amateur service newsletter
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A 2 KILOWATT 3-400Z LINEAR FOR SIX METERS

BY WILLIAM I. ORR, *W6SAI

The Six Meter DX operator literally twitches in anticipation as he watches the sunspot cycle slowly and inexorably rise from the 1964 low. Will the sunspot count rise high enough to permit the wild DX era of 1958 to be repeated—the era when international 50 mc DX was relatively commonplace? Or will the peak of the forthcoming cycle fall short of the last record-breaking maximum? At this stage of the cycle, no one can be sure of the coming events, and the F_2 propagation history for the future of the six meter band remains a tantalizing speculation.

Even so, other forms of long distance propagation lurk just around the corner of this fascinating band, and the avid six meter DX enthusiast cannot afford to relax, as propagation surprises await the operator who has the equipment, antennas, and "know-how" to fully exploit the interesting possibilities that abound in "Channel One."

The trend to sideband, while slower than on the d.c. bands, seems to be taking place at an accelerated rate on six meters. The advantages of s.s.b. which are apparent on lower frequencies apply equally well to six meters. It is the writer's opinion that the use of a.m. on six meters will gradually be eclipsed by s.s.b. during the forthcoming ascendency of the sunspot cycle. In support of six meter s.s.b. and in anticipation of the forthcoming DX seasons on six meters, this article is presented. Let's go six!

S.S.B. exciters and linear amplifiers are becoming commonplace on six meters. This amateur band, existing in the twilight area between h.f. and v.h.f., exhibiting the characteristics of both, poses some unique problems in the design of suitable transmitting equipment. While v.h.f. construction techniques apply to this band, their unqualified use is somewhat limited as cavities and tuned lines are just too large to be used comfortably at 50 megacycles. On the other hand, employment of conventional h.f. circuit techniques may be "asking for trouble" on this quasi-v.h.f. band. Conventional h.f. components and techniques often turn out to be cranky troublemakers at six meters, bypass capacitors resembling blocks of wood, tank coils overheating and melting to a pasty blob, tubes seemingly difficult to drive and conservative circuitry exhibiting an aggravating degree of instability. Parasitic oscillations race through proven circuits and, if proper design techniques are not used by the would-be six meter enthusiast, he is apt to become discouraged and call it a day, returning to the more serene pastures below 10 meters. In other words, he is forced to "drop the fiddle and the bow: take up the shovel and the hoe."

In no area of the amateur radio spectrum is circuit *finesse* demanded more than in the design of v.h.f. s.s.b. equipment wherein the requirements of amplifier linearity are combined with the problems of circuit stability. It would be fatuous to assume that this combination of problems does not exist at six meters.

This article describes the "case history" of conversion of a 3-30 mc h.f. linear amplifier to six meter operation and, in addition, points out some of the circuit problems that were overcome in the conversion of "conventional circuitry" to quasi-v.h.f. operation. While modification of a specific amplifier package is shown, the discussion applies equally well to similar gear, or to construction of six meter amplifiers in general, and grounded grid amplifiers in particular.

The Grounded Grid Linear Amplifier

The grounded grid amplifier has attained unprecedented popularity for s.s.b. linear service in the high frequency amateur bands. As the name implies, the circuit is one in which the grid of the amplifier tube is at r.f. ground potential and the drive signal is applied between cathode and grid, either element being at the necessary d.c. bias potential. Another (more accurate) name for the circuit is *cathode driven,* as the term "grounded grid" implies the grid is actually grounded to both r.f. and d.c. potentials. This may not be the case when d.c. bias is required, or if r.f. feedback is introduced in the amplifier to enhance the intermodulation distortion figure.

A simplified schematic of a typical h.f. grounded grid amplifier is shown in fig. 1. The

**Manager, Amateur Service Dept., Eimac Division of Varian, San Carlos, California.*

circuit possesses definite advantages over the grid-driven triode and tetrode circuits. For example, neutralization of the grounded grid circuit is either not required (depending upon the frequency of operation) or, if required, is simply added and easily adjusted. An economy of circuitry is achieved by the use of high-mu triodes that do not require costly screen and bias power supplies. The drive power of the grounded grid stage, moreover, is compatible with the power output of today's s.s.b. transmitters and transceivers and—best of all—a portion of the drive power shows up as "free" power in the output of the grounded grid stage.

In a conventional grounded grid amplifier, such as illustrated, the grid element of the tube is at r.f. ground potential and acts as a shield between the plate circuit and the input circuit. A careful observer will note that this configuration is similar to that of an oscillator and might suspect that the ground grid amplifier will perform admirably as an oscillator if the shielding action of the grid is insufficient to prevent undue feedback of energy from the plate to the cathode circuit. This suspicion is well founded, for this is exactly what happens in the upper reaches of the h.f. spectrum with many grounded grid amplifiers where feedback paths are difficult to control.

While the grounded grid stage is not neutralized in the true sense of the word, the degree of internal feedback through the grid structure of the tube at the lower frequencies is insufficient to permit oscillation to take place. Even so, while the amplifier seems stable, it may still be highly regenerative and, as the frequency of operation is raised, the shielding action of the grid will tend to deteriorate until stage oscillation takes place. This deterioration of intra-stage isolation is primarily due to decreasing cathode-to-plate reactance as the operating frequency rises, and also because of stray electro-magnetic coupling through the interstices in the grid structure itself. In either event, the intra-stage feedback through the grid circuit becomes of increasing importance as the frequency of operation of the stage is raised until, at some critical frequency, the isolation of the grid structure is insufficient to prevent the amplifier from oscillating at a frequency determined by the plate and cathode tuned circuits. In addition, if additional intra-stage coupling exists around the tube, by virtue of inductive or capacitive coupling between input and output circuits, it is possible for the feedback path to be enhanced and oscillation might possibly occur at some lower frequency than normally estimated.

After paying due attention to external feedback paths, oscillation and instability in a grounded grid amplifier may be suppressed by the use of a suitable neutralizing circuit that feeds energy back from the plate to the input circuit so that it is out of phase with the r.f. energy fed back through the grid structure of the tube. A satisfactory neutralizing circuit for a grounded grid amplifier is shown in fig. 2. The neutralizing coil is connected in such a way as to "buck" the feedthrough voltage and neutralization may be accomplished by adjustment of the neutralizing capacitor or the coupling between the neutralizing coil and the cathode coil.

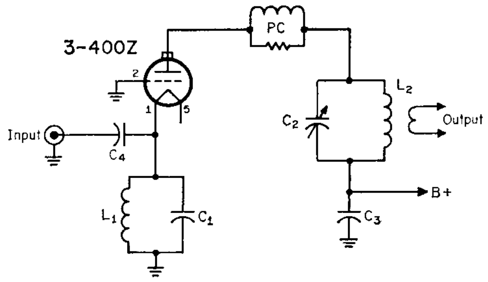


Fig. 1—Circuit of a grounded grid linear amplifier. The input signal is applied to a tuned cathode circuit, L_1, C_1. The circuit is adjusted to resonance with C_1 value of approximately 20 mmf per meter of wavelength (*i.e.*: for 20 meters, C_1 is about 400 mmf). Coupling capacitor C_4 and tuning capacitor C_1 should be able to stand circulating r.f. currents that exist in this circuit. The use of 1250 volt fixed mica capacitors is recommended. A value of 0.001 mf for C_4 is satisfactory for all bands between 80 and 6 meters. Parasitic suppressor PC is made of a noninductive composition resistor placed across a small inductance in the plate lead. For six meters, the inductance consists of a section of the plate strap material (see parts list). If the inductor is too large, the resistor will run hot.

The Prototype Six Meter Amplifier

When the experimenter "designs from scratch" all the exotic v.h.f. circuit techniques may be employed as desired. However, when an existing design is modified, the builder may be restricted in his attempts at redesign because of various features or peculiarities of the amplifier in question that do not readily fit into the scheme of things to come. Luckily, in this case, the amplifier to be modified proved to be very accommodating as far as the need for radical cir-

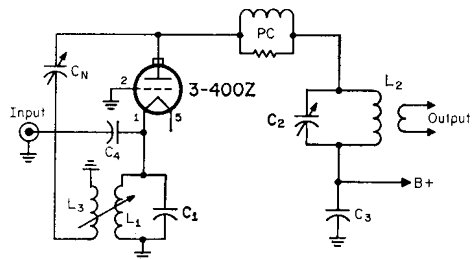
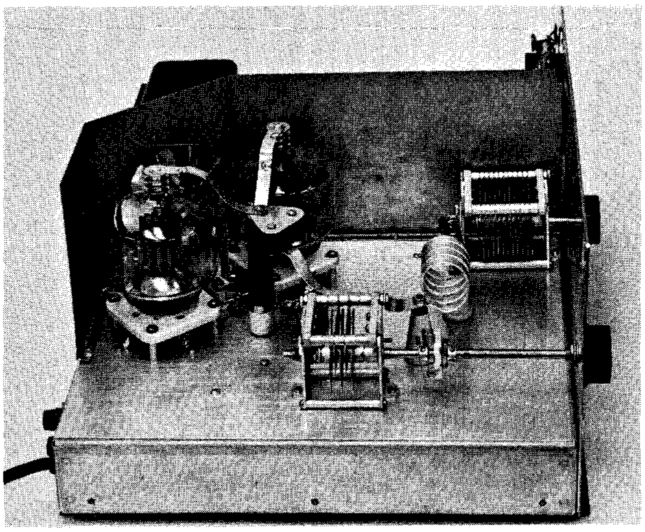


Fig. 2—The neutralized g.g. circuit. Energy fed through from plate to input circuit may cause the grounded grid amplifier to exhibit instability. The addition of a simple neutralizing circuit (C_N, L_3) permits energy to be fed back out of phase with the energy passing through the incompletely shielded grid structure. Neutralizing capacitor C_N is of the order of a few mmf. Neutralizing coil L_3 may be two or three turns placed in the coil of the cathode circuit. Adjustment of coil coupling or capacitance of C_N will neutralize the circuit. Neutralization is achieved when maximum grid current, minimum plate current and maximum power output coincide at one setting of the plate tank circuit.



Side view of the modified SWAN six meter linear amplifier. Conventional low frequency bandswitching circuitry is removed and replaced with six meter pi network tank. The plate tuning capacitor (C_2) is in the foreground. An insulated coupling connects the capacitor to the tuning dial, otherwise the metal shaft extension forms a closed loop closely coupled to the plate tank coil. The loading capacitor (C_3) is at the rear. The connection between the loading capacitor and the coaxial receptacle on the rear of the chassis is made with a short length of RG-8/U coaxial cable. In the modified amplifier, the original antenna changeover relay was used, remounted near the antenna receptacle to reduce lead length.

The three parallel connected 100 uuf, 5 kv plate blocking capacitors are suspended from the top of the plate r.f. choke. One of the parasitic suppressors may be seen above the glass envelope of the left-hand 3-400Z. While Eimac air-system sockets and chimneys are usually recommended for the home constructor, the Swan amplifier used special Johnson sockets (modified for the 3-400Z by reducing spring tension) and a special air scoop and blower system to cool the tubes.

cuit changes: nothing was required that could not be handled in the home workshop with a minimum of tools and test equipment.

The "victim" amplifier chosen for modification to six meters was the *Swan Mark I* linear amplifier covering 3.5-29.7 mc. It makes use of two Eimac 3-400Z tubes connected in parallel with a conventional pi-network circuit. The amplifier is rated for the so-called "two kilowatt p.e.p. level" and had a self-contained power supply. The modification consisted of removing the h.f. input and tank circuitry and substituting six meter circuitry, plus other minor circuit changes that resulted in a stable, maximum power linear amplifier, capable of smooth operation at six meters.

The first step was to simply drop in six meter tuned circuits in the input and plate tank configuration, modify the plate parasitic chokes for 50 mc operation, and apply the "smoke test." As might be expected, the amplifier responded in predictable fashion by "taking off like a bird" with a robust 50 mc parasitic oscillation that brought roars of protest from the small fry, their eyes and ears glued to a TV cartoon program on Channel 2.

The amplifier was immediately disconnected and the various circuits explored with a grid-dip oscillator. Resistance tests indicated that the numerous ceramic disc bypass capacitors in the amplifier, while satisfactory at 10 meters and below, were ineffective at six meters. Replacing or shunting these capacitors with 750 mmf mica units whose self-resonant frequency was above 54 mc was the first step in making the amplifier operable. A transmitting type ceramic capacitor having low internal inductance was substituted for the high voltage disc capacitor at the B-plus end of the choke. The final step was to clean the paint from the chassis, bottom plate and cover shield at the points of contact to insure hat a minimum of r.f. intra-stage leakage existed through the cabinet via the various joints and seams.

During this modification, it was discovered that the primary power cord was "hot" with 50 mc r.f., so the input terminals of the line were bypassed at the fuse connections.

After this series of simple modifications, the amplifier was turned on and loaded to maximum input into a dummy load. With excitation removed and no cutoff bias on the tubes, it was still possible for a weak 50 mc parasitic oscillation to take place, indicating that complete stability had not been achieved. The oscillation was noted by a slight show of grid current at random settings of the plate tuning and loading capacitors and by the fact that maximum grid current, maximum power output and minimum plate current did not coincide at the same tuning condition when the amplifier was in operation. Small indications, it is true, but symptoms that more work remained to be done on the amplifier.

The Neutralizing Circuit

The point had been reached where further modifications to the amplifier would be rather extensive and basic if it was desired to completely stabilize the unit by improving the intrastage isolation. The 3-400Z is used in grounded grid circuitry in commercial f.m. transmitting equipment up to 100 mc or so without the need of neutralization, but sophisticated shielding and bypass techniques appropriate to those frequencies are a necessity, and probably would be incompatible with the simple and uncomplicated design of the Swan amplifier, which is typical of

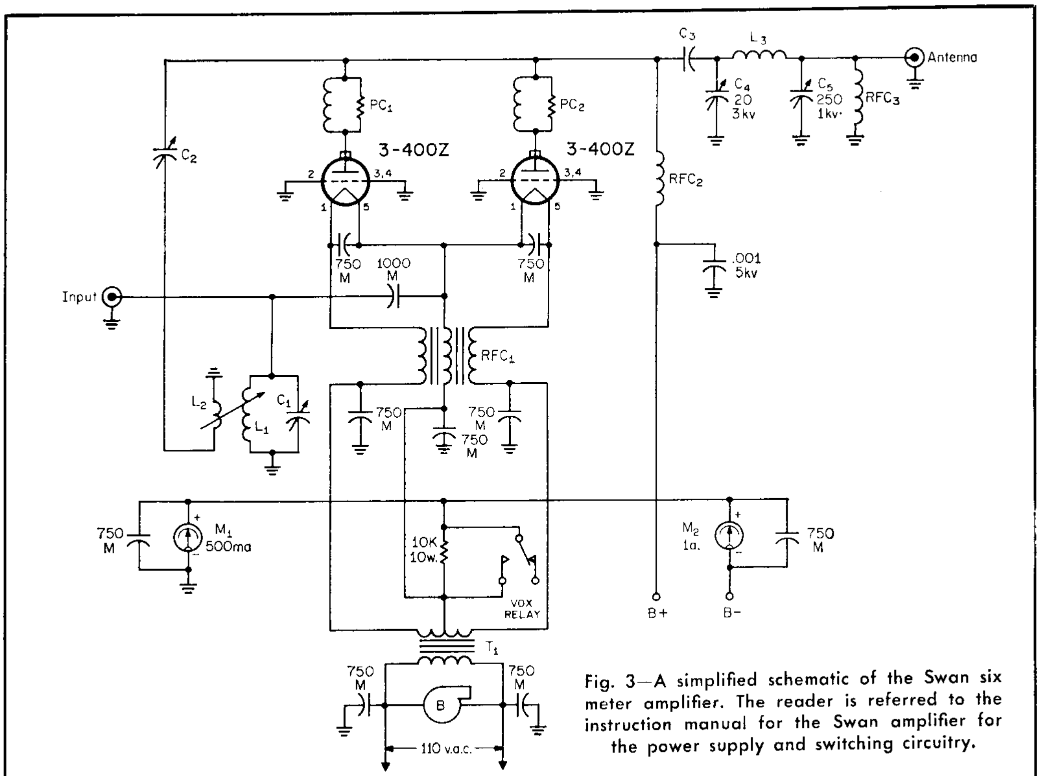


Fig. 3—A simplified schematic of the Swan six meter amplifier. The reader is referred to the instruction manual for the Swan amplifier for the power supply and switching circuitry.

C_1—50 mmf variable mica capacitor. Adjust coil L_1 to obtain resonance with the capacitor 90% compressed.

C_2—Neutralizing capacitor. Copper strap 3½" long and ½" wide mounted on a feedthrough insulator placed between the 3-400Z tubes. The capacitor "sees" the anodes of the tubes. The tubes are mounted about two inches apart, with the capacitor centered between them.

C_3—Three 100 mmf, 5 kv Centralab #850 capacitors in parallel bolted to a triangular aluminum plate atop RFC_2. See photograph.

C_4—20 mmf, 3 kv. Johnson 154-11, reduced to 3 rotor and 2 stator plates. Panel driven with insulated coupling.

C_5—250 mmf. Johnson 154-1.

L_1—3 turns #14 wire, ½" dia., ⅝" long.

L_2—2 turns #18 insulated hookup wire, ½" dia., placed between adjacent turns of coil L_1. Observe the polarity as shown. Adjust the coupling for proper neutralization.

L_3—4¼ turns of copper strap, ⅜" wide, 1⅜" dia., 2½" long.

PC_1, PC_2—50 ohm, 2 watt composition resistor shunted across 1½ of the plate lead (½" wide copper strap). Place a suppressor close to plate cap of each tube.

RFC_1—3½" long by ½" dia. ferrite rod (Lafayette Radio Co., N.Y. MS-333). File a nick in the rod at the correct length and break off remainder. Make triple winding (two #12 e., one #18 e.) consisting of 12½ turns. Wind all three wires at once, under tension. Coat with epoxy cement or nail polish to hold windings in position. (Equivalent of original Swan choke).

RFC_2—140 turns #22 e. wound on a ¾" diameter ceramic form. The winding length is about 3. (Equivalent of original Swan choke).

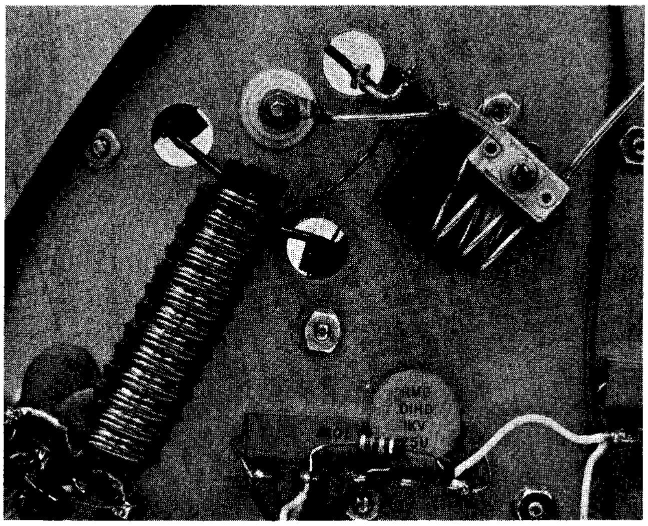
RFC_3—Ohmite Z-50.

T_1—10 volts at 15 amperes. Thordarson 21F146 or equiv. Blower—See text.

good amateur practice below 10 meters. Under the restrictions imposed by the circuit layout and assembly, therefore, it was decided to leave well enough alone as far as intra-stage isolation was concerned, and to complete the job of stabilizing the amplifier by the addition of a neutralizing circuit. The circuit of fig. 2 was chosen and installed. The neutralizing capacitor was fabricated from a length of copper strap mounted mid-way between the 3-400Z's on a ceramic feed-through insulator. The strap provided a small capacitance to the anodes of the tubes by virtue of its position. The under-chassis terminal of the feed through insulator was connected to a small link coil inserted into the cathode coil, as shown in the photograph. The neutralizing coil was mounted so that the polarity of the coil connections could be changed, if need be. Once neutralized, the amplifier proved to be a "winner" and tuned up and operated just as if it was on the "d.c. bands." The whole modification and tuning program took less than six hours and was well worth the effort.

Neutralizing and Tuning Adjustments

Neutralizing and tuning are no problem in the modified six meter amplifier, the schematic of which is shown in fig. 3. The cathode circuit is tuned to 50 mc with a grid-dip oscillator with the tubes in place in the sockets, after which this



Under-chassis view of the cathode circuit of the 6 meter linear. The tuned cathode circuit is at the upper right, mounted to a five lug terminal strip. Directly to the left is the ceramic feedthrough insulator, atop which the neutralizing capacitor is mounted. To the left is the three-winding (trifilar") filament choke. The five volt filaments of the two 3-400Z tubes are connected in series to reduce the filament current passing through the choke. A third wire to the common filament point is required to insure that equal voltage appears across each tube. Additional mica bypass capacitors are placed across original .01 mf disc ceramic capacitors at the cold end of the choke. The coaxial output cable running to the antenna receptacle cuts across the upper left of the photograph.

adjustment may be forgotten. The next step is to place the output loading capacitor at full capacitance and tune the plate tuning capacitor to approximate resonance using the grid-dip oscillator. The amplifier is turned on with appropriate filament and plate voltage but without excitation. The plate tuning and loading controls are varied at random from their previous settings and the grid meter of the amplifier is observed for signs of grid current. Without excitation, grid current is zero, but under conditions of oscillation, ten to twenty milliampere of grid current will be observed[1], and the resting plate current will climb a few milliamperes. With the amplifier oscillating, the neutralizing coil is moved about in the cathode coil until a point is found at which grid current disappears and oscillation stops.

In this operation, the bottom plate must be on the amplifier to complete the r.f. shielding and also to force the moving air through the tube sockets, if air-system sockets are used[2]. These special sockets are not used in this amplifier, but the problem of intra-stage r.f. leakage remains. As the link adjustment is simple, a modification was made that permitted the bottom plate to remain in place. A small hole was drilled in the bottom plate of the amplifier directly below the cathode circuit, and the neutralizing link was moved about by pushing it from below, using a wooden stick as the operative tool. Adjustment took about thirty seconds. The point of neutralization was found to be quite broad and noncritical. Once the correct coil placement was found, the coil was immobilized in position with a drop of "airplane cement," or "coil dope."

As could be guesssed, Kelly's Law[3] was in effect and the coil was first polarized improperly and the amplifier oscillated in a robust manner until the coil connections were reversed. When properly polarized and placed, the little neutralizing coil did the trick: the amplifier was completely stable and maximum grid current, maximum output and minimum plate current all coincided at one tuning adjustment.

Once the amplifier is neutralized, it should be properly loaded to the recommended grid and plate currents. In this case, at about 2500 volts plate potential, the peak (carrier) plate current was 800 milliamperes for two tubes, with about 300 milliamperes grid current. The Swan six meter s.s.b. transceiver had ample output to drive the linear amplifier with power to spare.

Final Thoughts and a Word of Warning

The modified Swan six meter amplifier certainly has proven to be a success, and this modification is recommended to those hardy souls who do not mind "butchering" a piece of commercial gear. For others, the circuitry is satisfactory for home construction from scratch. It must be pointed out, however, that the ventilation system used in the Swan amplifier is of a special design, in which the physical layout of the ventilation fan, the air scoop and the cabinet provide proper air cooling to the base and plate seals of the 3-400Z tubes. Unless the prospective builder has the means at hand to measure the temperature of the glass envelope of the tubes, it is recommended that the standard Eimac air-system sockets and tube chimneys be used, in conjunction with a squirrel cage blower for proper ventilation. Suggested blowers are the Dayton 1C-180, Ripley 81 or Ripley 8472. ■

[1] If vox operated cathode bias is used, such as shown, the bias resistor will have to be shorted out for these tests. The relay may be energized, or the resistor temporarily jumpered with a length of wire.

[2] The Eimac air-system sockets provide improved intra-stage isolation and insure maximum cooling. Their use is recommended. In any case, the amplifier should not be turned on its side when the filaments of the tubes are lit as the 3-400Z's are designed only for vertical (base up or down) operation.

[3] Kelly's Law*: If something *can* go wrong, it *will* go wrong.
**Also known as Murphy's Law. Ed.*

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