracket. The stator plate of the STN condenser must be insulated from this bracket by means of the two stand-off insulators supplied with the condenser.

Electrical Circuit

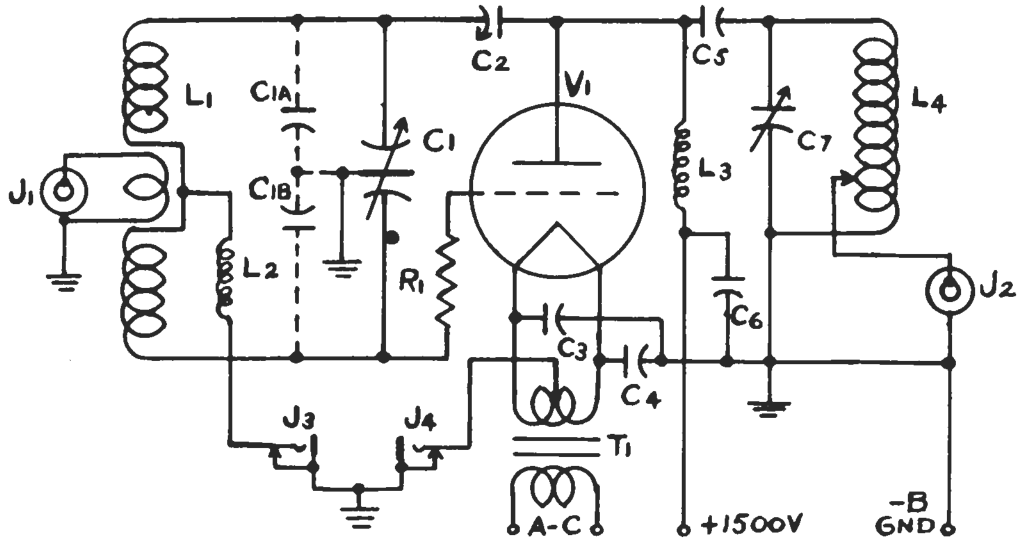


Fig. 2. Circuit diagram of Power Peaker

The tube socket should be spaced from the panel by two ¾-inch metal or ceramic spacers. The plane of pins 1 and 4 (filament pins) must be vertical as the panel is to be mounted. This is necessary to protect the tube from damage due to filament sag. The two 0.01 mfd ceramic disc filament by-pass condensers are mounted between the socket and the panel using shortest possible connections to a lug securely grounded. The plate supply by-pass condenser, C6, stands alongside the socket and one end is grounded to a lug fastened under the other socket spacer. The B plus end of the condenser is soldered to a lug mounted on a ceramic stand-off insulator. This point also serves to support the cold end of the National R-100, 2.5 millihenry shunt-feed r.f. choke. The plate blocking condenser, C5, is mounted between the stator lug of the plate tank condenser, C7, and the hot end of the shunt-feed choke, L3. A solid wire connects from this last-named point to the stator of the STN neutralizing condenser, C2. The objective here is to provide a rigid mounting for the blocking condenser, C5, and the top of the plate choke, L3, and to provide a connection point for the short insulated stranded-wire plate lead. The top of the blocking condenser, C5, should be below (toward the panel) the plane of the bottom of the plate of the tube to prevent interception of large amounts of heat radiated from the tube. A straight-across mounting of the blocking condenser should be about right, with due allowance made for inserting the GL-811-A. Fig. 3 shows these details clearly. A solid wire connection should be made from the same lug that mounts one end of the blocking condenser to the hot pin of the plate coil socket mounted on the end-plate of the tuning condenser. Use No. 14 AWG (or larger) for these solid-wire leads.

The filament transformer, T1, is mounted ½ inch from the panel on metal spacers to clear the leads which come out the bottom of the transformer. If the transformer you use does not have the leads coming out this way, it may be mounted flat against the panel. A terminal board is fastened to the top of the transformer by means of two right-angle metal brackets. This terminal board serves to connect the a-c supply and the 1500-volt d-c plate supply to the amplifier. A barrier-type terminal board is recommended for the sake of safety and to prevent inadvertent short circuits.

The center tap of the 6.3-volt winding of transformer T1 should be connected to the tip spring terminal of the closed-circuit cathode current jack, J4. Be certain to ground this jack securely to the metal panel. There is space on the panel below the transformer for a primary filament switch, if separate control of the filament is desired.

The ceramic socket, for the grid coil L1, is mounted on stand-off insulators so that the axis of the coil is vertical as shown in Fig. 3. The socket pins used for the swinging link should be toward the end of the panel for convenience in wiring and adjustment of the swinging link. The end connections (pins 2 and 5) of the grid tank coil should be connected with solid wire to the two stator sections of C1. The stator section away from the panel should be connected to the rotor of the STN neutralizing condenser. The stator section nearest the panel should connect to the grid pin of the GL-811-A socket (pin 3) through a 10-ohm, 1-watt non-inductive resistor (R1). This resistor is mounted by its pigtail leads between the stator connection and the socket terminal. The center tap of the grid coil (socket pin 4) should connect through a National R-100, 2.5 millihenry r.f. choke, (L2), to the tip connection of the closed-circuit grid current meter jack, J3. This choke may be supported by its pigtail leads from the socket connection and the jack terminal. Ground pin 3 of the grid coil socket to the panel with as short a lead as possible.

The filament wires may be twisted together and run between the plate condenser and the panel from the transformer to pins 1 and 4 of the GL-811-A socket. The B plus lead should run from the terminal board to the ceramic post supporting the shunt-feed r.f. choke. This lead should be kept clear of the stator connection of the plate tank condenser. Be certain to use wire with adequate insulation to withstand the 1500 volts.

CIRCUIT CONSTANTS

(All resistors and capacitors ±20% unless specified otherwise)

C1	*100-100 mmf variable condenser, Hammarlund MCD 100-M*
$C1_A$, $C1_B$	*See coil table*
C2	*3-18 mmf neutralizing condenser, National STN*
C3, C4	*0.01 mfd disk type ceramic condensers*
C5, C6	*0.001 mfd, 2500 volt mica condenser*
C7	*220 mmf variable condenser, Hammarlund TC-220K*
L1, L4	*National AR-17 coil, modified. See coil table*
L2, L3	*2.5 mh r.f. choke, National R-100*
R1	*10 ohm carbon, 1 watt resistor*
T1	*6.3 volt, 4 amp., ct, Stancor P4019 or equivalent*
J1, J2	*coax jack*
J3, J4	*Closed circuit phone jack*
V1	*GL-811-A tube*

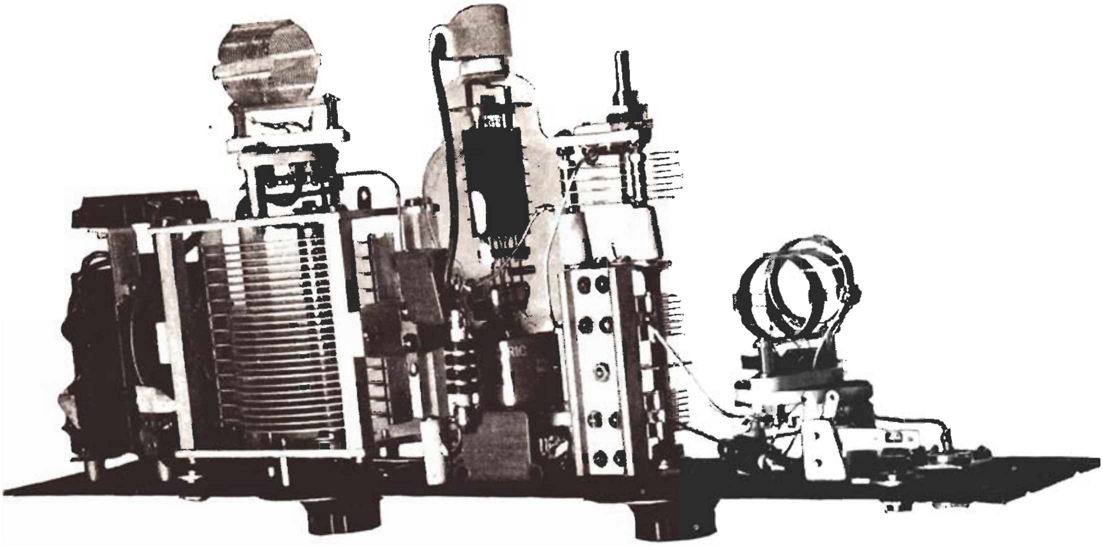


Fig. 3. Bottom view of Power Peaker

COIL DATA

It is essential to use coils having the correct inductance in order to meet the operating circuit Q's. The coils selected require modification in most cases in order to reach the required values. In addition, the two low-frequency-band grid coils require padding condensers mounted on the coil base as shown in Fig. 5.

Band	Coil	L µhy	Description
3.5–4.0	L4	10	National AR17-40E. Remove end link. Remove 8 turns. Provide 10 taps at ½ turn intervals from Pin No. 2 end. Connect Pin No. 6 to Pin No. 2 across top of coil base. Use a lead connected to Pin No. 1 for connection to taps.
	L1	14.5	National AR17-40S. Remove center tap of swinging link. Connect 150 mmf MICA condenser from each end of coil to Pin No. 3 of coil base. See Figs. 2 and 5.
7.0–7.3	L4	4.6	National AR17-20E. Remove end link. Tap each ¼ turn for 3 turns and make other connections as described for 3.5–4.0 MC plate coil.
	L1	7	National AR17-40S. Remove 3 turns from outer ends of each coil half. Remove center tap of swinging link from Pin No. 3 and connect a 50 mmf MICA condenser from each end of coil to Pin No. 3 of coil base. See Figs. 2 and 5.
14–14.4	L4	2.7	National AR17-20E. Remove end link. Remove 4 turns. Tap coil every ¼ turn for 3 turns and make other connections as described above for plate coils.
	L1	2.5	National AR17-20S—Remove CT from link.
21, 27–30	L4	0.9	National AR17-10E. Remove end link. Remove 2 turns. Tap each ⅛ turn for 2 turns and make other connections as described for plate coils.
	L1	1.2	National AR17-10S. Remove CT from link.

The inductance values for each coil are given for those who wish to make their own coils.

It might be necessary to remove some of the turns in the swinging links of the grid coils to facilitate matching the exciter into the Power Peaker. Do this if the exciter does not load properly when the link coil is fully meshed with the grid-tank coil.

POWER SUPPLY CONSIDERATIONS

A special word is in order concerning the plate power supply used with the Power Peaker linear amplifier. The L/C ratio chosen for the plate tank circuit is based on the use of a power-supply voltage of 1500 volts. Use of materially lower voltage (such as 1200 volts) will result in a loaded Q that is too low for proper operation of the amplifier when it is loaded as described under the section entitled MATCHING AND LOADING. A serious consequence of low output circuit Q is an abnormally high harmonic output. Thus, to develop rated output power while providing suitable load conditions for the amplifier tube, the power supply should deliver 1500 volts under load.

Good power-supply regulation is desirable for achievement of the best performance from any linear amplifier. A power supply that can deliver, say, 1500 volts at a load current of 200 ma, but which allows the voltage to rise to 1800 volts at the resting or static current of the Power Peaker amplifier will cause even the stand-by dissipation within the GL-811-A to exceed its rating—this will mean a short and unsatisfactory life for the tube. Design of a satisfactory power supply is discussed in G-E HAM NEWS, Vol. 7, No. 2 and THE RADIO AMATEUR'S HANDBOOK.

The type of load presented by a linear amplifier with single sideband input is identical to that of a class B modulator stage. To the information given in Vol. 7, No. 2 should be added that dynamic regulation of the power supply be considered also. Without going into details, one will end up with a really satisfactory plate power supply by following the design information given (especially with regard to input chokes, which affects "static" regulation) and then increasing the size of the output capacitor of the filter to a value considerably more than that required for satisfactory ripple performance.

Generally speaking, a power supply which has sufficient input choke to take care of static regulation needs only a single capacitor to meet the ripple requirement. This is provided the total value of capacitance is sufficient to iron out syllabic voltage fluctuations created by the intermittent load characteristic imposed by speech. At W2KUJ, where the Power Peaker was tested, an output capacitance of 25 mfd is used in the power supply to obtain good dynamic voltage regulation. An input choke of 60 henries is used to obtain good static regulation.

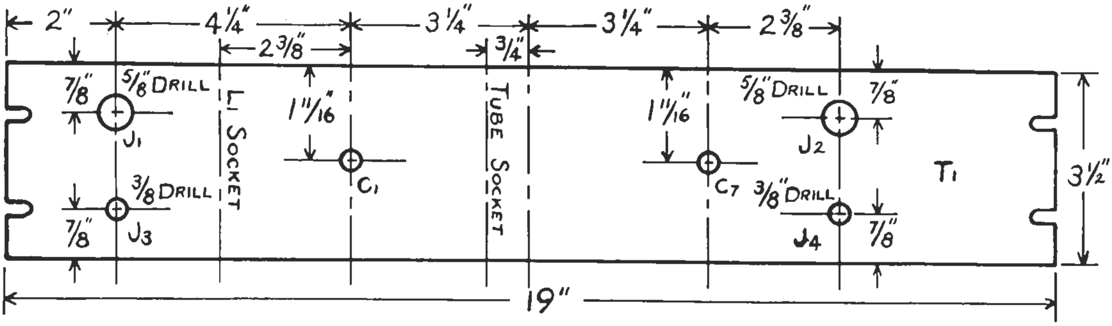


Fig. 4. Panel layout of the Power Peaker (Front Elevation)

Of course, transformer, rectifier tubes, and chokes of sufficient current rating (about 200 ma for the Power Peaker) and filter condensers of adequate voltage rating should be used.

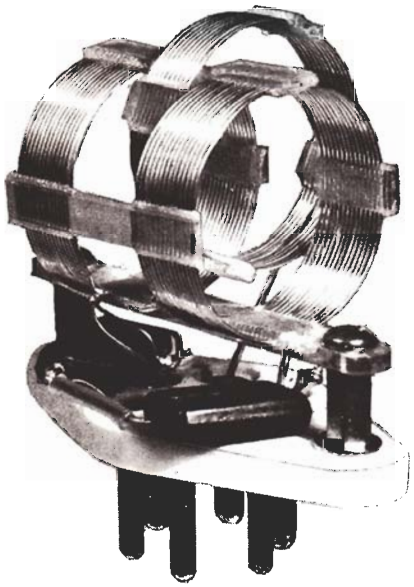


Fig. 5. Modification of grid tank coil

INITIAL TUNE-UP PROCEDURE

After checking the wiring and construction, apply power to the filament circuit. Insert the GL-811-A in its socket and connect the plate cap. Do not apply plate voltage—in fact, disconnect the plate power supply from the terminal board for the present. Plug in the set of coils covering the band you intend to operate and plug in a 0–50 ma meter in the grid current jack (J3). With power applied to the filament, it is normal to see about 2 or 3 ma grid current with *no* excitation.

Arrange to supply excitation to the amplifier at the desired frequency. Start with the center link loosely coupled and tune the grid circuit to resonance as indicated by maximum grid current. Set the neutralizing condenser about 90 degrees open and check grid circuit resonance. The amount of excitation used at this time is not critical—anywhere from 15 ma to 50 ma (maximum) will do. Adjust the coupling so that this order of magnitude is reached. If a single-sideband suppressed carrier exciter is used, it must be delivering some sort of a signal. A tone modulation, unbalanced carrier, or some reproducible signal will suffice.

NEUTRALIZATION

Disconnect the grid-current meter temporarily, but leave an open-circuited plug in the grid-current jack. Tune the plate tank circuit to resonance or near resonance as indicated by a lamp bulb connected to a loop of wire coupled to the plate coil, an oscilloscope connected to the output jack (use a one-turn tap on the coil) or any other neutralizing stunt you prefer. When fully neutralized, tuning the plate circuit through resonance will not affect the grid circuit. This may be verified by coupling the neutralizing indicator to the grid tank and tuning the plate circuit through its resonance point noted earlier.

With the amplifier neutralized, the plate supply may be connected, the grid-current meter reconnected, and a plate-current meter (0–250 ma) plugged into the cathode current jack (J4). With no excitation, the static plate current will be about 35 ma with 1500 volts applied. It will be noted that the static grid current will drop appreciably when plate voltage is applied. This is normal.

MATCHING AND LOADING

For further test, it is necessary to provide a load for the Power Peaker. Failure to do so will result in damaged coils. A dummy load which has the same resistance as your antenna is ideal for making coupling adjustments. Do not attempt to use incandescent lamp-bulb as a load because its resistance depends greatly on its temperature. An oscilloscope is also needed to check linearity and power when making a test with a two-tone signal. (See S. G. Reque, Linear R.F. Amplifiers, QST, May 1949, and R. W. Ehrlich, How To Test and Align a Linear Amplifier, QST, May 1952.)

Adjust the single-sideband exciter used as a driver for two-tone operation. Feed this signal into the input jack (J1), at a low level at first and connect the output link to a suitable load. Arrange the oscilloscope so that it can read the r.f. signal across the load. Enough signal will be available to see with the r.f. applied directly to the deflection plates. Apply plate voltage and resonate the grid tank (maximum grid current) and the plate tank (maximum load voltage) with fairly loose coupling to the output circuit.

(CAUTION—HIGH VOLTAGE! ALTHOUGH THE POWER PEAKER HAS BEEN DESIGNED WITH SAFETY IN MIND, IT IS WELL TO RECOGNIZE THE FACT THAT HIGH VOLTAGE IS USED AND THAT ALL "BACK OF THE PANEL" ADJUSTMENTS SHOULD BE MADE AFTER MAKING CERTAIN THAT THE HIGH-VOLTAGE SUPPLY IS NOT ONLY OFF BUT THAT THE FILTER CONDENSERS ARE DISCHARGED. WE DON'T WANT TO LOSE ANY OF OUR READERS JUST YET. STICK AROUND AND FIND OUT HOW WELL THE POWER PEAKER REALLY WORKS. 'NUFF SED?)

An arrangement should be made whereby the exciting signal can be turned off and on conveniently while making loading and matching adjustments. Do not run the test signal any longer at a time than is necessary to see the oscilloscope display and appraise it. Increase the input signal by either increasing the exciter output, or, the coupling in the grid circuit until the peaks of the two-tone output signal show definite flattening. Keeping the input signal at the level where flattening occurs, increase the coupling of the output by moving the tap up on L4 until the flattening disappears. Go a little further with this coupling. Next, increase the input signal until flattening again occurs and then increase the output coupling and so on. The tuning of plate and grid circuits should be checked for maximum output for each coupling adjustment made. You will note as the job progresses that the peak amplitude of the output signal keeps increasing. Along with this increased output you will note that the plate current has been increasing and so has the grid current. The stopping point is reached when either:

(a) The exciter can no longer deliver an undistorted two-tone signal, or,

(b) The plate current, with a two-tone test signal, has reached a value around 165 ma.

When condition (b) is reached, the tune-up procedure is completed, however, condition (a) requires an investigation of the exciter. Make certain that the Power Peaker is presenting a favorable load to the exciter. This is just a matter of juggling the coupling from the exciter and into the amplifier along with the exciter gain control if it has one. A peak driving power of about 2.5 watts is required, so if the exciter can deliver 5 watts peak power you have only to present the right load to the exciter.

The grid current under correctly loaded condition (b), will be somewhere around 20 ma with a total cathode current of 185 ma. Do not become concerned if the grid current is less than this amount, but if it is appreciably higher, increase the plate coupling or reduce the input signal or both.

If the procedure outlined has been followed carefully, the amplifier is loaded in an optimum manner. This may be checked by increasing the coupling to the output tank and noting the decrease in r.f. output signal (with fixed drive) and a slight decrease in grid current. Conversely, with fixed drive, decreasing the coupling from optimum will cause an increase in grid current and a flattening of the two-tone peaks as the signal passes through the amplifier. The plate current will drop. Bear in mind the objective is to load the amplifier for maximum output power for any given drive condition up to the maximum input current stated for condition (b). The objective is *not* to load the amplifier simply for maximum input, since the efficiency depends on the loading.

Although reading the tune-up procedure may raise several points not covered, remember that doing the job is probably not as bad as reading about it. The procedure is quite simple, as experience will show, and you will find that the description is quite detailed, perhaps needlessly so. Correct loading is essential to realize maximum output and efficiency together with low distortion.

OPERATING INFORMATION

Very little can be added here to what you already have learned in matching and loading the Power Peaker. Substitution of an antenna for the dummy load and a brief two-tone test with the oscilloscope as a monitor puts you on the air. Never try to exceed with speech signals the maximum peak level attained with the two-tone test. Not only will this fail, but also the quality of your single-sideband signal will be degraded. But worse than that, such practice destroys one of single-sideband's best points—a really narrow, minimum-interference, maximum intelligibility, signal. The Power Peaker linear amplifier can do a good job. Give it a chance and keep your sidebands clean.

Additional Coil Information

ADDED COIL DATA FOR POWER PEAKER LINEAR AMPLIFIER

Coil Substitutions for L_1

Band (Mc.)	National Number	uh	mmf	B & W Number
3.5-4.0	AR17-40S	14.5	145	3118-40JVL- Remove 5 turns each side
7.0-7.3	AR17-40S*	7.0	75	3118-40JVL- Remove 2 turns each side
14.0-14.3	AR17-20S	2.5	53	3116-15JVL- As is
21,27-30	AR17-10S	1.2	46-28	3115-10JVL- As is

Coil taps, padding capacitors and base connections should be made as listed in Coil Table on page 4 of the Volume 7, No. 5 issue of G-E HAM NEWS. Capacity listed is for low frequency end of each band.

*Remove 3 turns from each end.

Coil Substitutions for L_4

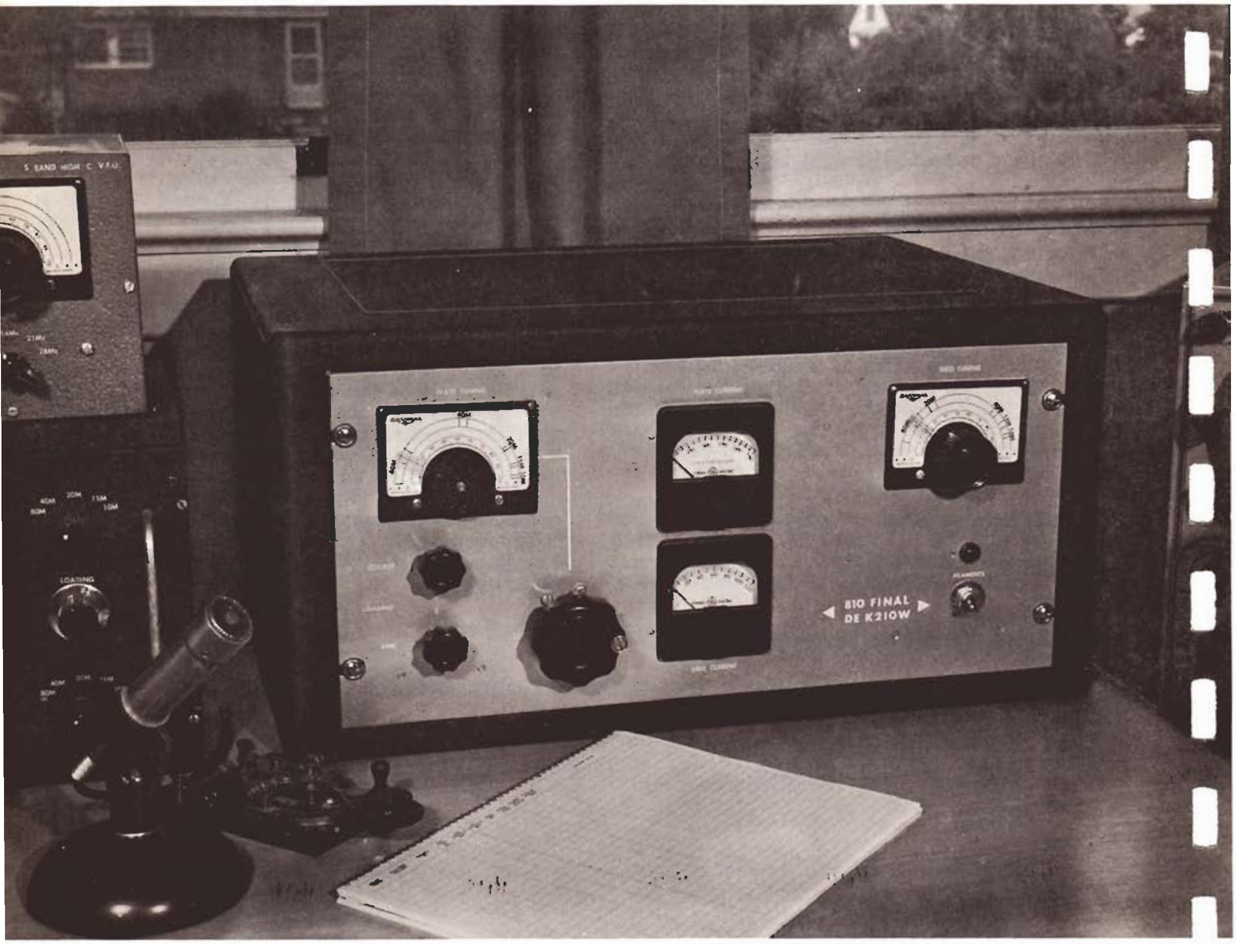
Band (Mc.)	National Number	uh	mmf	B & W Number	
				BEL*	JEL
3.5-4.0	AR17-40E remove 8 turns	10	210	40BEL remove 4 turns	40JEL remove 4 turns
7.0-7.3	AR17-20E as is	4.6	115	20BEL	20JEL
14.0- 4.3	AR17-20E remove 4 turns	2.7	48	15BEL	15JEL
21,27-30	AR17-10E remove 2 turns	0.9	63-30	10BEL	10JEL

Remove end links and make coil taps as listed in Coil Table on page 4 of Volume 7, No. 5.

* Use the B & W BEL series of coils if CW operation of the amplifier is also desired. JEL series coils will handle the SSB average power only.

COMPACT TRIODE KILOWATT

featuring —
GL-810 Triodes in parallel
Simplified tuning controls
Rapid bandchanging from panel
Complete, simple TVI shielding



TRIODE TRANSMITTING TUBES *have been historically associated with large, bulky final amplifier constructional techniques.*

"But bulk is not essential," says K2IOW, "look at the compact triode final in my shack. It fits into a standard 8¾-inch high table rack cabinet, and has a pair of non-critical GL-810 triodes in parallel."

MEET THE DESIGNER . . .
K2IOW again — Bob Hall of Schenectady, N. Y. has gone on from his latest offering, described herein, to whipping up more interesting gadgets at his workbench. The innocent-appearing 'scope in his ham shack (see page 3) includes a special circuit for transmitter monitoring. You'll read about it in an early issue.

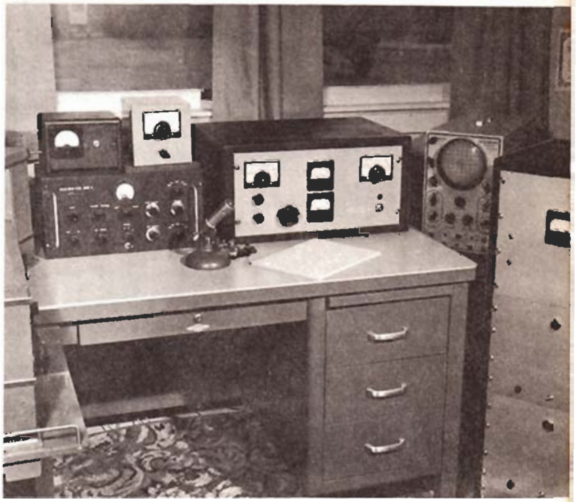
MODERN COMPONENTS, plus simplified circuitry, were primarily responsible for the evolution of this compact amplifier which can be operated in any of the popular transmission modes: class C for CW or AM phone; or as a class B linear amplifier for sideband. The two GL-810 triodes in parallel are fully capable of handling the maximum legal input in the above classes of service.

The amplifier can be driven by a transmitter with a power rating of from 75 to 150 watts, the range which spans most of the popular commercial transmitters. No power dissipating network is required, as is necessary when driving most tetrode and pentode kilowatt finals from these transmitters. Also, no screen voltage supply is needed.

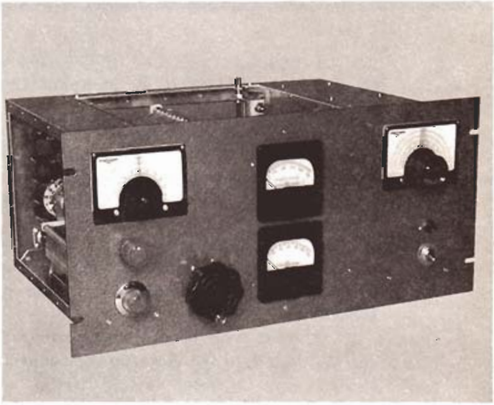
TELEVISION INTERFERENCE is a most imimportant consideration these days and the COMPACT TRIODE KILOWATT has passed interference tests with flying colors. It has been operated less than four feet away from a vintage television receiver without causing interference to local channels 6, 10 and 13; nor to a fringe-area signal on channel 2. Some old receivers with a 21-megacycle intermediate frequency may encounter interference from this final, as they would with any high power transmitter on this band.

Band changing and tuneup take very little time, since there are only four panel controls, as identified in the front panel view on page 3. The grid and plate circuit controls can be preset to the correct band from the calibrated indicators. Once an operator becomes familiar with the procedure, it should not be necessary to reduce plate voltage during tuneup.

THE CIRCUIT for the amplifier is quite standard. Since the triode tubes must be neutralized, a push-pull grid circuit, the multi-band tuner (National MB-150), shown in the schematic diagram, FIG. 1,



COMPLETE STATION at K2IOW with the Compact Triode Kilowatt at the right side of the operating desk. Other equipment includes an NC-240D receiver and speaker (extreme left); the 6L6-GC exciter which drives the 810 final; indicator for SWR bridge and High-C Bandswitching VFO atop the exciter; 5-inch 'scope for monitoring; and a 3-foot-high rack cabinet containing (top to bottom) class B GL-805 plate modulator, high voltage supply for the modulator, and a 2,000-volt DC supply for the 810 final.



PANEL VIEW of the 810 final. The large knob turns both the rotary inductor and input variable capacitor in the pi-network plate tuned circuit. Indicator dial at left shows band to which plate circuit is tuned. Dial at right is coupled to MB-150 multi-band tuner in grid circuit and provides convenient tuning rate.

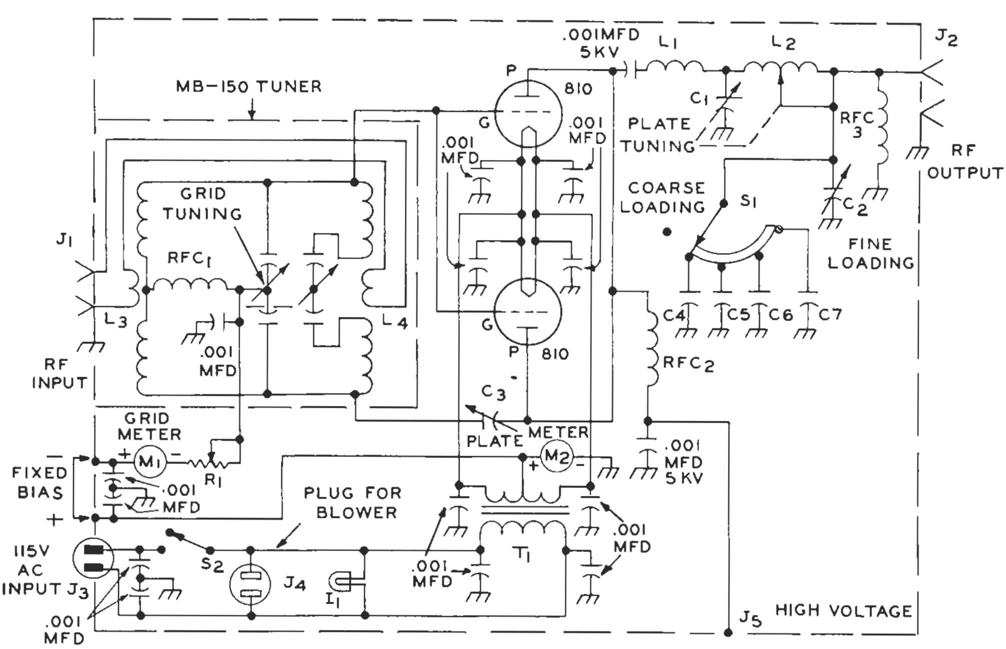


FIG. 1 SCHEMATIC DIAGRAM of the GL-810 triode final. Note that the grid bias return lead is connected directly to the center tap on the filament transformer (T_1) without going through the plate current meter (M_2). Thus, M_2 reads only plate current and not combined plate and grid current. All 0.001-mfd bypass capacitors are disc ceramic, 1,000 volts working, unless otherwise specified. All power and meter circuit wiring should be shielded.

PARTS LIST

C_1	30 — 150-mmf variable, 0.175-inch air gap (Johnson 150D70; or National TMA-150).
C_2	20 — 500-mmf variable, 0.045-inch air gap (Johnson 500E20, Cat. No. 154-3).
C_3	2 — 10-mmf air variable, 0.375-inch air gap (Johnson N375, Cat. 159-375 neutralizing cap).
C_4, C_5, C_6	500-mmf, 2,500-volt mica.
C_7	0.001-mfd, 2,500-volt mica.
I_1	115-volt candelabra base pilot lamp and bracket.
J_1 J_2	chassis type coaxial cable connector.
J_3	chassis type 2-prong male power connector.
J_4	chassis type 2-prong female power connector.
J_5	single prong high voltage connector (Millen type 37001, red plastic).
L_1	0.3 uh, 3 turns of 0.062 x 0.250-inch copper strip, 1¾ inches in diameter, 1½ inches long, 2 turns per inch, with 1-inch leads.
L_2	15 uh, 5-ampere ratary inductor, 27 turns, No. 12 wire (B & W No. 3852, used in this model; or Johnson Cat. No. 229-202).
L_3	8 turns, No. 16 insuloted wire, 1¼ inches in diameter, mounted inside center of larger coil on MB-150 tuner.
L_4	2 turns, No. 16 insulated wire, wound over center of small coils on MB-150 tuner.
M_1	0 — 150-ma DC milliameter (General Electric DO-41 or DO-71, 3½ inches square; or new type DW-91, 2½ inches square).
M_2	O — 500-ma DC milliameter (to match M_1).
MB-150	National MB-150 multi-band tuner, modified per instructions in mechanical details.
R_1	1,000 ohms, 25-watt patentiometer.
RFC_1	2.5-mh r.f. choke; part of MB-150.
RFC_2	145-uh single layer r.f. choke (National R-175A; B & W No. 800, or Raypar No. RL-100 also suitable).
S_1	11-positian, single section progressive shorting tap switch, stap set far 5 positions (Centralab P1S ceramic wafer and P-123 index).
S_2	single pole, 1 position toggle switch.
T_1	10-volt, 10-ampere filament transfarmer, 115-volt primary.
RFC_3	2.5-mh pi-wound r.f. choke (Natianal R-100).

was necessary. An r.f. voltage of the proper phase and amplitude to prevent regeneration or oscillation is fed back to the lower end of this tuner through C_3.

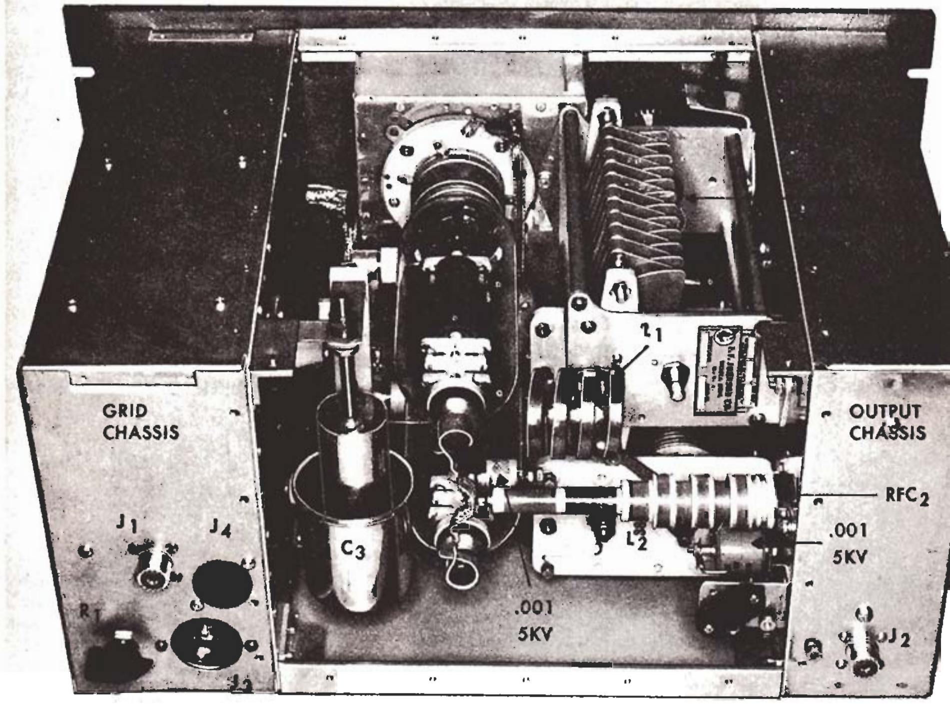
Greater link-coupling transfer efficiency was obtained in the multi-band tuner by replacing the original single link, only on the low-frequency coil, with individual links for it and the high frequency coils. This change is described in the construction details.

In the plate circuit, plate voltage is fed to the tubes through RFC_2. The pi-network is formed by capacitors C_1 and C_2, plus C_4, C_5, C_6 and C_7 in parallel, depending upon the setting of S_1; and coils L_1 and L_2 in series. All the capacitors across the pi-network output are needed when matching into low impedance loads — 100 down to 30 ohms — at 3.5 megacycles.

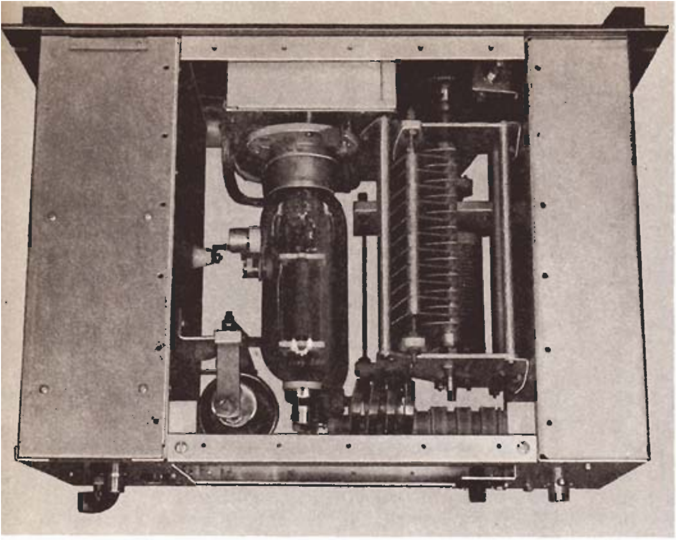
Mechanical ganging was employed between C_1 and L_2 to combine these controls and maintain a nearly constant L/C ratio in the plate tank circuit throughout the frequency range covered by this amplifier. A pair of worm gears having the proper ratio drives C_1 from maximum to minimum capacitance while L_2 is being cranked from maximum to minimum inductance.

The 28-megacycle inductance, L_1, was connected between the plates of the GL-810's and C_1 to remove C_1's minimum capacitance from the input side of the pi-network at this frequency. Thus, only the output capacitance of the two tubes appears across the input of the pi-network. About one half to two turns of L_2 are in the pi-network at 28 megacycles, and C_1 and C_2 are across the output side.

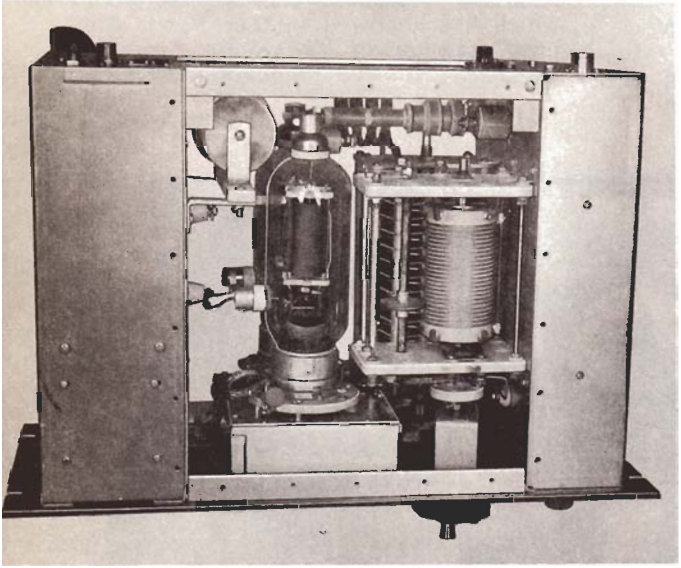
The power connections are identified on the schematic diagram. Fixed negative bias of about 80 volts is sufficient with the GL-810's operating at 2,000 volts on the plates. The bias supply should have good voltage regulation. K2IOW uses the electronically regulated bias supply circuit which has appeared in the "Power Supplies" chapter of *The Radio Amateur's Handbook* (ARRL) for several years.



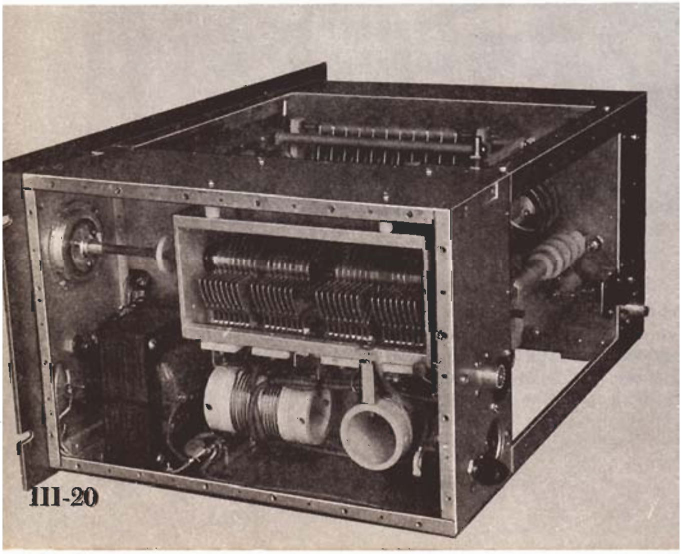
REAR VIEW, looking down into the final. A separate lead runs from each 810 plate cap to the plate circuit r.f. choke (RFC_3). Cylindrical blocking capacitor behind r.f. choke (0.001-mfd, 5,000 volts) connects to one end of 28-megacycle coil (L_1), made from copper strap. Other end of L_1 fastens to terminal on L_2. High voltage connector (J_5) is on small angle bracket just below base of r.f. choke, with bypass capacitor behind it. Aluminum angle in foreground connects upper rear corners of the chassis.



TOP VIEW, showing the white ceramic feedthrough insulator for connection between 810 grid caps and the MB-150 multi-band tuner, located inside chassis at left. Meters are shielded from r.f. compartment by the 5 x 7 x 2-inch chassis on which the 810 tube sockets are mounted with ¼-inch long spacers.



BOTTOM VIEW, showing the shielded leads running from the filament transformer (T_1) inside the grid chassis to the 810 tube sockets. Each filament pin is bypassed individually with shortest possible leads. Neutralizing capacitor (C_3) fastens to grid chassis with 2-inch-long angle brackets.



SIDE VIEW of the 4-inch deep grid circuit chassis, showing the modified MB-150 grid tuner. Note the 2-turn link coil (L_4) on the high frequency coil; see PARTS LIST for details. Insulated extension shaft runs between MCN dial and shaft on MB-150 tuner.

THE TRIODE KILOWATT was a pleasure to build, and it's a joy to operate. The vertical chassis arrangement lends itself to easy construction, requiring a minimum of framework to support shielding. The usual workshop hand tools, plus a 1/4-inch electric drill, were used for all the mechanical work except the meter and indicator dial holes. The latter can be cut with a circle cutter, hole saw or counterbore.

The pictures and accompanying captions on pages indicate placement of the major components in the amplifier. Precise locations of the chassis and holes on the panel, and critical dimensions, can be determined from the top and front view sketches in FIG. 2. The knob shaft which drives C_1 and L_2 may require slightly different placement, depending on the actual parts used, and the gear drive assembly.

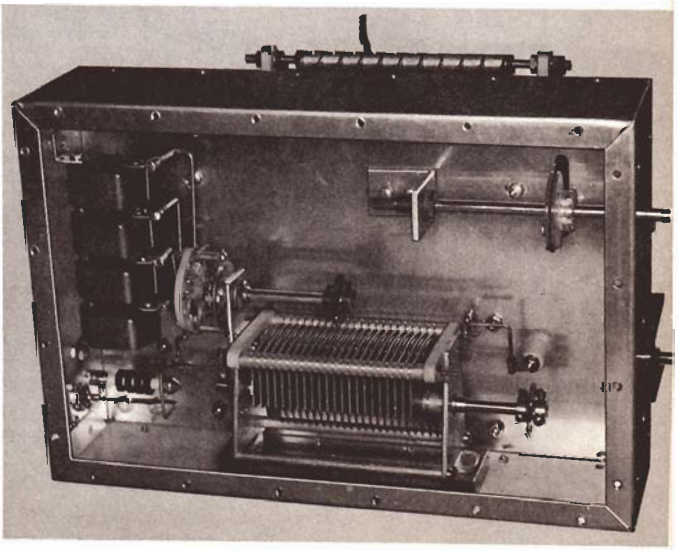
BOTH CHASSIS and other components on the panel were fastened with No. 8-32 screws driven into tapped holes in the 8¾ x 19-inch aluminum rack panel (Bud PA-1105, or equivalent). All screws were cut off and filed flush with the panel surface before painting. During assembly, the three chassis were lined up and clamped to the back of the panel. Holes were drilled from the panel front with a No. 29 drill and threaded with an 8-32 tap. Use turpentine to prevent the tap from becoming clogged with aluminum chips. Matching holes in the chassis were enlarged.

THE GRID CHASSIS, which had to be 4 inches deep to house the MB-150 tuner, was assembled from *See-Zak* chassis plates and side rails. An 8 x 12-inch plate (P-812) forms the chassis deck, inside the amplifier. A pair of 4 x 8-inch side rails (R-48) form the chassis front and rear; while a pair of 4 x 12-inch side rails (R-412) form the top and bottom side walls. The outside of the chassis was covered with shielding later.

The MB-150 tuner hangs upside down on pillars ¾ of an inch long inside the grid chassis, with the tuning shaft 6¼ inches above the bottom wall. Drill holes in the chassis top to match those in the capacitor frame on the tuner. There's sufficient room between the chassis front wall and the MB-150 tuner for a normal-size 10-volt, 10-ampere filament transformer (T_1), but some king-size transformers may not fit. Be sure to allow room for I_1 and S_2 in front of T_1.

The shield box for the meters — also the mounting for the 810 tube sockets — is 5 x 7 x 2 inches over-all (see detail view on page 9). A See-Zak chassis plate (P-57) forms the deck; while the end and side rails are 2 x 5 inches (R-25), and 2 x 7 inches (R-27), respectively. A conventional aluminum chassis of this size can be used, but must be fastened in place with self-tapping screws driven into the bottom lip from the front of the panel.

THE PLATE CIRCUIT pi-network is mounted on the top deck of an 8 x 12 x 3-inch aluminum chassis (Bud AC-424, or equivalent), as shown in the detail view on page 10. The capacitor (C_1) and rotary inductor (L_2) are coupled together through a right angle drive on the shaft of L_1; in turn connected through a panel bearing and shaft assembly to a worm (Boston No. LTHB) and a worm gear (Boston No. G-1029) on the shaft of C_1. The worm gear ratio — 50 to 1 — was selected to enable the rotor of C_1 to turn 180 degrees while the rotary inductor is being cranked through the 27 turns required to move the contact roller from end to end. The shafts on C_1 and L_2 are 4¼ inches apart.



INSIDE VIEW of the output chassis, showing the coarse (C_4-C_7) and fine (C_2) loading capacitors in pi-network. Extension shafts are used to turn C_2 and S_1. Note method of mounting plate circuit indicator shaft, and pulley for dial cord, which runs to same size pulley on shaft of C_1 (See view of pi-network on page 10).

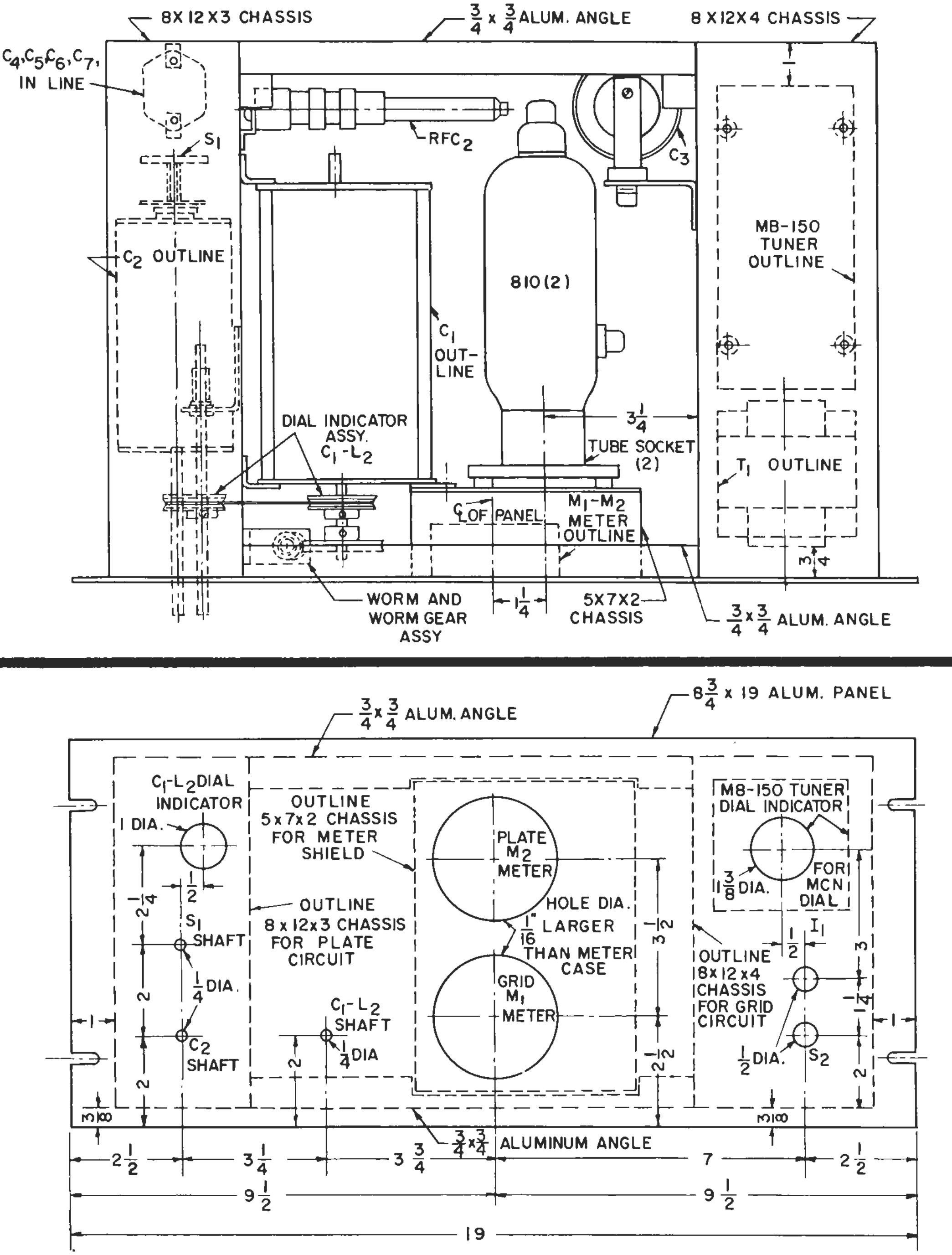


FIG. 2. TOP AND FRONT layout diagrams for the 810 triode final. Positions of all major components have been indicated, but may vary in accordance with the sizes of parts actually used in duplicating this amplifier. Panel layout allows room for meters with 3½-inch diameter flanges on cases. Spacing between the shafts on C_1 (top) and L_2 (bottom) is 4¼ inches. Note notches in angle behind panel to clear meter shield.

The knob shaft for L_2 was run through a box-section aluminum extrusion which houses the miter gears (2-Boston No. G-464). However, the lower end of the vertical shaft could be supported by a panel bearing mounted in an angle bracket similar to that at the upper end of the shaft. A panel bearing on the knob shaft for L_2 could support it at the panel.

Alignment of the miter gears is accomplished simply by sliding them into the proper relative positions before tightening the set screws. The worm gear on C_1 is then lined up with the vertical shaft. Provide a slot in the upper angle bracket for the vertical shaft. This permits the shaft to be moved for proper meshing of the worm gears. Finally, tighten the nut on the upper panel bearing to lock the shaft in this position.

The capacitors, switch and other parts in the pi-network output section are mounted inside the plate circuit chassis. Parts locations and assembly details are shown in the end view on page 7.

Once all the holes in the panel and chassis have been drilled, the chassis should be temporarily assembled to the panel. Four 10-inch lengths of ¾ x ¾-inch soft aluminum angle (do-it-yourself type) should then be cut. Two of them are fastened to the panel, as shown in the detail photo below. The others are fastened between the upper and lower rear corners of the chassis with small angle brackets cut from the same material. Shields are then cut from perforated sheet aluminum (do-it-yourself type) to cover the top, bottom and rear openings between the chassis; also the open ends of the two chassis. Drill holes for No. 6-32 machine screws in the aluminum angle; and for self-tapping screws in the chassis, spaced not more than 1½ inches, using the perforated shields as templates.

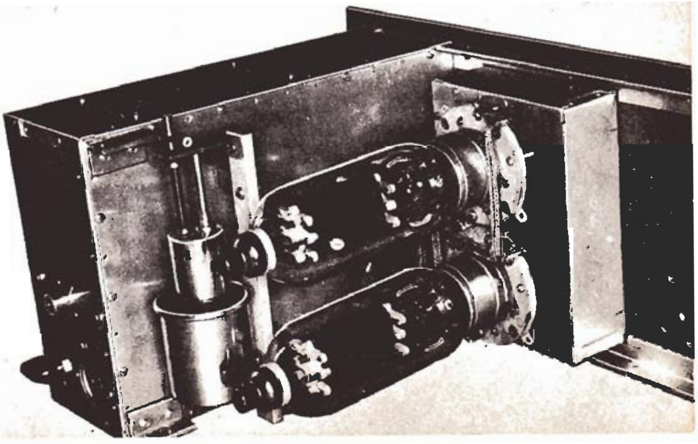
SMALL PARTS, such as angle brackets, should be facricated to fit the parts being mounted. Remove the aluminum base from C_3 and make two angle brackets to support it from the grid chassis deck. A frame for the plate tuning indicator to match the grid tuning MCN dial was made by tracing around the MCN frame onto a piece of sheet aluminum. This frame was cut out and painted black wrinkle.

The hub for the plate tuning dial pointer was made from a Lucite disc 1½ inches in diameter. It also was finished in black wrinkle paint. The pointer is of clear plastic to match the MCN dial pointer, with an indicator line scratched on it, and filled with black paint. The pointer was cemented to the back side of the hub. The hub was fastened to the indicator shaft with a 4-40 machine screw driven into a hole tapped in the end of the shaft.

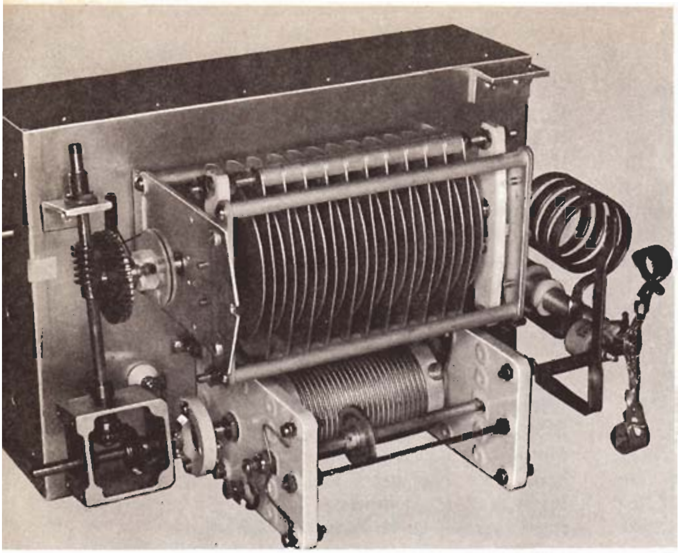
Two plastic pulleys about 2 inches in diameter — one on the shaft of C_1, and the other on the plate tuning indicator shaft inside the plate circuit chassis — drive the dial pointer. They can be adapted from table radio dial cord pulleys, or turned from sheet Lucite. Because the indicator rotates through only 180 degrees, the dial cord can be fastened at one point on each pulley to prevent slippage.

Modify the MB-150 tuner by removing the original link coil and substituting L_3 inside the low-frequency coil form. Make the leads on L_3 long enough to run out of the form, with one wire going to the r.f. input jack, J_1; and the other to L_4. Install L_4 between the two coils on the high-frequency coil form, as shown in the grid circuit view at the bottom of page 6.

FINAL ASSEMBLY of the parts on the two chassis may begin after the burrs are removed from all holes. All parts should be mounted and the wiring completed before fastening the grid chassis to the panel. Be sure to leave the shielded leads to the meters and 810 tube sockets long enough. Next, install the panel and meters, wiring



DETAIL VIEW showing the sockets for the 810 tubes positioned so that the plates lie in a vertical plane. This prevents possible grid-to-filament short circuits due to filament sag when filaments are hot. Details on grid chassis and meter shield boxes are given in the constructional details. Outside cup on C_3 connects to plates of 810 tubes; inside cup to MB-150 tuner through small feedthrough insulator.



DETAIL VIEW of the pi-network assembly and the gear drive between the shaft which turns L_2, and C_1. Shafts for the miter gears can be mounted on angle brackets, instead of the box-type housing shown. Note pulley for indicator dial with dial cord crossed for proper rotation of pointer. Insulated shaft coupling must be used on shaft of L_2. Feedthrough insulator behind gear box is for connection from L_2 to stator of C_3.

them before assembling their shield box. Mount the 810 sockets on the 5 x 7 shield cover and fasten it in place.

After the plate circuit chassis is in place, the ¹⁄₁₆ x ¼-inch, copper strap leads between the plate circuit components may be fitted in place. Flexible copper strap or braid should be used for the 810 grid and plate leads. One end of L_1 fastens to the 0.001-mfd ceramic capacitor at the top of RFC_2; the other end is bolted to the strap connecting the stator of C_1 and the input end of L_2.

Forced ventilation of the table rack cabinet was accomplished by fastening a small fan — a phono motor with a 3-inch diameter fan — over a 3⅛-inch diameter hole in the back of the cabinet, in line with the lower 810 tube. A short duct made from a 3-inch diameter can was fastened inside the cabinet, extending to within ⅛ of an inch of the amplifier shielding.

PRELIMINARY TUNEUP should be completed without the shields in place. Turn the plate tuning control until L_2 is about ½-turn from minimum inductance. Install the GL-810 tubes, turn C_2 to the half-meshed position, and set S_1 so that none of the fixed loading capacitors (C_4-C_7) are in the circuit. Obtain a grid dip meter covering the 30-megacycle range and hold its coil near L_1. A dip should be observed between 30 and 32 megacycles. If the dip is below 30 megacycles, spread the turns on L_1 and recheck. If necessary, decrease the diameter of L_1 slightly to shift the dip to above 30 megacycles.

Apply 115-volt AC power, bias voltage and about 50 to 75 watts of r.f. driving power at 14 or 21 megacycles through J_1. Do not connect plate voltage at this time. Tune the MB-150 to resonance, as indicated by maximum grid current on M_1. Leave C_2 and S_1 set as above and, while turning the plate tuning control with the roller on L_2 about 6 or 8 turns from minimum inductance, watch M_1 for a fluctuation in grid current. Starting with C_3 at maximum capacitance, turn it toward minimum capacitance while rocking the plate tuning back and forth until virtually no fluctuation in grid current is observed.[1] The amplifier is now neutralized.

Shielding may now be installed and the neutralization adjustment rechecked. A small hole was cut in the top shield over C_3 for this purpose. Connect a suitable dummy load[2] to J_2 and apply about 1,000 volts to J_5. With the same r.f. drive used for neutralizing, tune the MB-150 for maximum grid current, then tune the plate circuit for a dip in the plate current reading on M_2. Turn C_2 toward minimum capacitance to increase the loading to about 200 milliamperes plate current, readjusting the plate tuning for a dip.

If the amplifier is operating properly, increase the plate voltage and current to the normal rating for the class of service in which the amplifier will be operated. A fixed bias supply is recommended, especially for CW operation; and it is essential for class B linear operation.

Normal tuneup consists simply of adjusting the exciter to supply the required driving power, tuning the grid and plate circuits to resonance, and loading with the coarse and fine loading controls.

Type GL-8000 triodes, electrically and mechanically similar to the GL-810 except for amplification factor (mu), were tested in the amplifier and found to require somewhat less driving power.

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[1] Other procedures for neutralization are given in the amateur radio handbooks.

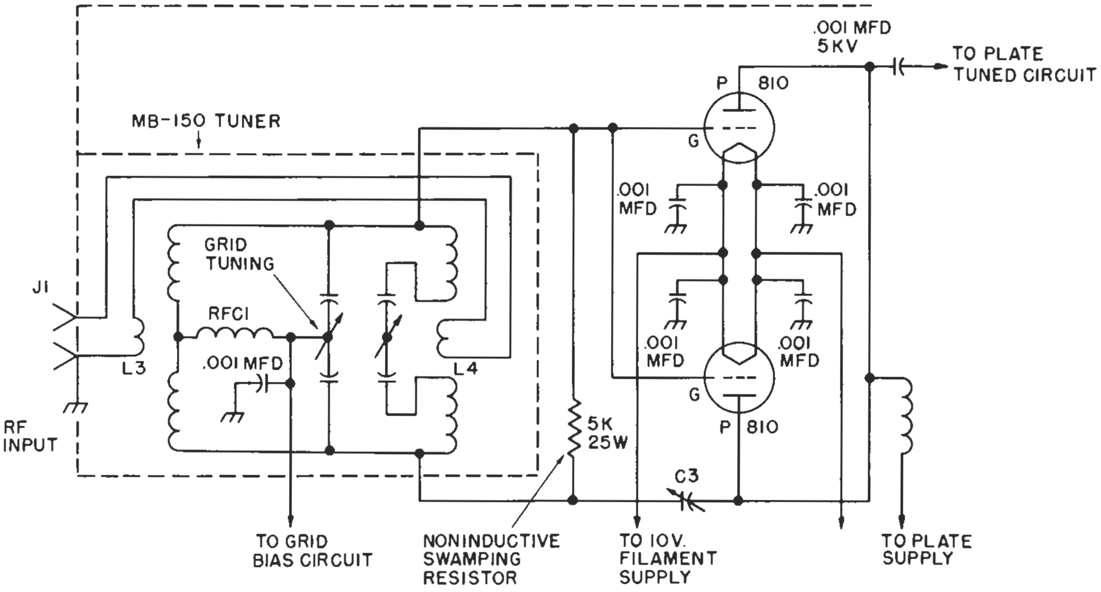
[2] Four 150-watt lamps in series-parallel; or, see "Using Resistors as RF Loads," **G-E HAM NEWS**, January-February, 1951 (Vol. 6, No. 1), for other ideas.

Additional Information for Compact Triode Kilowatt

1. A terminal into which fixed bias is applied to the control grids of the GL-810 tubes does not appear in the rear view on page 5, but was added by K2IOW just above the bias adjustment potentiometer, R_1.
2. K2IOW has since converted this amplifier from class C operation into a class B linear simply by shunting the MB-150 grid tank circuit with a 5,000-ohm, 25-watt non-inductive resistor. The resistor was placed between the GL-810 grid connection, and the connection to the neutralization capacitor, C_3, at the lower end of the MB-150 on the schematic diagram, Fig. 1, on page 4 of this issue. Normal bias for class B audio operation is given in the table below. Potentiometer R_1 should be set at minimum resistance.
3. GROUNDED-GRID OPERATION--Either GL-810 or GL-8000 triodes can be operated in a grounded-grid linear amplifier circuit constructed much the same as K2IOW's amplifier, except that the grid tank circuit and neutralizing components are eliminated. Each tube grid is bypassed to ground separately through a 0.005-mfd disc ceramic capacitor with shortest possible leads. Normal class B bias is applied to the grids. A B & W FC-15 filament RF choke is inserted in the filament circuit, following normal grounded-grid techniques, and the r.f. input is fed from the coaxial cable input jack to both sides of each tube filament through 0.001-mfd disc ceramic capacitors.

TABLE I - CLASS B GRID BIAS FOR GL-810 and GL-8000

Tube Type	Operating Plate Voltage					
	1,500	1,750	2,000	2,250	2,500	Volts
GL-810	-38	-44	-50	-60	-70	Volts
GL-8000	-90	-105	-120	-130	-150	Volts



COMPARISON OF DSB AND SSB

Boy! What would we hams do for rag-chewing topics if new technical developments were not constantly coming along for us to hash over! Lately, one of the most popular topics for discussion—on the air, at radio club meetings, or wherever a group of amateurs congregate—is double-sideband, suppressed-carrier transmission and reception (DSB)[1].

Undoubtedly the big advantage of both SSB and DSB signals over conventional AM is that absence of that old heterodyne-producing carrier. Spacewise, the *two* sidebands of AM and DSB signals normally will make these signals twice as broad as that from a ***properly-adjusted*** SSB transmitter having adequate unwanted sideband suppression (30 db or greater). Overdriving a linear amplifier following either a SSB or DSB exciter usually results in a much too-broad signal containing an abundance of distortion products. (We've heard this condition far too often lately, so watch that gain!)

To many amateurs the big decision seems to be, "Should I convert my present AM rig to SSB or DSB?; and, which system offers the best results, plus the least complicated conversion?" The "best results" question is highly controversial[2], but two simple methods have been suggested for converting an AM transmitter to DSB, both of which utilize a greater portion of an existing AM rig than a similar conversion to SSB.

The same basic type of balanced modulator circuit is used in both DSB systems, but the DSB signal may be generated in either the final amplifier stage[3], or a low-level exciter stage[4]. The low-level DSB signal is then amplified by operating succeeding stages as linear amplifiers, as in an SSB transmitter.

In contrast, even a low-power, ***all-band*** SSB exciter is quite complex, and the amateur who has built his own really deserves a pat on the back! The abundance of commercially-built SSB exciters on the air verifies this fact.

However, a one-band SSB exciter can be quite simple (see SSB, Jr., G-E HAM NEWS, November–December, 1950, Vol. 5, No. 6) without the extra frequency conversion and spurious signal problems that usually arise when designing an SSB exciter for several bands. This is an easy way for the build-it-yourself radio amateur to get started on SSB, since the phasing type circuit in the SSB, Jr., can later be incorporated into a heterodyne-type exciter for two or more bands.

The reception of DSB signals on a garden-variety communications receiver (one that will respond to both sidebands at once) is not so delightfully simple, however. The carrier that you re-insert with the receiver's BFO should be exactly the same frequency and ***phase*** as the DSB transmitter carrier for best readability. Mis-tuning a DSB signal only a few cycles on such a receiver results in greatly reduced audio intelligibility[5]. This problem can be avoided by means of a receiver or adapter unit that has a complex carrier phase synchronization system. For the radio amateur, a much easier solution to receiving DSB signals is to use a SSB receiving adapter. This deliberately ignores one sideband of a DSB signal—and it lets you select the sideband on which there is least interference. Both SSB and DSB signals can be mis-tuned nearly 100 cycles on most receivers equipped with an SSB adapter and still be readable, even though the voice may sound like Donald Duck!

Thus, a DSB signal usually is as simple to generate as a conventional AM signal, and somewhat easier than generating an SSB signal. Conversely, DSB signals are more difficult to ***receive*** properly than AM or SSB signals without a special adapter on your receiver.

* * *

Now that we've briefly outlined the relative simplicity of the equipment required for SSB and DSB operation, let's talk a bit about what happens when you put either type of rig on the air. A lot of the SSB boys contact each other en-masse in round-table QSO's, some of which collect staggering numbers of participants! The ensuing conversations often greatly resemble the good old-fashioned party-line telephone circuits! Operating thusly practically requires all stations to be equipped for voice-controlled break-in operation.

After listening to—or operating in—one of these round tables, the advantages over the old system of long-winded alternate transmissions are obvious (and this applies equally to CW break-in). Being able to warn the other fellow instantly when some QRM lands on the channel is much easier than straining to maintain solid copy through heterodynes and other hash. It also eliminates note-taking—or relying on your memory—to be sure of commenting on all subjects the other fellow has covered. —And how many times have you patiently sweated out listening to a long transmission without being able to break in right after the XYL has told you that the steaks are on the table—and you had better get there fast before everything gets cold? Need I say more?

Of course, most boys using DSB transmitters also will want to equip their stations with voice-controlled break-in so that they can jump right into the round-table QSO's. There should be practically no detectable difference in sound between a SSB and DSB signal when copied on a SSB receiver, except that a DSB signal will be readable on both lower and upper sideband positions.

We seldom hear a roundtable QSO in which all three types of stations—AM, SSB and DSB—are participating. For this, it is simply desirable that all stations be within a few cycles of the same carrier frequency, and that voice-controlled or other means of fast break-in be employed. This could and should be a good way to make new acquaintances—as well as renew old ones—among amateurs using other modulation methods, and similarly increase your enjoyment of amateur radio as a hobby. Finally, let's coin an appropriate slogan, which obviously is: "Live modern—supress that carrier and install rapid break-in at your station."

—*Lighthouse Larry*

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[1] Costas, "Synchronous Communications," *Proc. IRE*, December, 1956, page 1713.

[2] Costas, "Single-Sideband: Is It Really Better than Amplitude Modulation?" *CQ*, January, 1957, page 26.

[3] Najork, "100-Watt DSB Mobile," *CQ*, March, 1957, page 52.

[4] Stoner, "DX-100 to DSB," *CQ*, April, 1957, page 54.

[5] Grammer, "Suppressed-Carrier AM," *QST*, March, 1957, p. 21.

Maximum Ratings and Typical Operating Conditions for Transmitting Tubes

From September-October, 1950

Question: How are the Maximum Ratings that are generally included in transmitting tube data arrived at? Is it ever permissible to exceed these ratings and, if so, in what type of service and with what probable result as regards tube life?

Answer: The data sheet of almost any transmitting tube contains information of two types. One set of information is the Maximum Ratings referred to in the question, and the other set of information is called Typical Operating Conditions. The Maximum Ratings are intended to be just what the name implies, that is, ratings that should not be exceeded. Typical Operating Conditions are examples of various voltages and currents that are likely to occur when the tube is operated as specified. Let us discuss both types of information.

Maximum Ratings are placed on plate voltage, screen voltage, and grid voltage. These voltage ratings are those which the tube manufacturer knows it is safe to use, from the standpoint of the physical and mechanical properties of the tube. For example, if the rated maximum plate voltage is stated as 3000 volts, then the tube in question may be operated safely at this voltage. If a higher voltage were to be used, a voltage fault of some sort might occur, such as excessive leakage across an insulator, or perhaps even an arc between electrodes.

The same sort of reasoning applies to screen voltage and grid voltage. Of course, some safety factor is included in these ratings, but this safety factor is one which has been computed for the particular tube type in general. If you were to exceed some maximum voltage rating, it might just be that you would do it on a tube that was very close to the limit on internal spacing, and a voltage failure would occur.

Maximum Ratings are also placed on the various currents, such as plate current, screen-grid current and grid current. The tube manufacturer does his design work in terms of peak currents, and these allowable peak currents depend upon the amount of emission available from the filament. Knowing the available emission, the manufacturer computes the peak currents allowable, and then transfers these peak current figures into d-c current values which are then used as Maximum Ratings. This philosophy holds for plate and screen-grid currents, but the maximum allowable control-grid current is figured on a different basis.

The control grid is a relatively fragile element. It is capable of dissipating only so much energy before it melts or deforms. Therefore the Maximum Rating for control-grid current is set at a figure which will not permit the grid to overheat.

In exactly the same fashion, the Maximum Allowable Plate Dissipation is a figure which the plate or anode of the tube can dissipate safely without overheating.

Maximum Allowable Input is a rating based upon operation of the tube at the maximum expected efficiency. That is, if the maximum efficiency possible is known to be seventy-five percent, and the maximum allowable plate dissipation is 250 watts, then the maximum allowable input would be one kilowatt.

Another rating frequently given is the maximum frequency at which it is permissible to use the other Maximum Ratings. This rating is brought about because as tubes are operated at higher and higher frequencies, they reach a point where the efficiency begins to fall off rapidly. At this frequency it is necessary to derate all Maximum Ratings, else the various elements will overheat due to the lower efficiency.

From the above discussion it is obvious that Maximum Ratings cannot be used together. That is, if the maximum voltage is 3000, and the maximum plate current is given as 300, it would not be possible to run the tube at 3000 volts with a plate current of 300 mils, because by so doing you would be exceeding either the plate dissipation or the maximum allowable input.

To save the user of the tube from the bother of computing a set of operating conditions that are safe, the tube manufacturer has done this for a number of different voltages, and these are called Typical Operating Conditions. Let us examine a set of these for the GL-810.

For a d-c plate voltage of 2000 volts and a d-c grid voltage of minus 160, the peak r-f grid voltage should be approximately 330 volts. Under these conditions the d-c plate current should be adjusted to 250 mils. The typical grid current is listed as 40 mils, and the power output is shown to be 375 watts.

These are the conditions that you would find if your transmitter used a GL-810 that was exactly an average tube in all respects. However, rarely will you have a tube that has average characteristics. For that reason, do not be surprised if some of the currents do not turn out to be exactly as specified. In other words, if you apply a driving voltage of 330 volts, and you measure the d-c grid current and find it is as rated, that is, minus 160 volts, then it is quite possible that the d-c grid current could be 35 or 45 instead of the 40 mils specified.

The Typical Operating Conditions are intended as a guide to the tube user. They are not intended to be hard and fast figures. Use them merely as a guide, but observe carefully the Maximum Ratings, because they are intended to keep the tube safe from harm, for your protection.—Lighthouse Larry.

Computing Driving Power for Transmitting Tubes

From July-August, 1947

Question: How do you compute the driving power for RF amplifier circuits? All technical information sheets give data for single tube operation only. I am interested in both push-pull and parallel operation.

Answer: To compute the drive requirements when more than one tube is involved it is necessary to use the following data from the typical operating conditions for a single tube: Grid bias, peak r-f grid input voltage, grid current and driving power. The following two examples are based on the data for class C telegraphy use of the GL-812 using 1500 volts on the plate. For a typical case, a single tube requires a d-c grid bias of −175 volts, a peak r-f grid voltage of 285 volts, a grid current of .025 amperes, and a driving power of approximately 6.5 watts.

If GL-812 tubes are used in push-pull, the d-c grid voltage will still be the same (−175 volts) but inasmuch as the grid current will be doubled (.050 amperes) the grid resistor should be one-half the value of that used with a single tube. Assuming no fixed bias, this resistor, for push-pull operation, would be computed by $R = E \div .05$. (3500 ohms). The required peak r-f grid voltage per tube (grid to ground) will be the same but the peak r-f grid to grid voltage will now be 570 volts. This means that the driving stage must be capable of supplying an r-f voltage of at least that amount. Driving power requirements are doubled, hence at least 13 watts is now required.

For parallel operation of two tubes, grid bias is still −175 volts and the grid current is again doubled, requiring a grid resistor of 3500 ohms. The peak r-f grid voltage required is 285 volts, but as before, the driving power required is double, or approximately 13 watts.

—Lighthouse Larry.

Frequency Limitations on Transmitting Tubes

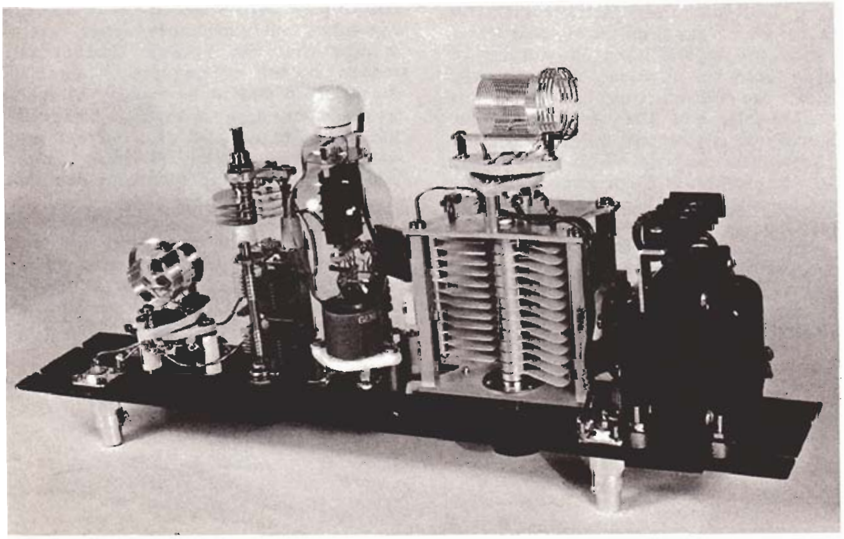
From September-October, 1946

Question: As the frequency is continually increased will various tubes reach a certain limiting frequency and cut out in all their functions simultaneously or will certain tubes amplify at higher frequencies than they would oscillate or vice versa?

Answer: Every tube has its own resonant frequency—that is, a maximum frequency at which it will oscillate. This limit is brought about by tube capacitance and inductance and at this limiting frequency the entire circuit is effectively contained within the tube envelope.

It is possible that a tube would act as an amplifier at a slightly higher frequency than it could oscillate, but the difference in these two frequencies would be small. The important point is that the efficiency at these limiting frequencies is so very poor that it would not be practical to operate the tube at frequencies even close to the limiting or resonant frequency of the tube.

—Lighthouse Larry.



Top view of the Power Peaker Linear Amplifier described fully on pages III-10 to III-15 in this chapter.