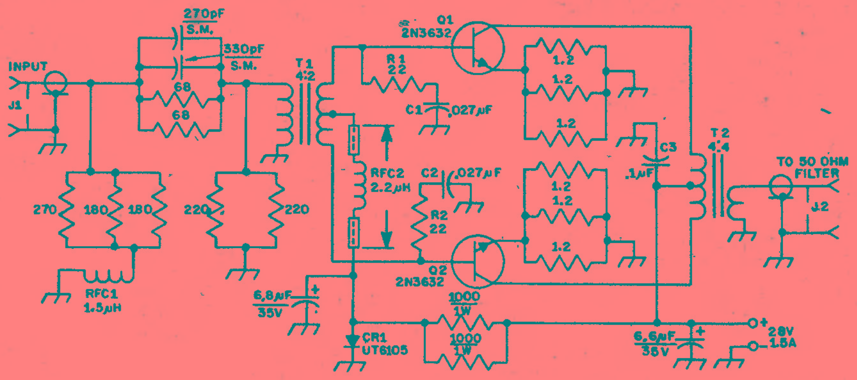

Fig. 1 — Schematic diagram of the amplifier. Resistance is in ohms, resistors are 1/2 watt unless otherwise indicated, except for R1 and R2 which are 1/4 watt. SM = silver mica. Polarized capacitors are electrolytic. C1, C2, and C3 are Aerovox Hi-*Q* units, type CK05 (available from Newark Electronics, Chicago, IL, catalog No. 101). RFC1 and RFC2 are small encapsulated chokes. See text for discussion of other components shown here.

output transformer, and the series 1041 toroids are used for the input transformer.[2] In order to reduce flux leakage the center winding of the primary of the output transformer (and the secondary of the input transformer) should be made of braid similar to the shield-diameter of small coaxial cable. A broadband match to a low-impedance termination is readily achieved with these transformers.

Following is a step-by-step procedure for fabricating the output transformer. First, slip a 1-inch-long piece of braid over a 2-inch-long 10-32 screw, preferably one that does not take solder easily. Next, place two of the cores over the braid, pushing the cores tightly against each other. Now, flare out the ends of the braid on each end of the cores and flow solder in the flared portions of the braid as shown in Fig. 3. After this step is completed the excess braid can be clipped close to the edge of the cylinders at one end. When both cylinders are constructed they can be individually wrapped with tape and then taped together side by side. On the end where the braid was left extending over the edge of the core, a solder connection is made to join the two cylinders electrically. Of course, some pruning is necessary in order to get the two cylinders mechanically close to each other. When this step is completed, the point where the braid from the two cylinders is joined is the center tap of the transformer primary. If a total of 2 turns is required on each side of the center tap, the braid from the center tap to one end of one of the cylinders is a half a turn. Therefore, 1 1/2 more turns of No. 22 enameled wire must be added by tacking the wire with solder to the end of the braid and running the wire through the holes left in the cylinders after removing the 10-32 screws. Similarly, 1 1/2 turns are added from the other cylinder end. Fig. 4 shows the transformer. The secondary is wound by running 4 turns of wire through the same two holes in the cylinders but with the leads extending out the opposite side of the transformer.

The transformer at the input of the amplifier is constructed in a similar manner with a 4:2 turns ratio. In this case the smaller Ferroxcube toroid core, series 1041, can be used. These cylinders are made by stacking 4 cores on top of each other. With a total of two turns required on the secondary, only 1/2 turn of enameled wire is needed to complete the winding once the braid is through the cylinders. No. 28 wire is used on the input transformer. Four more turns of wire (with the leads extending out the other end of the transformer) make up the primary winding of the input transformer.

The amplifier is constructed on a 1/8-inch-thick aluminum plate, 4 inches long by 3 inches wide. This plate should provide an adequate heat sink for the duty cycle incurred with ssb or cw operation. The transistors are mounted 2 inches from the end

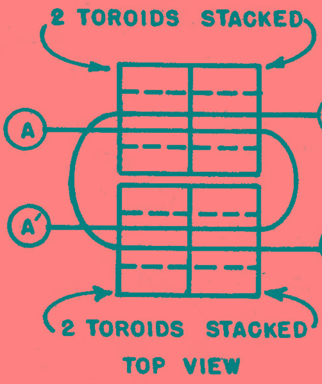

Fig. 2 — Illustration of how the broadband transformers are assembled.

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[2] Elna Ferrite Laboratories, Inc., 9 Pine Grove St., Woodstock, NY 12498.

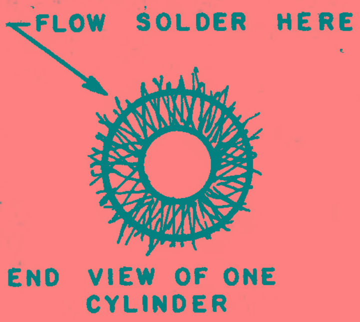

Fig. 3 — Drawing of end view of one cylinder of the broadband transformers.

of the plate and 3/8 inch off the center line running the length of the plate. Very short leads are maintained for the emitter resistors to minimize lead inductance. The two 1000-ohm biasing resistors, the biasing diode, and the 6.8-μF capacitor are located on the bottom side of the plate. The biasing diode used in the original circuit is a Unitrode UT6105 rectifier diode. This diode is fairly expensive, but any silicon rectifier diode rated at 3 A and 50 volts PRV should work.

A circuit diagram of the filters is shown in Fig. 5, and component values are given in Table 6-IV. L1 and C2 should be resonated at the proper frequency before being placed in the rest of the circuit. L1, L2, and L3 can be wound on toroid cores available from Amidon[3] when the inductance values are too large for convenient air coils.

Before applying voltage to the amplifier, a check should be made with an ohmmeter to insure there are no shorts between the primary and secondary of the transformer. If all looks well at that step, connect a 50-ohm load and apply dc voltage. Always terminate the amplifier output with a 50-ohm load before applying voltage; otherwise instability may result. The amplifier idling current, with no drive applied, should be approximately 100 mA. If this value is not obtained, there is probably a short in one of the transformers. If the correct idling current is present, apply drive (375 mW cw or peak ssb), and 15 watts of rf power should appear at the output. If a two-tone signal is used for ssb tests, the output level will indicate only 7.5 watts on an averaging-type wattmeter. Now, the amplifier is ready to connect to the antenna (one with an SWR below 1.5:1). Operation in any part of any band is acceptable, as long as the filter for that band is used and the SWR is low.

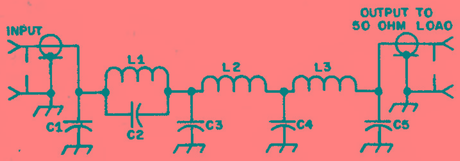

Fig. 5 — Circuit diagram for a low-pass filter.

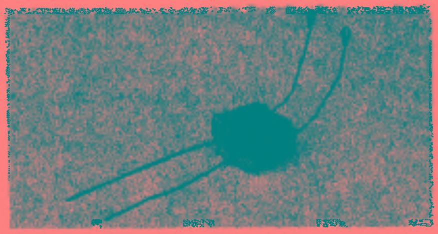

Fig. 4 — Close-up view of the input transformer used in the circuit of Fig. 1.

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TABLE 6-IV

Impedance at f_u	*80M $f_u = 4$ MHz*	*40M $f_u = 8$ MHz*	*20M $f_u = 15$ MHz*	*15M & 10M $f_u = 30$ MHz*
C1 −j50	800 pF	400 pF	210 pF	105 pF
C2 −j60	680 pF	340 pF	180 pF	90 pF
C3 −j18	2200 pF	1100 pF	590 pF	300 pF
C4 −j14	2800 pF	1400 pF	750 pF	380 pF
C5 −j35	1150 pF	575 pF	300 pF	150 pF
L1 +j30	1.2 μH	0.59 μH	0.32 μH	0.16 μH
L2 +j42	1.6 μH	0.80 μH	0.45 μH	0.23 μH
L3 +j50	2.0 μH	1.0 μH	0.52 μH	0.26 μH
Resonant Frequency for L1 & C2	5.55 MHz	11.1 MHz	20.8 MHz	41.6 MHz

Table of values for the filter shown schematically in Fig. 1.

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[3] Amidon Associates, 12033 Otsego Street, North Hollywood, CA 91607.

CHAPTER 7

VHF and UHF Transmitting

Before planning operation on the frequencies above 50 MHz, we should understand the FCC rules, as they apply to the bands we are interested in. The necessary information is included in the allocations table in the first chapter of this *Handbook* and in *The Radio Amateur's License Manual*, but some points will bear emphasis here.

Standards governing signal quality in the 50-MHz band are the same as for all lower amateur frequencies. Frequency stability, modulation, keying characteristics, and freedom from spurious products must be consistent with good engineering practice. Simultaneous amplitude and frequency modulation is prohibited. These standards are not *imposed by law* on amateur frequencies from 144 MHz up. This is not to say that we should not strive for excellence on the higher bands, as well as on 50 MHz, but it is important to remember that we may be cited by FCC for failing to meet the required standards in 50-MHz work.

A sideband signal having excessive bandwidth, an a-m signal whose frequency jumps when modulation is applied, an fm signal that is also amplitude-modulated, a cw signal with excessive keying chirp or objectionable key clicks – any of these is undesirable on any band, but they are all *illegal* on 50 MHz. Any of them could earn the operator an FCC citation in 50-MHz work. And misinterpretation of these points in an FCC examination could cost the would-be amateur his first ticket.

The frequencies above 50 MHz were once a world apart from the rest of amateur radio, in equipment required, in modes of operation and in results obtained. Today these worlds blend increasingly. Thus, if the reader does not find what he needs in these pages to solve a transmitter problem, it will be covered in the hf transmitting chapter. This chapter deals mainly with aspects of transmitter design and operation that call for different techniques in equipment for 50 MHz and up.

DESIGNING FOR SSB AND CW

Almost universal use of ssb for voice work in the hf range has had a major impact on equipment design for the vhf and even uhf bands. Many amateurs have a considerable investment in hf sideband gear. This equipment provides accurate frequency calibration and good mechanical and electrical stability. It is effective in cw as well as ssb communication. These qualities being attractive to the vhf operator, it is natural for him to look for ways to use his hf gear on frequencies above 50 MHz.

Thus increasing use is being made of vhf accessory devices, both ready made and home-built. This started years ago with the vhf converter, for receiving. Rather similar conversion equipment for transmitting has been widely used since ssb began taking over the hf bands. Today the hf trend is to one-package stations, called transceivers. The obvious move for many vhf men is a companion box to perform both transmitting and receiving conversion functions. Known as transverters, these are offered by several transceiver manufacturers. They are also relatively simple to build, and are thus likely projects for the home-builder of vhf gear.

Transverter vs. Separate Units

It does not necessarily follow that what is popular in hf work is ideal for vhf use. Our bands are wide, and piling-up in a narrow segment of a band, which the transceiver encourages, is less than ideal use of a major asset of the vhf bands – spectrum space. Separate ssb exciters and receivers, with separate vhf conversion units for transmitting and receiving, tend to suit our purposes better than the transceiver-transverter combination, at least in home-station service.

Future of Other Modes

It should not be assumed that ssb will monopolize voice work in the world above 50 MHz in the way that it has the amateur voice frequencies below 29 MHz. Sideband is unquestionably far superior to other voice modes for weak-signal DX work, but where there is plenty of room, as there is in all vhf and higher bands, both amplitude and frequency modulation have merit. A low-powered a-m transmitter is a fine construction project for a vhf beginner, and fm has been gaining in popularity rapidly in recent years. A reprint of a very popular 4-part *QST* series describing a complete two-band vhf station for the beginner is available from ARRL for 50 cents.

The decline in use of amplitude modulation has been mainly in high-powered stations. The heavy-iron modulator seems destined to become a thing of the past, but this should not rule out use of a-m. Many ssb transceivers are capable of producing high-quality a-m, and one linear amplifier stage can build as little as 2 watts a-m output up to 200 watts or so, with excellent voice quality, if the equipment is adjusted with care. It should be remembered that the transmitting converter (or heterodyne unit as it is often called) is not a sideband device only. It will serve equally well with a-m, fm or cw drive.

THE OSCILLATOR-MULTIPLIER APPROACH

Where modes other than ssb are used, most vhf transmitters have an oscillator, usually in the hf range, one or more frequency multiplier stages, and at least one amplifier stage. The basics of this type of transmitter are well covered in the preceding chapter, so only those aspects of design that are of special concern in vhf applications will be discussed here.

Oscillators

Because any instability in the oscillator is multiplied along with the frequency itself, special attention must be paid to both mechanical and electrical factors in the oscillator of a vhf transmitter. The power source must be pure dc, of unvarying voltage. The oscillator should run at low input, to avoid drift due to heating. Except where fm is wanted, care should be taken to isolate the oscillator from the modulated stage or stages.

Crystal oscillators in vhf transmitters may use either *fundamental* or *overtone* crystals. The fundamental type is normally supplied for frequencies up to 18 MHz. For higher frequencies the overtone type is preferred in most applications, though fundamental crystals for up to about 30 MHz can be obtained on order. The fundamental crystal oscillates on the frequency marked on its holder. The marked frequency of the overtone type is approximately an odd multiple of its fundamental frequency, usually the third multiple for frequencies between 12 and 54 MHz, the fifth for roughly 54 to 75 MHz, and the seventh or ninth for frequencies up to about 150 MHz. Crystals are seldom used for direct frequency control above about 75 MHz in amateur work, though crystals for 144-MHz oscillation can be made.

Most fundamental crystals can be made to oscillate on at least the third overtone, and often higher, with suitable circuits to provide feedback at the desired overtone frequency. Conversely, an overtone crystal is likely to oscillate on its fundamental frequency, unless the tuned circuit is properly designed. An overtone crystal circuit should be adjusted so that there is no oscillation at or near one-third of the frequency marked on the holder, nor should there be energy detectable on the *even* multiples of the fundamental frequency.

It should be noted that the overtone is not necessarily an exact multiple of the fundamental. An 8000-kHz fundamental frequency does not guarantee overtone oscillation on 24.000 MHz, though it may work out that way in some circuits, with some crystals. Overtone crystals can also be made to oscillate on other overtones than the intended one. A third-overtone 24-MHz crystal can be used for its fifth overtone, about 40 MHz, or its seventh, about 56 MHz, by use of a suitable tuned circuit and careful adjustment of the feedback.

Variable-frequency oscillators are in great demand for vhf-transmitter frequency control, but except where heterodyning to a higher frequency is used, as opposed to frequency multiplication, the VFO is generally unsatisfactory. Small instabilities, hardly noticeable in hf work, are multiplied to unacceptable proportions in the oscillator-multiplier type of transmitter. The fact that many such unstable VFO rigs are on the air, particularly on 6 meters, does not make them desirable, or even *legal.* Only careful attention to all the fine points of VFO design and use can result in satisfactory stability in vhf transmitters.

Frequency Multipliers

Frequency multiplication is treated in Chapter 6. The principal factor to keep in mind in multipliers for the vhf bands is the probability that frequencies other than the desired harmonics will be present in the output. These can be sources of TVI in vhf transmitters. Examples are the 9th harmonic of 6 MHz and the 7th harmonic of 8 MHz, both falling in TV Channel 2. The 10th harmonic of 8-MHz oscillators falling in Channel 6 is a similar problem. These unwanted multiples can be held down by the use of the highest practical degree of selectivity in interstage coupling circuits in the vhf transmitter, and by proper shielding and interstage impedance matching. This last is particularly important in transistor frequency multipliers and amplifiers. More on avoiding TVI will be found later in this chapter, and in the chapter on interference problems.

The varactor multiplier (see Chapter 4) is much used for developing power in the 420-MHz band. Requiring no power supply, it uses only driving power from a previous stage, yet quite high orders of efficiency are possible. Two examples are shown later in this chapter. A 220-MHz exciter tuned down to 216 MHz makes a good driver for a 432-MHz varactor doubler. More commonly used is a tripler such as the one described in this chapter, using 144-MHz drive. The output of a varactor multiplier tends to have appreciable amounts of power at other frequencies than the desired, so use of a strip-line or coaxial filter is recommended, whether the multiplier drives an amplifier or works into the antenna directly.

AMPLIFIER DESIGN AND OPERATION

Amplifiers in vhf transmitters all once ran Class C, or as near thereto as available drive levels would permit. This was mainly for high-efficiency cw, and quality high-level amplitude modulation. Class C is now used mostly for cw or fm, and in either of these modes the drive level is completely uncritical, except as it affects the operating efficiency. The influence of ssb techniques is seen clearly in current amplifier trends. Today Class AB_1 is popular and most amplifiers are set up for linear amplification, for ssb and – to a lesser extent – a-m. The latter is often used in connection with small amplitude-modulated vhf transmitters, having their own built-in audio equipment. Where a-m output is available from the ssb exciter, it is also useful with the Class AB_1 linear amplifier, for only a watt or two of driver output is required.

There is no essential circuit difference between the AB_1 linear amplifier and the Class-C amplifier;

only the operating conditions are changed for different classes of service. Though the plate efficiency of the AB$_1$ linear amplifier is low in a-m service, this type of operation makes switching modes a very simple matter. Moving toward the high efficiency of Class C from AB$_1$, for cw or fm service, is accomplished by merely raising the drive from the low AB$_1$ level. In AB$_1$ service the efficiency is typically 30 to 35 percent. No grid current is ever drawn. As the grid drive is increased, and grid current starts to flow, the efficiency rises rapidly. In a well-designed amplifier it may reach 60 percent, with only a small amount of grid current flowing. Unless the drive is run well into the Class C region, the operating conditions in the amplifier can be left unchanged, other than the small increasing of the drive, to improve the efficiency available for cw or fm. No switching or major adjustments of any kind are required for near-optimum operation on ssb, a-m, fm or cw, if the amplifier is designed primarily for AB$_1$ service. If high-level a-m were to be used, there would have to be major operating-conditions changes, and very much higher available driving power.

Tank-Circuit Design

Except in compact low-powered transmitters, conventional coil-and-capacitor circuitry is seldom used in transmitter amplifiers for 144 MHz and higher frequencies. U-shaped loops of sheet metal or copper tubing, or even copper-laminated circuit board, generally give higher *Q* and circuit efficiency at 144 and 220 MHz. At 420 MHz and higher, coaxial tank circuits are effective. Resonant cavities are used in some applications above 1000 MHz. Examples of all types of circuits are seen later in this chapter. Coil and capacitor circuits are common in 50-MHz amplifiers, and in low-powered, mobile and portable equipment for 144 and even 220 MHz.

Stabilization

Most vhf amplifiers, other than the grounded-grid variety, require neutralization if they are to be satisfactorily stable. This is particularly true of AB$_1$ amplifiers, which are characterized by very high power sensitivity. Conventional neutralization is discussed in Chapter 6. An example is shown in Fig. 7-1A.

A tetrode tube has some frequency where it is inherently neutralized. This is likely to be in the lower part of the vhf region, for tubes designed for hf service. Neutralization of the opposite sense may be required in such amplifiers, as in the example shown in Fig. 7-1B.

Conventional screen bypassing methods may be ineffective in the vhf range. Series-tuning the screen to ground, as in 7-1C, may be useful in this situation. A critical combination of fixed capacitance and lead length may accomplish the same result. Neutralization of transistorized amplifiers is not generally practical, at least where bipolar transistors are used.

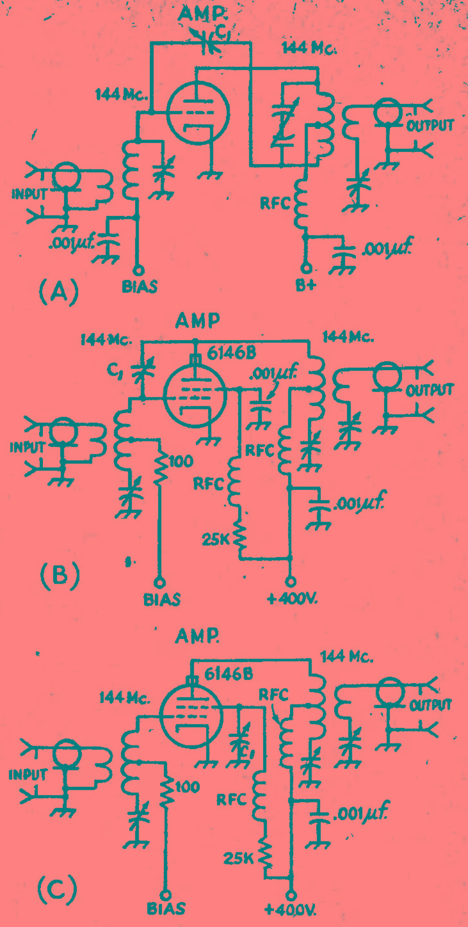


Fig. 7-1 — Representative circuits for neutralizing vhf single-ended amplifiers. The same techniques are applicable to stages that operate in push-pull. At A, C1 is connectad in the manner that is common to most vhf or uhf amplifiers. The circuits at B and C are required when the tube is operated above its natural salf-neutralizing frequency. At B, C1 is connected between the grid and plate of the amplifier. Ordinarily, a short length of stiff wire can be soldered to the grid pin of the tube socket, then routed through the chassis and placed adjacent to the tube envelope, and parallel to the anode elament. Neutralization is effected by verying the placement of the wire with respect to the anode of the tube, thus providing variable capacitance at C1. The circuit at C is a variation of tha one shown at B. It too is useful when a tube is operated above its self-neutralizing frequency. In this instance, C1 provides a low-*Z* screen-to-ground path at the opereting frequency. RFC in all circuits shown are vhf types and should be selected for the operating frequency of the amplifier.

Parasitic oscillation can occur in vhf amplifiers, and, as with hf circuits, the oscillation is usually at a frequency considerably higher than the operating frequency, and it cannot be neutralized out. Usually it is damped out by methods illustrated in Fig. 7-2. Circuits A and B are commonly used in 6-meter transmitters. Circuit A may absorb sufficient fundamental energy to burn up in all but low-power transmitters. A better approach is to use

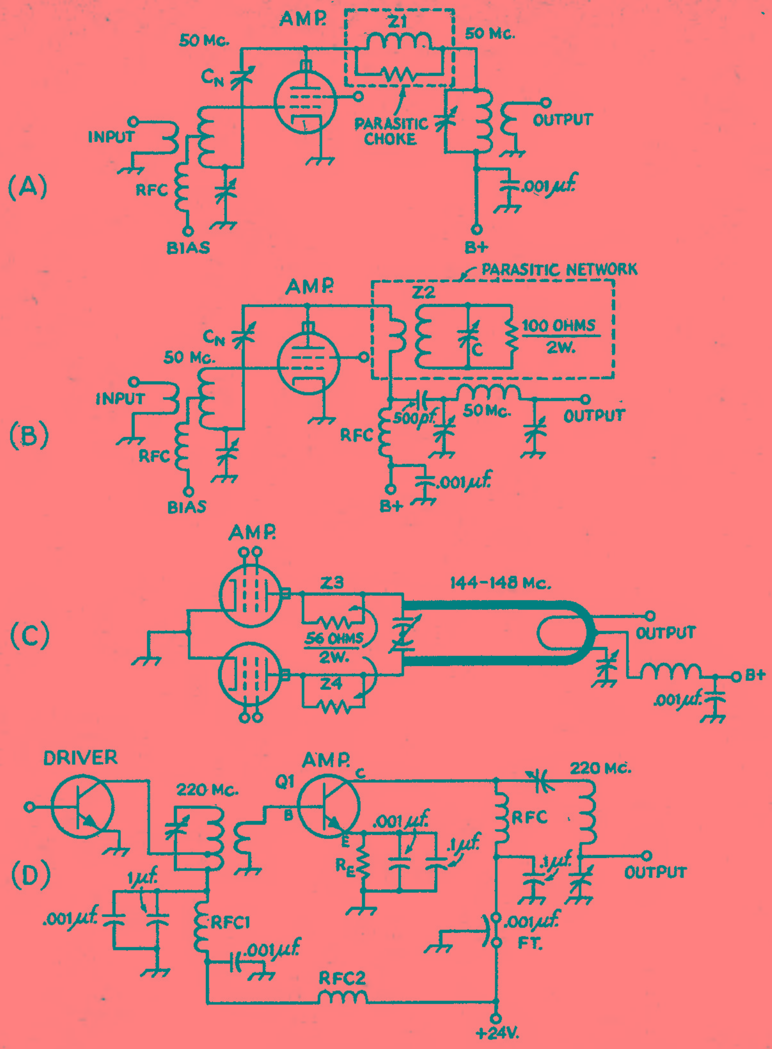


Fig. 7-2 — Representative circuits for vhf parasitic suppression are shown at A, B, and C. At A, Z1 (for 6-meter operation) would typically consist of 3 or 4 turns of No. 14 wire wound on e 100-ohm 2-watt non-inductive rasistor. Z1 overheats in all but very low power circuits. The circuit at B, also for 6-meter use, is more practical where heating is concerned. Z2 is tuned to resonance at the parasitic frequency by C. Eech winding of Z2 consists of two or more turns of No. 14 wire — determined experimentally — wound over the body of e 100-ohm 2-watt (or lerger) noninductive resistor. At C, an illustretion of uhf parasitic suppression as applied to a 2-meter amplifier. Noninductive 56-ohm 2-watt resistors ere bridged across a short length of the connecting leed between the tube anode and the main element of the tank inductor, thus forming Z3 and Z4.

The circuit at D illustrates how bypassing for both the opereting frequency and lower frequencies is accomplished. Low-frequency oscillation is discouraged by the addition of the 0.1-µF disk caramic capacitors. RFC1 and RFC2 are part of the decoupling network used to isolata the two stages. This technique is not required in vacuum-tube circuits.

the selective circuit illustrated at B. The circuit is coupled to the plate tank circuit and tuned to the parasitic frequency. Since a minimum amount of the fundamental energy will be absorbed by the trap, heating should no longer be a problem.

At 144 MHz and higher, it is difficult to construct a parasitic choke that will not be resonant at or near the operating frequency. Should uhf parasitics occur, an effective cure can often be realized by shunting a 56-ohm 2-watt resistor across a small section of the plate end of the tuned circuit as shown in Fig. 7-2, at C. The resistor should be attached as near the plate connector as practical. Such a trap can often be constructed by bridging the resistor across a portion of the flexible strap-connector that is used in some transmitters to join the anode fitting to the plate-tank inductor.

Instability in solid-state vhf and uhf amplifiers can often be traced to oscillations in the lf and hf regions. Because the gain of the transistors is very high at the lower frequencies, instability is almost certain to occur unless proper bypassing and decoupling of stages is carried out. Low-frequency oscillation can usually be cured by selecting a bypass-capacitor value that is effective at the frequency of oscillation and connecting it in parallel with the vhf bypass capacitor in the same part of the circuit. It is not unusual, for example, to employ a 0.1-μF disk ceramic in parallel with a .001-μF disk capacitor in such circuits as the emitter, base, or collector return. The actual values used will depend upon the frequencies involved. This technique is shown in Fig. 7-2D. For more on transmitter stabilization, see Chapter 6.

TIPS ON AB_1 LINEAR AMPLIFIERS

As its name implies, the function of a linear is to amplify an amplitude-modulated signal in a manner so that the result is an exact reproduction of the driving signal. (Remember, ssb is a form of amplitude modulation.) The nature of the a-m signal with carrier is such that linear amplification of it is inherently an inefficient process, in terms of power input to power output, which is the conventional way of looking at amplifier efficiency. But when all factors are considered, particularly the very small exciter power required and elimination of the cumbersome and expensive high-level plate-modulation equipment, "efficiency" takes on a different meaning. Viewed in this way, the Class-AB_1 a-m linear has only two disadvantages: it is incapable of providing as much power output (within the amateur power limit of 1 kW) as the high-level-modulated amplifier, and it requires considerable skill and care in adjustment.

The maximum plate efficiency possible with an AB_1 a-m linear is about 35 percent. The power output in watts that is possible with a given amplifier tube is roughly half its rated plate dissipation. If the first factor is exceeded the result is poor quality and splatter. If the second is ignored, the tube life is shortened markedly.

There being no carrier to worry about in ssb operation, the linear amplifier can run considerably higher efficiency in amplifying ssb signals, and the popularity of ssb has brought the advantages of the linear amplifier for all classes of service into focus. The difference between a-m with carrier and ssb without carrier, in the adjustment of a linear, is mainly a matter of the drive level. Drive can never be run up to the point where the stage begins to draw grid current, but it can run close with ssb, whereas it must be held well below the grid-current level when the carrier is present.

With a-m drive the plate and screen currents must remain steady during modulation. (The screen current may be negative in some amplifiers, so observation of it is simpler if the screen-current meter is the zero-center type.) The plate, screen and grid meters are the best simple indicator of safe AB_1 operation, but they do not show whether or not you are getting all you can out of the amplifier. The signal can be monitored in the station receiver, if the signal in the receiver can be held below the point at which the receiver is overloaded. Cutting the voltage from a converter amplifier stage is a good way to do this. But the only way to know for sure is to use an oscilloscope.

One that can be used conveniently is the Heath Monitor Scope, any version. Some modification of the connections to this instrument may be needed, to prevent excessive rf pickup and resultant pattern distortion, when using it for vhf work. Normally a coupling loop within the scope, connected between two coaxial fittings on the rear of the instrument, is used. The line from the transmitter to the antenna or dummy load runs through these two fittings. For vhf service, a coaxial T fitting is connected to one of these terminals, and the line is run through it, only. With full power it may even be necessary to remove the center pin from the T fitting, to reduce the input to the scope still further, particularly in 144-MHz service.

Really effective adjustment of the linear amplifier, whether with ssb or a-m drive, involves many factors. The amplifier must be loaded as heavily as possible. Its plate and grid circuits must be tuned carefully for maximum amplifier output. (Detuning the grid circuit is *not* the way to cut down drive.) If the power level is changed, all operating conditions must be checked carefully again. Constant metering of the grid, screen and plate currents is very helpful. One meter, switched to the various circuits, is definitely not recommended. A relative-power indicator in the antenna line is a necessity.

All this makes it appear that adjustment of a linear is a very complex and difficult process, but with experience it becomes almost second nature, even with all the points that must be kept in mind. It boils down to keeping the amplifier adjusted for maximum power output, and the drive level low enough so that there is no distortion, but high enough so that maximum efficiency is obtained. Practice doing this with the amplifier running into a dummy load, and the process will soon become almost automatic. Your amateur neighbors (and perhaps TV viewers nearby, as well) will appreciate your cooperation!

About Driver Stages

If the amplifier is capable of reproducing the driving signal exactly, it follows that the driver quality must be above reproach. This is quite readily assured, in view of the low driving power required with the AB_1 linear. Only about two watts exciter power is needed to drive a grounded-cathode AB_1 linear of good design, so it is possible to build excellent quality and modulation charac-

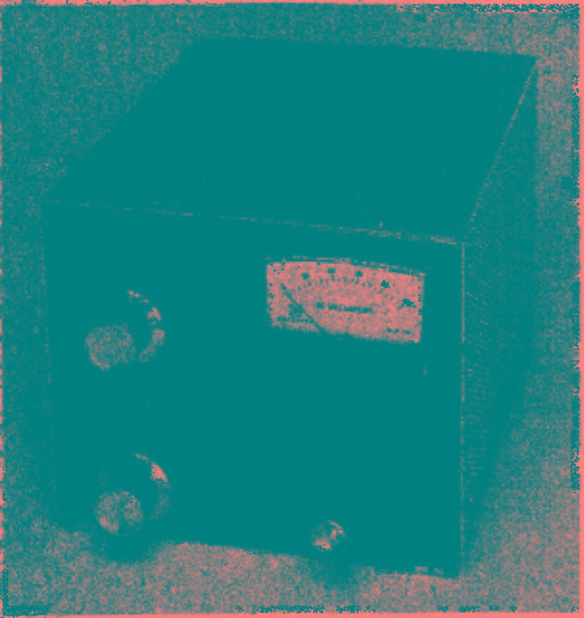


Fig. 7-3 — The 6-meter trensverter, with shield cover in place. Large knobs are for amplifier tuning and loading. Small knob, lower right is for a meter sensitivity control. The meter switch is just above it.

teristics into the a-m driver or ssb exciter. If this is done, and the amplifier is operated properly, the result can be a signal that will bring appreciative and complimentary reports from stations worked, on both a-m and ssb.

VHF TVI CAUSES AND CURES

The principal causes of TVI from vhf transmitters are as follows:

1) Adjacent-channel interference in Channels 2 and 3 from 50 MHz.

2) Fourth harmonic of 50 MHz in Channels 11, 12 or 13, depending on the operating frequency.

3) Radiation of unused harmonics of the oscillator or multiplier stages. Examples are 9th harmonic of 6 MHz, and 7th harmonic of 8 MHz in Channel 2; 10th harmonic of 8 MHz in Channel 6; 7th harmonic of 25-MHz stages in Channel 7; 4th harmonic of 48-MHz stages in Channel 9 or 10; and many other combinations. This may include i-f pickup, as in the cases of 24-MHz interference in receivers having 21-MHz i-f systems, and 48-MHz trouble in 45-MHz i-fs.

4) Fundamental blocking effects, including modulation bars, usually found only in the lower channels, from 50-MHz equipment.

5) Image interference in Channel 2 from 144 MHz, in receivers having a 45-MHz i-f.

6) Sound interference (picture clear in some cases) resulting from rf pickup by the audio circuits of the TV receiver.

There are other possibilities, but nearly all can be corrected completely, and the rest can be substantially reduced.

Items 1, 4 and 5 are receiver faults, and nothing can be done at the transmitter to reduce them, except to lower the power or increase separation between the transmitting and TV antenna systems. Item 6 is also a receiver fault, but it can be alleviated at the transmitter by using fm or cw instead of a-m phone.

Treatment of the various harmonic troubles, Items 2 and 3, follows the standard methods detailed elsewhere in this *Handbook*. It is suggested that the prospective builder of new vhf equipment familiarize himself with TVI prevention techniques, and incorporate them in new construction projects.

Use as high a starting frequency as possible, to reduce the number of harmonics that might cause trouble. Select crystal frequencies that do not have harmonics in TV channels in use locally. Example: The 10th harmonic of 8-MHz crystals used for operation in the low part of the 50-MHz band falls in Channel 6, but 6-MHz crystals for the same band have no harmonic in that channel.

If TVI is a serious problem, use the lowest transmitter power that will do the job at hand. Keep the power in the multiplier and driver stages at the lowest practical level, and use link coupling in preference to capacitive coupling. Plan for complete shielding and filtering of the rf sections of the transmitter, should these steps become necessary.

Use coaxial line to feed the antenna system, and locate the radiating portion of the antenna as far as possible from TV receivers and their antenna systems.

50-MHZ TRANSVERTER

With the increase in use of ssb on the vhf bands, there is much interest in adapting hf ssb gear to use on higher frequencies. The transverter of Fig. 7-3 will provide transceiver-style operation on 50 MHz, when used with a low-powered 28-MHz transceiver. The output of the transmitter portion is about 40 watts, adequate for much interesting work. It can be used to drive an amplifier such as the grounded-grid 3-500Z unit described later in this chapter. The receiving converter combines simplicity, adequate gain and noise figure, and freedom from overloading problems.

Circuit Details

The receiving front end uses a grounded-gate JFET rf amplifier, Q1 in Fig. 7-5, followed by a dual-gate MOSFET mixer, Q2. Its 22-MHz injection voltage is taken from the oscillator and buffer stages that also supply injection for transmitter mixing. The difference frequency is 28 MHz, so the transceiver dial reading bears a direct 28-50 relationship to the 50-MHz signal being received. For more detail on the converter construction and adjustment, see Fig. 9-9 and associated text. The transverter uses the grounded-gate rf amplifier circuit, while the converter referred to above has a grounded source, but they are quite similar otherwise.

The triode portion of a 6LN8, V1A, is a

22-MHz crystal oscillator. The pentode, V1B, is a buffer, for isolation of the oscillator, and increased stability. Injection voltage for the receiving mixer is taken from the buffer output circuit, L8, through a two-turn link, L9, and small-diameter coax, to gate 2 of the mixer, through a 10-pF blocking capacitor.

The grid circuit of the 6EJ7 transmitting mixer, V2, is tuned to 22 MHz and is inductively coupled to the buffer plate circuit. The 28-MHz input is applied to the grid circuit through a link around L11, and small-diameter coax. The mixer output, L12, is tuned to the sum frequency, 50 MHz, and coupled to a 6GK6 amplifier, V3, by a bandpass circuit, L12 and L13. The 6GK6 is bandpass-coupled to the grid of a 6146 output stage, V4. This amplifier employs a pi-network output stage.

The 6146 plate dissipation is held down during the receiving periods by fixed bias that is switched in by relay K1. The mixer and driver tubes have their screen voltage removed during receiving, by the same relay, which also switches the antenna and 28-MHz input circuits for transmitting and receiving. The relay is energized by grounding pin 7 of P1 through an external switch, or by the VOX relay in the transceiver.

Construction

A 7 X 9 X 2-inch aluminum chassis is used for the transverter, with a front panel 6 inches high, made of sheet aluminum. The top and sides are enclosed by a one-piece cover of perforated aluminum. The output-stage tuning control, C5, is on the upper left of the panel, 2 inches above the chassis. The loading control, C6, is immediately below, under the chassis. The meter, upper right, monitors either 6146 plate current or relative output, as selected by the switch, S1, immediately below it. A sensitivity control for calibrating the output-metering circuit completes the front-panel controls.

The output connector, J2, is centered on the rear apron of the chassis, which also has the input jack, J1, the 8-pin connector, P1, and the bias-adjusting control mounted on it.

The meter is a 1-mA movement, with multiplier resistors to give a full-scale reading on a current of 200 mA. The front cover snaps off easily, to allow calibration marks to be put on as desired.

An enclosure of perforated aluminum, 3 1/4 inches high, 4 inches wide and 4 3/4 inches long shields the 6146 and its plate circuit. There is also an L-shaped shield around the 6146 socket, under the chassis.

The receiving converter is built on a 2 1/2 X 4 1/4-inch etched board, and mounted vertically in a three-sided shield of sheet aluminum. Before mounting the converter shield, be sure to check for clearance with the terminals on the meter. Remember, the meter has full plate voltage on it when the switch is set to read plate current, even when the transverter is in the receiving mode.

Testing of the transverter was done with the General-Purpose Supply for Transceivers, described in the power supply chapter. Separate provision must be made for 12 volts dc for the receiving converter.

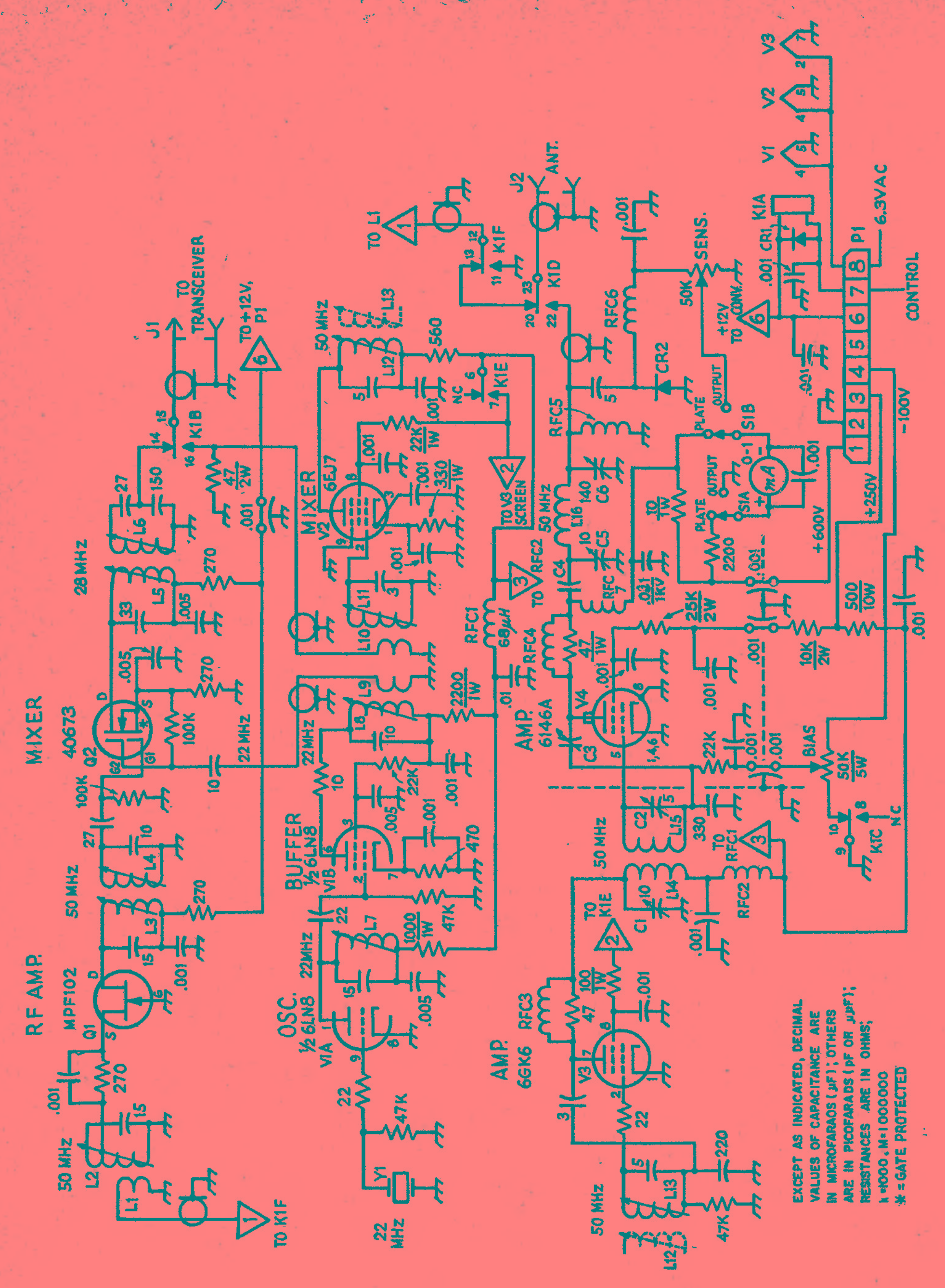
Fig. 7-4 – Top view of the transverter. The receiving converter is inside the shield at the left. The 22-MHz crystal oscillator end buffer are in the left rear portion of the chassis. In the right corner is the transmitting mixer. Above it is the first amplifier. The 6146 output amplifier is in the shielded compartment at the left front.

Injection voltage, signal input and i-f output connections to the converter are made with small-diameter coax. These and the 12-volt wiring are brought up through small holes in the chassis, under the converter. As seen in Fig. 9-11, the input JFET, Q1, is on the left. The mixer is near the center. The 28-MHz output coils, L5 and L6, are just to the right of Q2.

Note that there are two sets of relay contacts, K1D and K1F, in series in the receiver line. This guarantees high isolation of the receiver input, to protect the rf amplifier transistor. Another protective device is the diode, CR1, across the coil of the relay. If there are other relays external to this unit that use the same 12-volt supply, it is advisable to put diodes across their coils also. Spikes of several volts can be induced with making and breaking of the coil circuits.

Adjustment

A dip meter is very useful in the preliminary tuning. Be sure that L7 and L8 are tuned to 22 MHz and L12 and L13 are tuned to 50 MHz. The driver and output circuits should also be tuned to 50 MHz. Check to be sure that slug-tuned coils really tune *through* the desired frequency. Quite



often troubles are eventually traced to coils where the circuit is only approaching resonance as the core centers in the winding. Such a circuit will appear to work, but drive will be low, and spurious outputs will tend to be high. This is a common trouble in overtone oscillators, with slug-tuned coils.

Once the circuits have been set approximately, apply heater and plate voltage to the oscillator, and tune L7 for best oscillation, as checked with a wavemeter or a receiver tuned to 22 MHz. Connect a 28-MHz receiver to the input, J1, and apply dc to the converter. It should be possible to hear a strong local station or test signal immediately. Peak all coils for best reception, then stagger-tune L5 and L6 for good response across the first 500 kHz of the band.

Before applying plate voltage to the 6146, it is advisable to protect the tube during tuneup by inserting a 1500- or 2000-ohm 25-watt resistor in series with the plate supply. Connect a 50-ohm load to the output jack, and energize K1. Adjust

Fig. 7-5 — Schematic diagram and part information for the 50-MHz transverter.

C1 — 10-pF subminiature variable (Hammarlund MAC-10).
C2 — 5-pF subminiature variable (Hammarlund MAC-5).
C3 — 2 1/2-inch length No. 14 wire, parallel to and 1/4 inch away from tube envelope. Cover with insulating sleeve.
C4 — 500-pF 3000-volt disk ceramic.
C5 — 10-pF variable (Johnson 149-3, with one stator and one rotor plate removed).
C6 — 140-pF variable (Millen 22140).
CR1 — 1N128 diode.
CR2 — 1N83A diode.
J1 — Phono jack.
J2 — Coaxial jack, SO-239.
K1 — 6-pole double-throw relay, 12-volt dc coil.
L1 — 2 turns small insulated wire over ground end of L2.
L2, L3, L4 — 10 turns No. 24 enamel closewound on J. W. Miller 4500-4 iron-slug form.
L5, L6 — 12 turns No. 24 enamel on J. W. Miller 4500-2 iron-slug form.
L7, L8, L11 — Iron-slug coils adjusted for 4.1, 5.5 and 5.5 µH, respectively (Miller 4405).
L9, L10 — 2 turns small insulated wire over ground ends of L8 and L11.
L12, L13 — 1-µH iron-slug coil J. W. Miller 4403, 3 turns removed.
L14 — 7 turns No. 20, 1/2-inch dia, 1/2 inch long (B & W 3003).
L15 — Like L14, but 6 turns.
L16 — 6 turns No. 20, 5/8-inch dia, 3/4 inch long (B & W 3006).
P1 — 8-pin power connector.
RFC1 — 68-µH rf choke (Millen 34300).
RFC2 — 8.2-µH rf choke (Millen J-300).
RFC3 — 5 turns No. 22 on 47-ohm 1/2-watt resistor.
RFC4 — 4 turns No. 15 on 47-ohm 1-watt resistor.
RFC5, RFC6, RFC7 — 8.2-µH rf choke (Millen 34300).
S1 — Dpdt toggle.
Y1 — 22-MHz overtone crystal (International Crystal Co., Type EX).

Fig. 7-6 — Bottom of the transverter, with the 6146 socket inside the shield compartment at the right. Three sets of inductively-coupled circuits are visible in the upper-right corner. The first two, near the top of the picture, are on 22 MHz. Next to the right and down, are the mixer plate and first-amplifier grid circuits. The self-supporting 6GK6 plate and 6146 grid coils are just outside the amplifier shield compartment. The large variable capacitor is the loading control.

the bias control for 25 to 30 mA plate current. Apply a small amount of 28-MHz drive. A fraction of a watt, enough to produce a dim glow in a No. 47 pilot lamp load, will do. Some output should be indicated on the meter, with the sensitivity control fully clockwise. Adjust the amplifier tuning and loading for maximum output, and readjust all of the 50-MHz circuits likewise.

After the circuits have been peaked up, adjust the bandpass circuits by applying first a 28.1-MHz input and then a 28.4-MHz input, and peaking alternate coils until good operation is obtained over the range of 50.0 to 50.5 MHz. Most ssb operation currently is close to 50.1 MHz, so uniform response across a 500-kHz range is not too important, if only this mode is used. If the 10-meter transceiver is capable of a-m operation, and you want to use this mode, coverage up to 50.5 with uniform output may be more desirable. Adjust the position of the neutralizing wire, C3, for minimum rf in L16, with drive on, but no screen or plate voltage on the 6146.

Now apply full plate voltage. With no drive, set the bias adjustment for a 6146 plate current of 25 to 30 mA. With the dummy load connected, experiment with the amount of drive needed to reach maximum plate current. Preferably, use a scope to check for flat-topping as the drive is increased. An output of 40 watts, cw, should be obtainable. The quality of the ssb signal is determined first by the equipment generating it, but it can be ruined by improper operation. Over driving the mixer or the 6146, and improper loading of the amplifier will cause distortion and splatter. Continuous monitoring with a scope is the best preventive measure.

Because of the frequencies mixed, and the bandpass coupling between stages, the output of the transverter is reasonably clean. Still, use of an antenna coupler or filter between the transverter and antenna is good insurance. The same treatment of the transverter output is desirable when driving a linear amplifier.

Fig. 7-7 — Panel view of the 2-meter transverter. This version is patterned after a transmitting converter design by K9UIF. The on-off switches for ac and dc sections of the power supply are mounted on the front panel of the unit as are the pilot lamps and plate meter for the PA stage. The tuning controls for the various stages are accessible from the top of the chassis.

A 2-METER TRANSVERTER

This transverter is designed to be used with any 14- or 28-MHz ssb exciter capable of delivering approximately 20 watts peak output. It is stable both in terms of frequency and general operating conditions. It can provide up to 20 watts PEP output at 144 MHz — sufficient, say, for driving a pair of 4CX250 tubes in Class C for cw operation, or the same pair of tubes can be operated AB_1 to provide 1200 watts PEP input with this unit as a driver. The output signal is clean and TVI should not be experienced except where receiver faults are involved.

It is not recommended that beginners attempt this project since vhf ssb circuits require special care in their construction and operation, sometimes a requirement that is a bit beyond the inexperienced builder.

How It Operates

Starting with V1A, the oscillator, Fig. 7-8, a 43.333-MHz or overtone crystal is used at Y1 to provide the local-oscillator signal for the exciter. Output from V1A is amplified by V1B to a suitable level for driving the tripler, V2. 130-MHz or 116-MHz energy is fed to the grids of V3, a 6360 mixer, by means of a bandpass tuned circuit, L3,C1, and L4,C2. The selectivity of this circuit is high, thus reducing unwanted spurious energy at the mixer grids.

Output from the exciter is supplied through an attenuator pad at J1 and is injected to the mixer, V3, at its cathode circuit, across a 270-ohm resistor. The attenuator pad can be eliminated if a very low-power exciter is to be used. The values shown in Fig. 7-8 were chosen for operation with a Central Electronics 20A exciter operating at full input, or nearly so. The amount of driving power needed at the cathode of V3 is approximately 4 or 5 watts PEP.

B1 — Small 15-volt battery.
C1 — 20-pF miniature variable (E. F. Johnson 160-110 suitable).
C2, C3, C5 — 10-pF per section miniature butterfly (E. J. Johnson 167-21 suitable).
C4 — 5-pF per section miniature butterfly (E. F. Johnson 160-205 suitable).
C6 — 20-pF miniature variable (same as C1).
I1, I2 — 117-Vac neon panel lamp assembly.
J1-J3, incl. — SO-239-style coax connector.
J3 — Closed-circuit phone jack.
L1 — 15 turns No. 28 enam. wire, close-wound, on 1/4-inch dia slug-tuned form (Millan 69058 form suitable).
L2 — 12 turns No. 28 enam. wire, close-wound, on same type form as L1.
L3 — 5 turns No. 18 wire space-wound to 7/8-inch length, 1/2-inch dia, center-tapped.
L4 — 3 turns No. 18 wire, 1/2-inch dia, 3/8-inch long, center-tapped.
L5 — 5 turns No. 18 wire, 1/2-inch dia, 5/8-inch long, center-tapped.
L6 — 3 turns No. 18 wire, 1/2-inch dia, 5/8-inch long, center-tapped.
L7 — 4 turns No. 18 wire, 1/2-inch dia, 1/2-inch long, center-tapped.
L8 — 1-turn link of insulated hookup wire, 1/2-inch dia, inserted in center of L7.
L9 — 2 turns of insulated hookup wire over L3.
M1 — 0 to 200-mA dc meter.
P1 — 11-pin chassis-mount male plug (Amphenol 86PM11).
R1 — 50,000-ohm linear-taper, 5-watt control.
RFC1-RFC3, incl. — 2.7-μH rf choke (Millen 34300-2.7).
S1, S2 — Spst rocker-type switch (Carling TIGK60).
Y1 — 43.333-MHz third-overtone crystal for 14-MHz input. If a 28-MHz transceiver will be used, a 38.667-MHz crystal is required.

After the 130-MHz and 14-MHz signals are mixed at V3, the *sum* frequency of 144-MHz is coupled to the grids of V4, the PA stage, by means of another bandpass tuned circuit — further reducing spurious output from the exciter. PA stage V4 operates in the AB_1 mode. Its idling plate current is approximately 25 mA. The plate current rises to approximately 100 mA at full input.

If cw operation is desired, the grid-block keying circuit in the mixer stage (J3) can be included. If ssb operation is all that is contemplated, the minus 100-volt bias line can be eliminated along with J3, R1, and the shaping network at J3. In that case the 15,000-ohm grid resistor from the center tap of L4 would be grounded to the chassis.

The receiving section uses a low-noise uhf MOSFET as the rf amplifier and a second dual-gate MOSFET as the mixer. See Fig. 7-10. The gate-1 and drain connections of the rf amplifier are tapped down on the tuned circuits so that unconditional stability is achieved without neutralization. Oscillator energy is sampled with a two-turn link wound over L3. A short length of RG-58A/U carries the injection energy to Q2. The converter is built in a 5 X 2 1/4 X 2 1/4-inch box constructed from four pieces of double-sided circuit board that have been soldered on all abutting edges. The unit is mounted on the transverter front panel.

Fig. 7-8 – Schematic diagram of the transmitting converter portion of the transverter. Fixed-value capacitors ara disk ceramic unless noted differently. The polarized capacitor is electrolytic. Fixed-value resistors are 1/2-watt carbon unless otherwise noted.

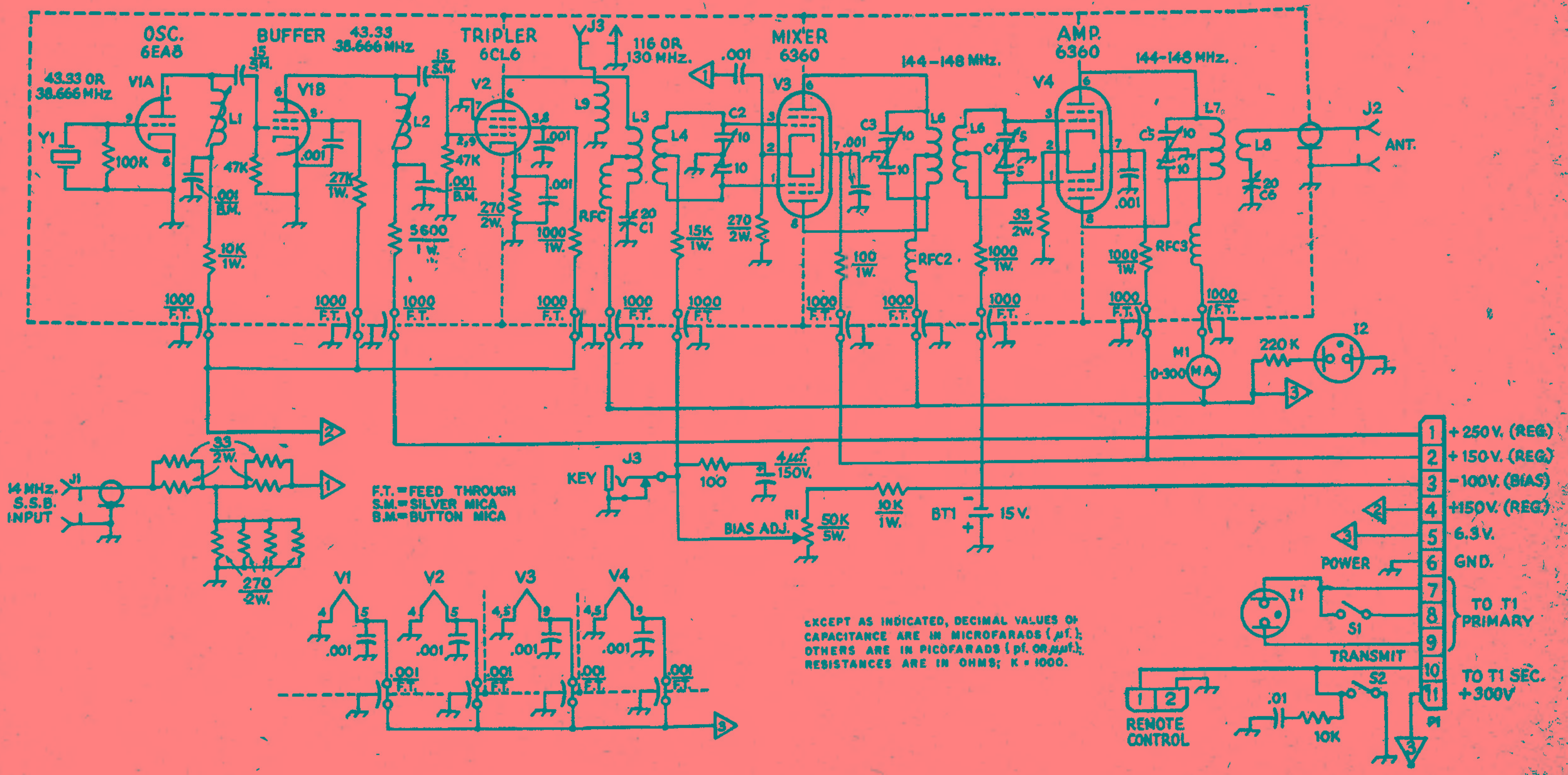


Fig. 7-9 — Inside view of the converter. Shields are used between the rf amplifier input and output circuits, and between the latter and the mixer input circuit. The cable entering the bottom side of the enclosure carries the oscillator injection energy. Output to the associated receiver or transceiver is taken through the jack to the left.

Construction Notes

The photographs show the construction techniques that should be followed for duplicating this equipment. The more seasoned builder should have no difficulty changing the prescribed layout to fit his particular needs, but the shielding and bypassing methods used here should be adhered to even if changes are made.

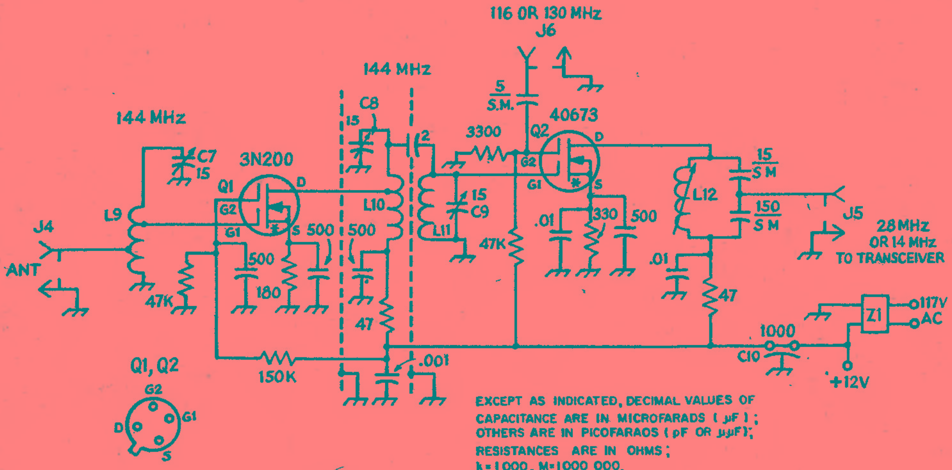
An 8 X 12 X 3-inch aluminum chassis is used for this equipment. An internal chassis, 5 inches wide, 3 inches deep, and 12 inches long, is made from flashing copper and installed along one edge of the main chassis. This method makes it possible to solder directly to the chassis for making positive ground connections rather than rely on mechanical joints. Shield partitions are made of copper and are soldered in place as indicated on the schematic diagram and in the photo. An aluminum bottom plate is used to enclose the underside of the chassis for confining the rf.

Feedthrough capacitors are used to bring power leads into the copper compartment. Though this adds somewhat to the overall cost of the project, it provides excellent bypassing and decoupling, thus reducing unwanted interstage coupling. It also contributes to TVI reduction. Most surplus houses stock feedthrough capacitors, and offer them at reasonable cost.

Tune-Up

An antenna-changeover relay and a set of normally-open relay contacts, both operated by the exciter, must be provided. The remote control leads, from P2, should be connected to the relay contacts. With power applied to the converter, L12 should be set for maximum noise input to the transceiver. Then, using a signal generator or off-the-air weak signal, peak L9, L10 and L11 for best signal-to-noise ratio.

The transmitter section can be powered by the circuit of Fig. 7-12, or the builder can design a supply of his own choice. Regulated voltages are



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF) ; OTHERS ARE IN PICOFARAOS (pF OR μμF);
RESISTANCES ARE IN OHMS ;
k = 1000, M = 1000 000.
S M = SILVER MICA
✱ = GATE PROTECTED

Fig. 7-10 — Diagrem of the converter section. Resistors are 1/4-watt composition and capacitors are disk ceramic, excapt es noted otherwise.

C7-C9, incl. — Air variable, pc mount (Johnson 189-505-5).
C10 — Feedthrough type.
L9 — 4 1/2 turns, No. 18 tinned wire, 1/4-inch ID. Tap at 1 1/2 turns up from the ground end for the antenna connection, and at 3 turns for the Q1 gate.
L10 — 4 1/2 turns, No. 18 tinned wire, 1/4-inch ID. Tap at 3 turns up from the cold end for the Q1 drain connection.
L11 — 5 turns No. 18 tinned wire, 1/4-inch ID.
L12 —1.99-2.42-μH slug-tuned coil, pc mount, for 28-MHz output (J. W. Miller 46A226CPC); or, for 14-MHz output, 7.3-8.9-μH (J. W. Miller 46A826CPC).
J4-J6, incl. — Phono type.
Q1, Q2 — RCA dual-gate MOSFET.
Z1 — 12-V miniature power supply, transistor radio type.

Fig. 7-11 — Looking into the bottom of the chassis, the rf section is enclosed in a shield compartment made from flashing copper. Additional divider sections isolate the input and output tuned circuits of the last three stages of the exciter. Feedthrough capacitors are mounted on one wall of the copper compertment to provide decoupling of the power leads.

recommended for best operation.

With a dummy load connected to J2, apply operating voltage. Couple a wavemeter to L1 and tune the oscillator plate for maximum output. Then, detune the slug of L1 slightly (toward minimum inductance) to assure reliable oscillator starting. Couple the wavemeter to L2 and tune for peak output. With the wavemeter applied to L4, adjust C1 and C2 for maximum indicated output.

The next step is to connect the transceiver to J1 and supply just enough drive to cause a rise in PA plate current of a few milliamperes. Tune C3 and C4 for maximum indicated plate current at M1, then adjust C5 and C6 for maximum power output to the dummy load. C1, C2, C3 and C4 should be readjusted at this point for maximum plate current of the PA stage. Use only enough drive to bring the PA plate current up to 100 mA at maximum dc input power.

A closed-circuit keying jack is used at J3 so that the mixer stage is not biased to cutoff during voice operation. Inserting the key permits full bias to be applied, thus cutting off V3. R1 should be adjusted for complete cutoff of V3 when the key is open.

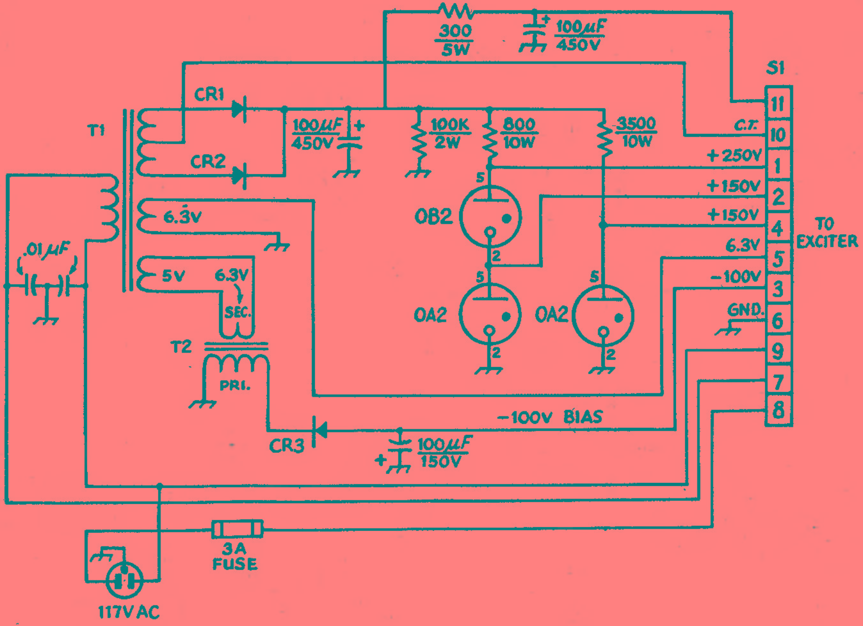


Fig. 7-12 — Schematic of the power supply section. On-off switches for the ac and dc circuits are mounted in the rf deck along with the pilot lamps. Polarized capacitors are electrolytic, others are disk ceramic. CR1 and CR2 are 1000-volt, 1-ampere silicon diodes. CR3 is a 200-PRV 600-mA silicon diode. T1 is a power transformer with a 540-volt ct secondary at 120 mA. Filament windings are 5 volts at 3 A, and 6.3 volts at 3.5 A. T2 is a 6.3-volt, 1-ampere filament transformer connected back to back with the 5-volt winding of T1. S1 is an 11-pin socket (female). A 10,000-ohm resistor and a .01-µF disk capacitor are connected in series between the center tep of T1's secondary and ground for transient suppression when S2 is switched to on. The suppressor is mounted at S2, in the rf deck.

A 500-WATT FM AND CW TRANSMITTER FOR 220 MHZ

This 220-MHz transmitter was designed and built by R. B. Stevens, W1QWJ, and was first described in May 1969 *QST*. It is capable of 300 watts output, cw or fm, or the exciter portion can be used alone to deliver approximately 8 watts output.

The RF Circuits

Looking at the schematic diagram, Fig. 7-15, it will be seen that the first three stages of the transmitter look very much like any vhf transmitter using vacuum tubes. A conventional 6CL6 crystal oscillator, V1, uses 6-, 8- or 12-MHz crystals, multiplying in its plate circuit to 24 MHz (12 MHz crystals should be the fundamental type.) A 6BQ5, V2, triples to 73 MHz, and drives a 2E26 amplifier, V3, straight-through on this frequency. A variable capacitor, C6, across the crystal, permits a small adjustment of the frequency.

A varactor tripler, driven by the 2E26, is used to get up to 220. Requiring no power supply of its own, it is capable of more than enough power output at 220 to drive our 500-watt amplifier.

The output of a varactor multiplier contains harmonics other than the desired one, so a strip-line filter is connected between the varactor output and the final amplifier grid circuit. The filter is a separate assembly mounted on the end of the chassis, visible in two of the photographs. Full details of the filter may be found in any edition of the *VHF Manual*, and in this *Handbook*.

The final amplifier is a 4CX250 series external-anode tube, with a coaxial tank circuit. The B version is used here, but the R and F types have the same mechanical design.

The coaxial plate circuit follows a standard design. Such a tank has extremely high *Q*, and the heavy copper (or brass) construction offers considerable heat sinking. Probably its only disadvantage is the necessity for feeding the high voltage in through some kind of rf bypassing device. This and the other mechanical features of a good coaxial tank are not readily made with the simpler tools. Details of the assembly are given in Fig. 7-19.

The final grid circuit, visible in the end view along with the varactor multiplier and the strip-line filter, is a half-wave strip-line. The fan blows cooling air into the grid compartment, up through the 4CX250 socket, and out through the end of the tank assembly, by way of the hollow inner conductor, L10. The coaxial output fitting, J6, the coupling loop, L11, and its series capacitor, C21, are mounted on a small detachable plate bent to fit the curvature of the coaxial assembly, and mounted near the outer end. The varactor tripler is built into the top of the amplifier grid assembly, and is visible in the end view along with the final grid circuit and the strip-line filter.

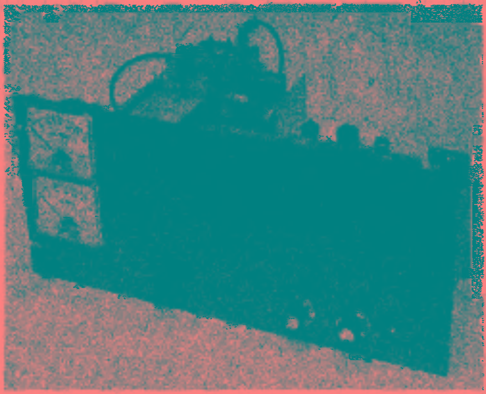


Fig. 7-13 — The 220-MHz transmitter is set up for rack mounting on 8 3/4-inch panel. Meters at the left can be switched to read driver plate, amplifier screen and amplifier plate currents, and amplifier plate voltage.

Generating the Frequency Modulation

Where only a small swing at the control frequency is needed, as in a vhf or uhf transmitter having a high order of frequency multiplication, the modulation can be applied very easily. A voltage-variable capacitor, CR1, changes capacitance in relation to the audio voltage applied across it, and this changing capacitance is used to "pull" the frequency of the crystal oscillator slightly. A good 8-MHz crystal can be pulled about 600 Hz in this way. With 27-times frequency multiplication this gives a maximum deviation in excess of 16 kHz

Fig. 7-14 — Rear view of the 220-MHz transmitter. The exciter stages are on a circuit board in the foreground. Chassis at the right side houses the varactor tripler and the amplifier grid circuit. Air blows into this compartment and out through the center conductor of the coaxial plate-circuit assembly.

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[1] Brayley, "Coaxial-Tank Amplifier for 220 and 420 MHz," *QST*, May 1951. Also, *VHF Manual*, Chapter 10.

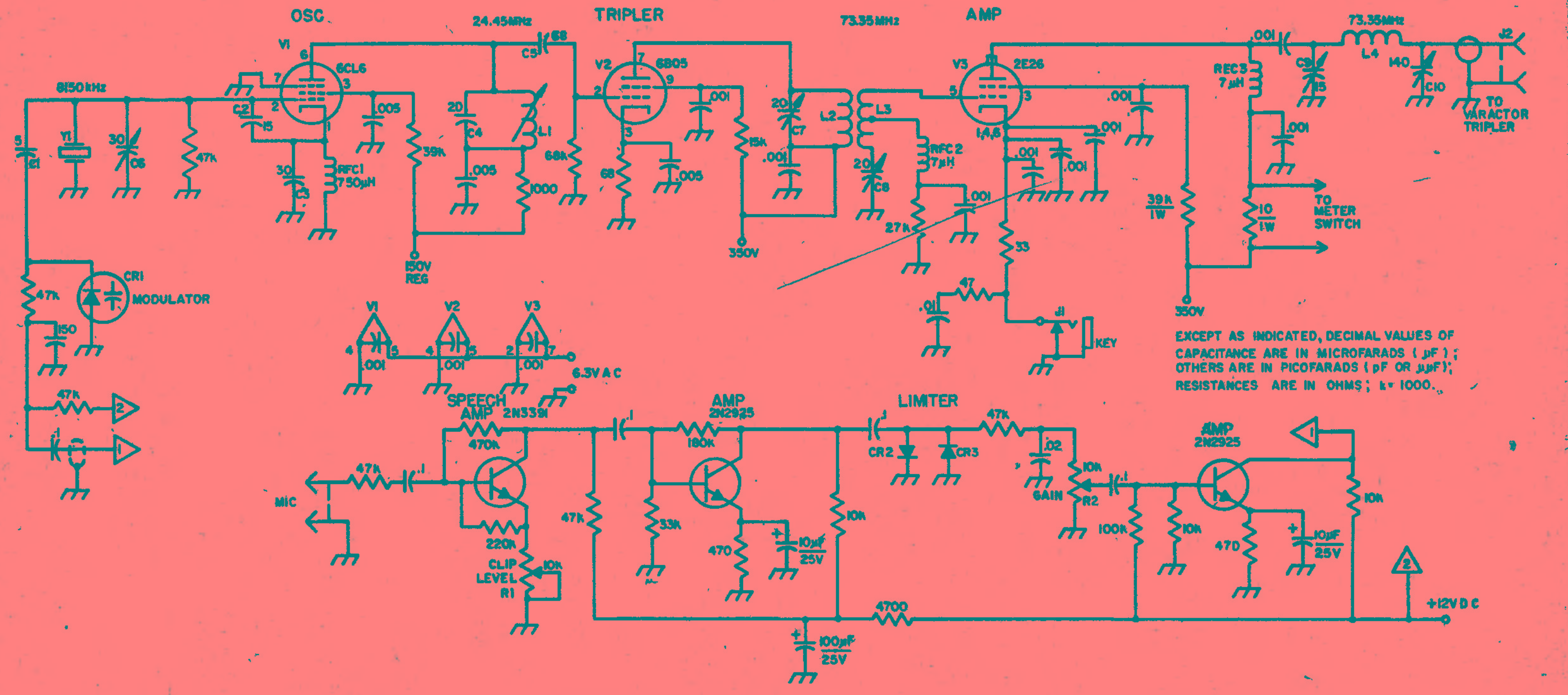


Fig. 7-15 — Schematic diagram and parts information for the W1QWJ 220-MHz exciter and frequency modulator. Capacitors with polarity marked are electrolytic. Components not specified below are marked for text reference purposes. C1 through C5 are dipped mica or silver mica.

C6 — 30-pF miniature trimmer (Johnson 160-130).
C7, C8 — 20-pF miniature trimmer (Johnson 160-110).
C9 — 15-pF variable, double-spaced (Hammarlund HF-15-X).
C10 — 140-pF variable (Hammarlund HF-140).
CR1 — Varicep diode.
CR2, CR3 — Any silicon diode (Motorola 2105 or similar).
J1 — Closed-circuit jack.
J2 — BNC chassis fitting.
L1 — 10 turns No. 22 enamel, closewound on 1/4-inch slug-tuned form.
L2 — 4 turns No. 22, 1/2-inch dia, 7/16 inch long.
L3 — 7 turns No. 22, 1/2-inch dia, 3/8 inch long. Tap 4 turns from grid end.
L4 — 5 turns No. 16, 1/2-inch dia, 1 inch long.
Y1 — 8150-kHz crystal, HC-6/U holder preferred. 6112 kHz or 12223-kHz fundamental crystal also usable. Frequencies given are for low-frequency end of the band. Use C6 for slight frequency adjustment.

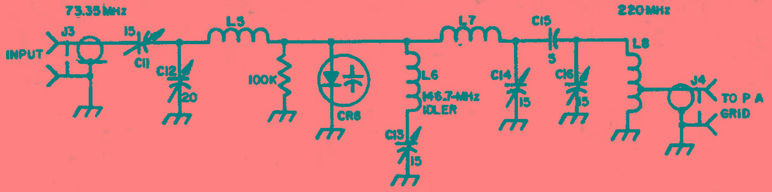


Fig. 7-16 – Circuit of the varactor multiplier, 73 to 220 MHz.

C11, C13, C14, C16 – 15-pF miniature variable (Johnson 160-107). Rotor of C11 must be insulated from chassis.
C12 – 20-pF miniature variable (Johnson 160-110).
C15 – 5-pF ceremic.
L5 – 8 turns No. 16, 1/2-inch dia, 7/8 inch long.
L6 – 4 turns No. 16, 1/2-inch dia, 1/2 inch long.
L7 – 3 turns No. 16, 3/8-inch dia, 3/8 inch long.
L8 – 3 turns No. 16, 3/8-inch dia, 3/8 inch long, tapped at 1 turn from grounded end.
CR8 – Varactor diode (Amperex H4A/1N4885).
J3, J4 – BNC fitting.

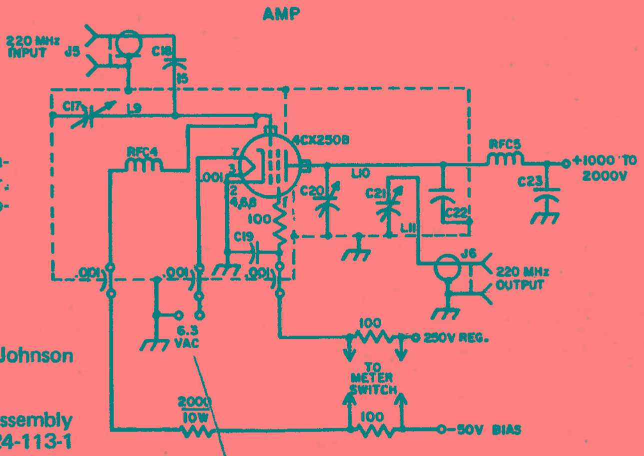


Fig. 7-17 – Schematic diagram and parts information for the 220-MHz final amplifier. Decimal values of capacitance are in microfarads (μF); others in pF.

C17 – 20-pF miniature variable (Johnson 160-110). Stator supports end of L9.
C18 – 15-pF silver mica.
C19 – Capacitor built into socket assembly (Johnson 124-109-1 socket, with 124-113-1 bypass ring end 124-111-1 chimney).
C20 – Disk-type tuning capacitor; see Fig. 7-19.
C21 – 15-pF miniature variable (Johnson 160-110).
C22 – Built-in bypass capacitor; see Fig. 7-19.
C23 – 500-pF, 5-kV or more.
J6 – N-type fitting.
L9 – Brass strip, 1/16 by 3/8 by 6 1/2 inches. Bolts to grid terminal on socket. Tap C18 7/8 inch from grid.
L10 – Coaxial line inner conductor; see Fig. 7-19.
L11 – Output coupling loop made from 3 1/4 inches No. 16. Cover with insulating sleeving and bend to 3/4 inch high and 1 3/4 inch long. See Fig. 7-1.
RFC4, RFC5 – 0.84 μH rf choke (Ohmite Z-235).
J5 – BNC fitting.

at the operating frequency, close to the optimum for most of the fm receivers currently in use in fixed-frequency service on 6 and 2. Lesser deviation, for working into communications receivers, most of them having about a 3-kHz bandwidth today, is merely a matter of applying less audio.

Adjustment and Operation

This is not intended to be a beginner's project, so detailed discussion of the mechanical layout will be omitted. The mechanical arrangement of the components could be altered to suit one's own requirements, since the complete transmitter is made up of many subassemblies. Adjustment for best results may be somewhat strange to anyone who has not had experience with varactor multipliers.

The first step is to get a good 52-ohm load. For the present, it will have to handle a maximum of about 10 watts. A good SWR bridge is also needed for the tests. The first step is to adjust the exciter. Procedure here is like that for any similar lineup of tubes, but the 2E26 must be adjusted for optimum

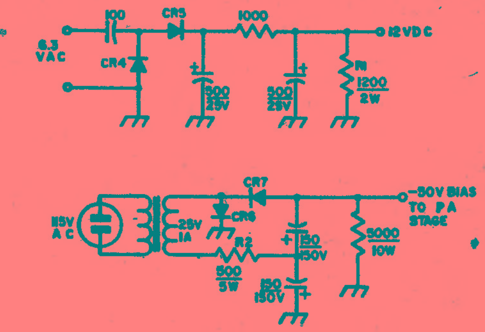
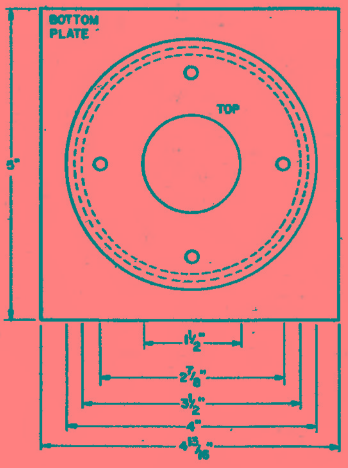


Fig. 7-18 — Circuit details of the built-in power supplies for amplifier bies (lower) and speech amplifier-modulator (upper) for tha 220-MHz transmitter. Capacitors with polarity marked are electrolytic. All diodes are 200-volt PRV, 1A. R1 and R2 are approximate values. Select for 12 and minus 50 volts output, respectively. Capacitance is in microfarads.



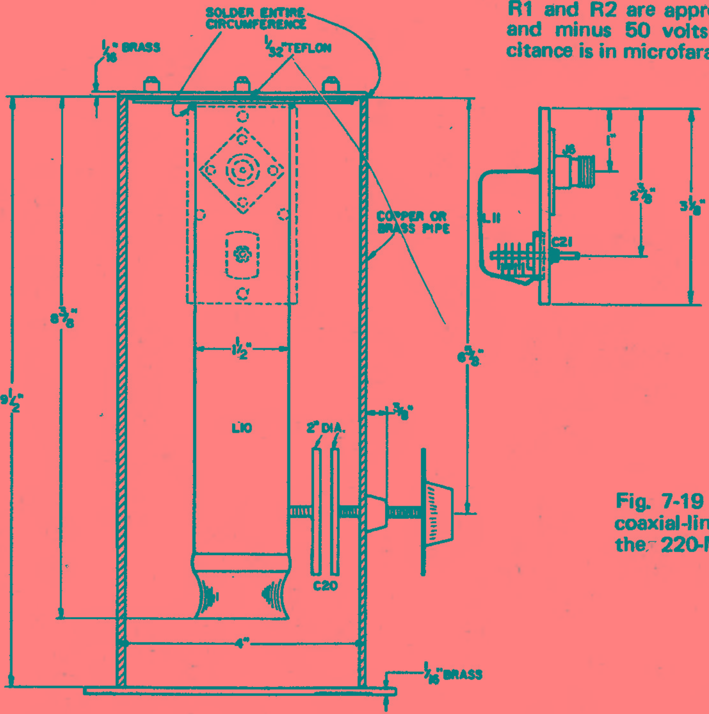


Fig. 7-19 — Details of the coaxial-lina plate circuit of the 220-MHz transmitter.

results when working into a 52-ohm load. Once an output of 10 to 12 watts is obtained in this way, leave the tuning of the 2E26 and preceding stages alone thereafter.

Now connect the SWR bridge output to J3 of the varactor multiplier, and tune C11 and C12 for lowest SWR indication. Leave the 2E26 adjustments alone.

Now connect a coaxial cable from J2 to J3, and connect the bridge or wattmeter in a line from J4 to the dummy load. Adjust C13, C14 and C16 for maximum output at 220 MHz. Adjustments in the multiplier interlock, and several passes through all adjustments may be needed for best output. But remember that the 2E26 is set for a 52-ohm load. Leave it alone, and make the multiplier adjustments do the job. An indication of some 8 watts or so of output should be obtained. Part of this will be harmonic energy, however, so the SWR bridge should now be connected between the strip-line filter and the amplifier grid circuit, and the filter adjusted for maximum forward power and the

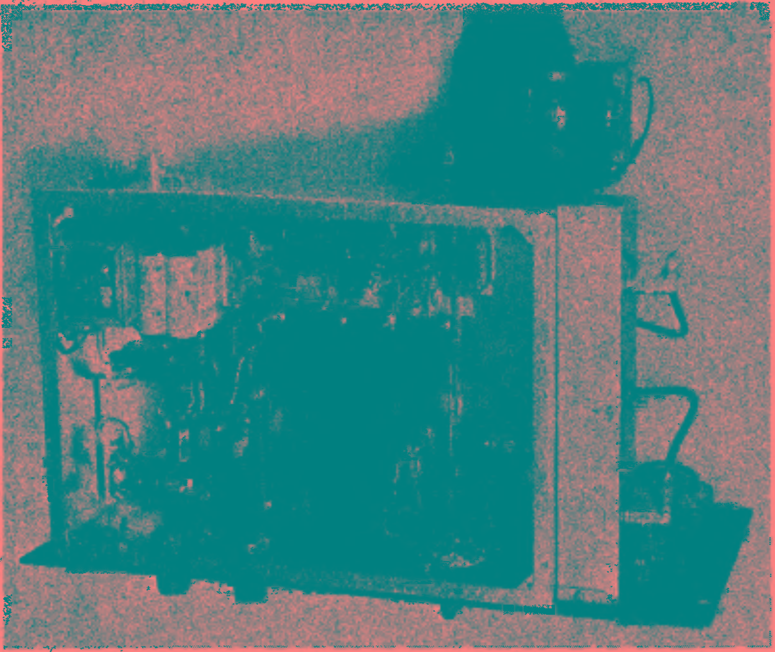


Fig. 7-20 – Looking underneath the chassis of the 220-MHz transmitter, we see the speech amplifier-clipper at the lower left, the exciter circuits across the top, power supply components at the upper left, and meter switching, lower right.

amplifier input circuit for minimum reflected. This should result in maximum grid current in the final amplifier.

It is likely that getting enough grid current for the 4CX250B will not be difficult, as the lineup described gives more than ample drive. Up to 20 mA grid current has been obtained, but not this much is needed. In fact, with fm or cw operation, only a slight increase in efficiency is noted after the drive is raised beyond the point where grid current begins to flow.

Adjustment of the coupling loop, L11, and the loading capacitor, C21, will be fairly critical when striving for the absolute maximum output. Following the manufacturer's recommendations as to maximum plate voltage and current, 2000 volts at 250 mA, resulted in about 320 watts output. Raising the plate current to 300 mA, by increasing the screen voltage, netted 400 watts output. Even at this input the tube seemed to be operating well and the tank circuit did not indicate excessive heating.

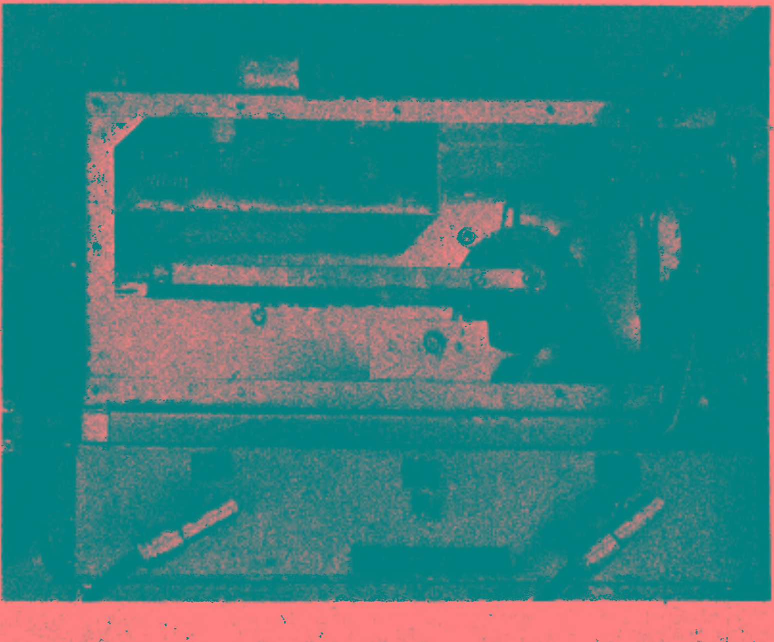


Fig. 7-21 – Looking into the amplifier grid compertment. The veractor tripler is in the upper left portion. Below the compartment is the 220-MHz strip-line filter.

A VARACTOR TRIPLER FOR 420 MHz

It is indeed fortunate that the 420-MHz band is related harmonically to the 144-MHz band, since a simple exciter or transmitter for the lower frequency can be pressed into service as an exciter for the higher band as well. Discussions and designs using varactor diodes as frequency multipliers have been seen in printed form many times, and all have pointed out the ease of obtaining output at the second, third, fourth or higher order of multiplication.

Many of the designs had some drawbacks that prevented their acceptance to other than the avid experimenter; the simple circuits had too many unwanted frequencies in the rf output and the "clean" designs were large physically. The tripler presented in Fig. 1 is a step toward overcoming some of these deficiencies.

The Circuit

The input circuit for this varactor multiplier was chosen because it does its job well, and of no less importance, it is not as confusing in schematic form. L1 is the input-coupling link and its reactance is tuned out by C1. L2-C2 form a conventional series-resonant circuit tuned to the input frequency. The combination of these circuits, then, becomes the familiar tuned circuit with link-coupled input. The link is coupled to the cold end of L2 and the amount of coupling is adjustable by changing the position of L1. It is easier to visualize the end of L2 as being "cold" by remembering that the varactor diode is a low impedance device.

L3-C3 is the series-tuned idler circuit that is necessary for efficient harmonic generation, and L4-C4 is a series-tuned circuit for the output frequency. L5 and C6 are resonant at the output frequency also, with a small capacitor, C5, to provide coupling to the diode output circuitry.

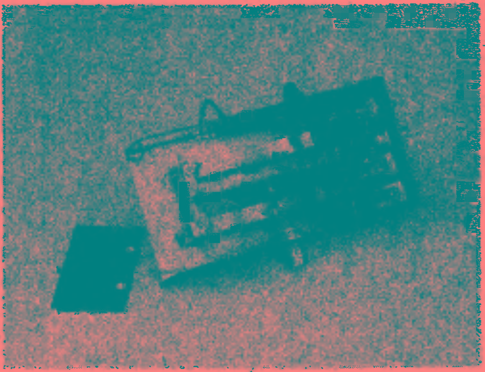


Fig. 2 — The varactor tripler is assembled in a box made from double-sided pc board. Input is at the right. The idlar coil, L3, is mounted et right angles to L1 and L2 to prevent undesired coupling. The copper strips tune to the output frequency. Two tabs of copper provide coupling between the strips. Output is teken from J2, at the bottom center. A piece of pc board with holes for access to C4 and C6 should be soldered to the end of the enclosure. Othar pieces can be soldered to the top to provide complete shielding, if desired. The box is 3-in. wide × 5-1/4-in. long and 1-1/2-in. high.

Construction

Double-sided pc-board material was used as a housing for the tripler, shown in Fig. 2. J1, C1, C2 and C3 are all mounted on one end of the box. The diode is mounted on the bottom of the enclosure, fastened in place by means of a nut on the outside. A small piece of aluminum sheet, used as a heat sink, is placed over the diode mounting stud before

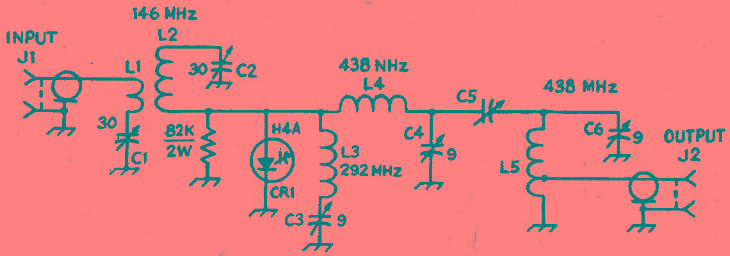


Fig. 1 — Schematic for the varactor tripler.

C1, C2 — 2.2- to 34-pF miniature variable (E.F. Johnson 190-0010-001).

C3, C4, C6 — 1.4- to 9.2-pF miniature variable (E.F. Johnson 189-563-001).

C5 — Copper strip 1-in. long × 1/4-in. wide. Bend one end up to form a tab 3/8-in. long. Spacing between tabs approx. 1/8 inch.

CR1 — Varactor diode (Amperex H4A or equiv.).

J1, J2 — Coaxial connector. Type 8NC suitable.

L1 — 3 turns No. 16 enam., 3/8-in. ID × 3/8-in. long.

L2 — 6-1/2 turns No. 16 tinned bus wire, 3/8-in. ID × 7/8-in. long.

L3 — 3-1/2 turns No. 16 tinned bus wire, 3/8-in. ID × 1/2-in. long.

L4 — Copper strip, 3-1/4-in. long × 3/8-in. wide. Space 1/2-in. above ground.

L5 — Copper strip, 3-3/8-in. long × 3/8-in. wide. Space 1/2-in. above ground. Tap 1-3/8 in. from ground end.

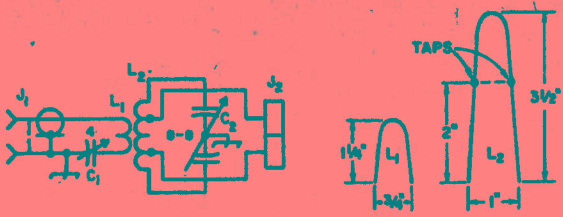


Fig. 3 — 432-MHz transmatch diagram.

C1 — 15-pF variable (Johnson 160-107).
C2 — 8-8-pF dual-section variable (Johnson 160-208).
J1 — BNC coaxial receptacle, chassis mounting.
J2 — Crystal socket.
L1 — Hairpin loop No. 14 wire; see above.
L2 — Hairpin loop No. 10 wire; see above; tap as shown.

the nut is secured. The heat sink need be only two or three inches square for drive levels up to five or six watts. For higher input power, the heat sink should be larger; three or four inches on a side of finned aluminum will be needed if the diode is pushed to its rated limit. L4 is a copper strip with one end connected directly to the diode. C4 is mounted at the end of L4 opposite the varactor. L5 is likewise a strip of copper, and is tuned by C6. The ground end of L5 connects to a shield that isolates the input circuitry from the rest of the compartment. Another shield is placed lengthwise in the box to separate L4 and L5. The coupling capacitor, C5, is made from two small tabs of copper strip bent into an L shape. Coupling is adjusted by bending the tabs slightly. Output is taken from a tap connection near the ground end of L5.

Adjustment

Tune-up of the tripler is not difficult if a few pieces of test gear are available. An SWR indicator will be needed for the input, and an output-power indicator should be connected to J2. A grid-dip meter is also of great help. The first step should be to tune the input, L1-C1 and L2-C2, to resonance as indicated by the dip meter. Likewise, the idler circuit should be tuned to the second harmonic of the intended input frequency, 292 MHz, if the input is 146 MHz. Not many of the currently available dip meters will tune to 440 MHz, but a pilot-lamp dummy load should provide an indication of output when L4-C4 is tuned while low driving power is applied to J1.

The input circuits should be tuned for minimum reflected power at J1, and then the output circuits adjusted for maximum output as shown by a lamp load or power meter. The copper tabs of C5 can be bent toward or away from each other by means of an insulated tuning tool. Overcoupling is indicated by the tuning of C4 and C6 becoming quite broad or even out of range of their adjustments.

Efficiency of the tripler can be as high as 70 percent, but it is recommended that the tuning be set to a condition where the most stable output results. If there is a sudden step, either up or down, in power output as the circuits are adjusted, the input coupling, or the capacitance of C5, should be increased slightly to alleviate this critical condition. With all circuits adjusted properly, the efficiency will be in the vicinity of 60 percent. Moderate temperature changes will have little effect on the output. Spurious signals should be 45 dB below the desired output.

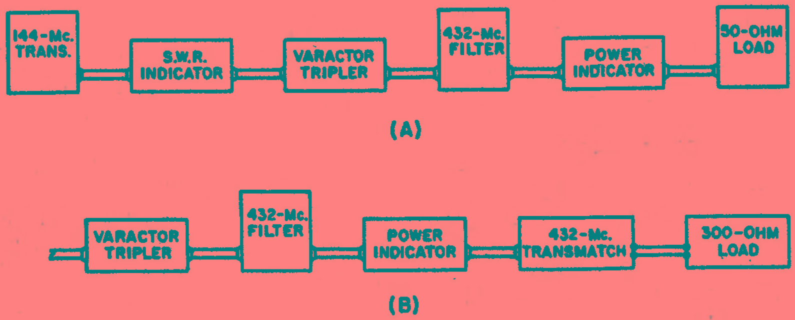


Fig. 4 — Test setups for checking varactor multipliars.

GROUNDED-GRID 50-MHZ AMPLIFIER

Increasing use of 50-MHz transceivers and transmitters having outputs of 25 watts or more has created a demand for amplifiers to be used with such equipment as the driver. The grounded-grid amplifier of Fig. 7-27 is designed for this use. With 30 watts or more of driving power it will deliver 600 watts cw output. As a Class-B linear, single-tone conditions, its rated PEP output is 750 watts.

Circuit

The Eimac 3-500Z triode is designed for grounded-grid service. As may be seen from Fig. 7-30, driving power is applied to the filament circuit, which must be kept above rf ground by means of high-current bifilar rf chokes, RFC1 and RFC2. These are a central feature of the bottom view, Fig. 7-29. The input impedance is low, so the input circuit, L1,C1, tunes broadly, and the 50-ohm line from the exciter is tapped well up on L1. The plate circuit is merely a coil of copper tubing, L2, inductively tuned by means of a "shorted turn" of copper strip, rotated inside its cold end. See Fig. 7-28. Tuning is smooth and the rotating loop avoids many problems commonly encountered in tuning high-powered amplifiers by conventional methods. Plate voltage is shunt fed to the tube, to prevent the high dc voltage from accidentally appearing on the output coupling loop or on the antenna line.

Most of the lower part of the schematic diagram has to do with control and metering, and is largely self-explanatory. The exciter voice-control relay shorts out R1, allowing grid current to flow, and making the amplifier operative, if the filament and primary-control switches, S1 and S2, have been closed. Feeding ac voltage to the plate-supply relay through J4, J5 and P1 makes application of plate voltage without the filament and blower being on impossible.

Construction

The amplifier chassis is aluminum, 10 X 12 X 3 inches in size, with the tube socket centered 3 1/8 inches from the front edge. The sheet-aluminum panel is 10 inches high. The decorative edging is "cove molding," used by cabinet makers for counter tops. Sides and back are also sheet aluminum. Where they need not be removable, parts are fastened together by pop-riveting. Tools and rivets for this work can be found in most hardware stores. Perforated aluminum (cane metal) is used for the top, and for covering the panel viewing hole.

Stretch the wire for the bifilar rf chokes, before winding. Then, with the wires side by side, under tension, wind them on a form of wood or metal. This is left in until the choke ends are soldered in position. Then remove the form and coat the windings with coil cement, to help maintain turn alignment.

Fig. 7-27 — Table-top 50-MHz amplifier of grounded-grid design, only 10 X 12 inches in size. Grid and plate current are monitored simulteneously. Knobs at the right are for input tuning, bottom, amplifier loading, center, and plate tuning, top.

Connections to the grid terminals (on opposite sides of the socket) are made with short 1/4-inch copper straps soldered to the pins and bolted to the chassis with No. 6 screws, nuts and lockwashers. Be sure that a clean, tight rf ground results.

In Fig. 7-28 it will be seen that the hot end of L2 is supported on the top of the two blocking capacitors, C3 and C4, which in turn, are mounted on the Teflon rod that serves as the form for RFC3. The ground end of L2 is supported on a vertical post made of 3/8-inch copper tubing, 1 3/8 inches high. The end of the coil can be fitted with a heavy copper lug, or pounded flat. A hole is drilled in the flat portion and a 2-inch brass bolt runs through it and the post and chassis. Be sure that there is a permanent solid rf ground at this point.

The shunt-feed rf choke is effectively across the tuned circuit, so it must be a good one. Hand-winding as described below is strongly recommended, as no ready-made choke is likely to be as good. Teflon is slippery, so a light thread cut in the form will help keep the winding in place. If this cannot be done, prepare and wind two wires, as for the filament chokes. Feed the wire ends through one hole in the form, and wind a bifilar coil. Pull the other ends through the finish hole, bending one

Fig. 7-28 – Interior view of the 50-MHz amplifier shows the shorted-turn tuning system, plete coil and output coupling, upper right. The tuning and loading controls are mounted on e bracket to the right of the 3-500Z tube and chimney. Meter shielding is partially visible in the left front corner.

back tightly at the hole edge. Remove the other winding, which should leave a tight evenly-spaced coil that makes an excellent vhf choke.

The blocking capacitors, C3 and C4, are mounted between brass plates, one of which is fastened to the top of the rf choke form with a sheet-metal screw. The other plate is connected to the hot end of L2 by means of a wrap-around clip of flashing copper. The lead to the tube plate cap is made with braid removed from a scrap of coax. A strip of flashing copper about 1/4 inch wide is also good for this. Use a good heat-dissipating connector such as the Eimac HR6.

The shorted-turn tuning ring is centered between the first two turns of L2. The ring is attached to a ceramic pillar, and that to a 1/4-inch shaft, the end of which is tapped for 8-32 thread. This shaft runs through a bearing mounted in a bracket 4 inches high and 2 3/4 inches wide, fastened to the chassis and the side of the enclosure. The output loading capacitor, C6, is also mounted on this bracket. It is one inch above the chassis, and the tuning-ring shaft is 3 1/4 inches above the chassis. The input tuning capacitor, C1, is mounted under the chassis, with equal spacing between the three, for symmetrical appearance.

The output coupling loop, L3, is just inside the cold end of L2. It can be adjusted for optimum coupling by "leaning" it slightly into or out of L2. Be sure that it clears the shorted turn throughout movement of the latter.

The coaxial output jack, J3, is on the rear wall of the enclosure. A small bracket of aluminum grounds it to the chassis, independent of the bonding between the chassis and the enclosure. Plate voltage enters through a Millen 37001 high-voltage connector, J2, on the rear wall, and is bypassed immediately inside the compartment with a TV "doorknob" high-voltage capacitor, C5.

The blower assembly in the left rear corner of the chassis draws air in through a hole in the back of the compartment, and forces it down into the enclosed chassis. The only air path is then back up through the socket and chimney (Eimac parts SK-410 and SK-406 recommended) and out through the top of the enclosure. The data sheet for the 3-500Z specifies an air flow of at least 13 cubic feet per minute, when the tube is operated at 500 watts plate dissipation. The ac leads for the blower motor come into the enclosure on feedthrough capacitors.

The meters are enclosed in a shield fastened to the front and side panels. Meter terminals are bypassed for rf inside the shield, and leads come through the chassis on feedthrough capacitors. The rocker-type switches just below the meters have built-in illumination. The high-voltage switch is not meant to control the plate supply directly, but rather through a relay, as in the 3000-volt supply shown in Chapter 5. The plate meter is in the negative lead, so be sure that your supply is compatible with this arrangement. Do not use this system where a potential difference exists between the amplifier and power supply chassis. All power leads are made with shielded wire (Belden 8862) and all exposed points are bypassed to ground.

Adjustment and Use

Do not apply drive to the 3-500Z without the plate voltage being on. Also, it is recommended that initial testing be done with low drive, and with a plate voltage of 1500 or less. With a 50-ohm load

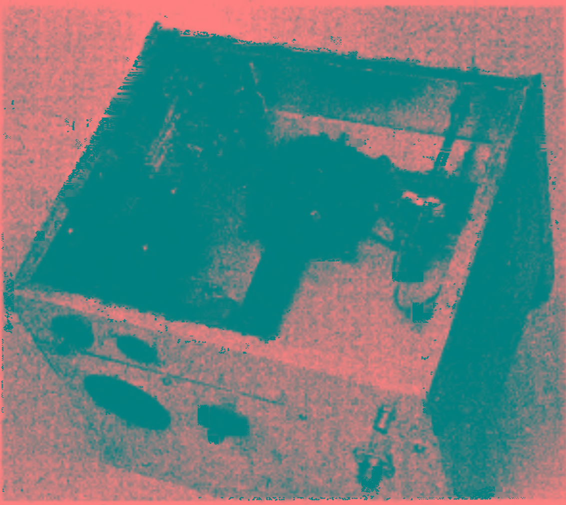


Fig. 7-29 – With the bottom cover removed, a look into the chassis from the rear shows the input circuit, L1,C1, right, the bifilar filement chokes, foreground, filament transformer and control switches. Opening in the rear wall is for air intake.

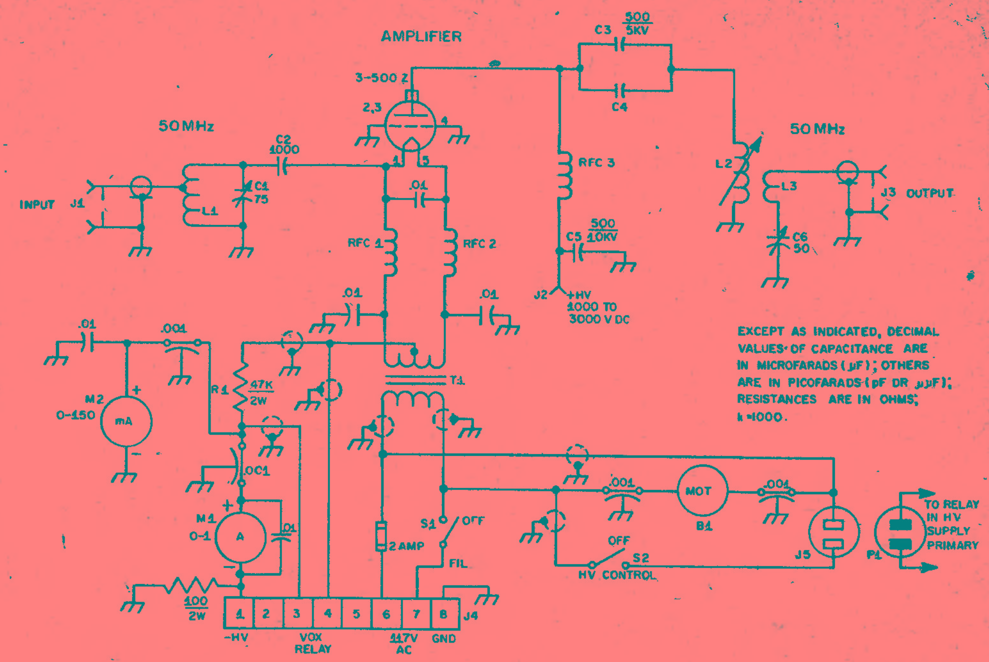


Fig. 7-30 — Schematic diagram and parts information for the 50-MHz grounded-grid amplifier.

B1 — Blower, 15 ft^3/min or more.
C1 — 75-pF variable (Johnson 167-4).
C2 — 1000-pF dipped mica.
C3, C4 — 500-pF 5-kV transmitting ceramic (Centralab 858S-500).
C5 — 500-pF, 10-kV or more, TV "Doorknob."
C6 — 50-pF variable (Johnson 167-3).
J1 — BNC coaxial receptacle.
J2 — High-voltage connector (Millan 37001).
J3 — Type N coaxial receptacla.
J4 — 8-pin mala power connector, chassis-mounting.
J6 — AC receptacle, chassis-mounting.
L1 — 4 turns No. 12 enam, 1 inch long, 1inch dia. Tap 2 1/2 turns from ground end.
L2 — 3 1/2 turns 1/4-inch copper tubing, 3 1/2-inch dia, 5 1/4 inches long. Diameter is finished dimension, not that of form used for winding. See text and photo for turn spacing. Tuning ring is closed loop of 1/2-inch copper strip, 2 5/8-inch dia.
L3 — 1 turn, 3-inch dia, and leads, made from one piece of 1/8-inch copper tubing or No. 8 wire.
M1 — DC meter, 0-1 ampare (Simpson Wide-Vue, Model 1327).
M2 — 0-300 mA, like M1.
P1 — AC plug, on cable to power supply.
R1 — 47,000-ohm 2-watt resistor.
RFC1, RFC2 — 21 turns each, No. 12 enam, 1/2-inch dia, bifilar.
RFC3 — 30 turns No. 20 anam, spaced wire dia, on 3/4-inch Teflon rod, 3 3/4 inches long. Drill end holes 1/2 and 2 3/4 inches from top.
S1, S2 — Spst, rockar-type, neon-lighted (Carling LT1L, with snap-in bracket).
T1 — Filament transformer, 5 V, 15 A (Stancor P6433; check any electrical equivalent for fit under 3-inch chassis).

connected to J3, apply 1000 to 1500 volts through J2, and turn on the driver. Adjust the tuning ring inside L2 for a dip in plate current. Tune C1 for maximum grid current. Tune C6 and adjust the position of L3 with respect to L2 for maximum output. If the amplifier seems to be running properly, connect an SWR bridge between the driver and J1, and check reflected power. It should be close to zero. If otherwise, adjust the tap position on L1.

Tuning range of the plate circuit can be checked with a grid-dip meter, with the power off the amplifier. The range is affected by turn spacing overall, and at the cold end. The closer the first two turns are together the greater the effect of the tuning ring. No other tuning device is used, so some experimentation with diameter and length of L2 may be needed if you want other than the 49.8 to 52.7 MHz obtained with the graduated turn spacing visible in the interior view. The highest frequency is reached with the ring in a vertical plane. Dimensions that affect tuning range are as follows: Grounded support for L2 — 1 1/8 inches from right side of chassis, and 3 1/4 inches from rear. RFC3 mounting position — 4 inches from rear and 5 1/2 inches from left. Shorted turn approximately centered between turns 1 and 2 of L2. The start of L3 bends from the stator of C6 to near the start of L2. The end toward J2 passes between the first two turns of L2, clearing the tuning ring in any position of the latter.

Once the amplifier seems to work normally at moderate plate voltages, apply higher, up to the maximum of 3000. Plate current, with no drive, should be about 160 mA. It can be lowered by inserting 0.1 to 0.4 ohm in series with R1 and the filament center-tap. A Zener diode, 2 to 9 volts, 10 watts, could do this job, as well.

Keep the amplifier tuned for maximum output. Do not decouple to reduce output; cut down drive and/or plate voltage instead. Adjustment for linear operation requires a scope. Maximum output, minimum plate current and maximum grid current should all occur at the same setting of the plate tuning. If they do not, the output loading is over coupled, or there is regeneration in the amplifier. The plate-current dip at resonance is noticeable and smooth, but not of great magnitude.

Typical operating conditions given by the manufacturer, and in the tube-data section of the *Handbook*, are guides to good practice. The amplifier works well with as little as 1000 volts on the tube plate, so varying the ac voltage to the plate-supply transformer is a convenient way to control power level. It is seldom necessary to run the maximum legal power in vhf communication, so some provision for this voltage control is recommended. With just one high-voltage supply needed and no critical tuning adjustments, power variations from 100 to 600 watts output are quickly and easily made. This amplifier was built by Tom McMullen, W1SL, and first described in *QST* for November, 1970.

A 2-KW PEP AMPLIFIER FOR 144 MHz

Large external-anode triodes, in a cathode-driven configuration, offer outstanding reliability, stability and ease in obtaining high power at 144 MHz. The selection is somewhat limited and they are not inexpensive. Data on the recently introduced 3CX1500A7/8877, a high-mu, external-anode power triode, appeared very promising. A reasonable heater requirement (5V at 10 A) and an inexpensive socket and chimney combination made the tube even more attractive.

The techniques employed in the design and construction of the cathode-driven 3CX1500A7/8877 amplifier described here have removed many of the mechanical impositions of other designs. Those interested in obtaining complete constructional details should refer to the two part article appearing in December, 1973, and January, 1974 *QST*.

The plate tank operates with a loaded *Q* on the order of 40 at 2-kW PEP and 80 at 1 kW. Typical loaded *Q* values of 10 to 15 are used in hf amplifiers. In comparison, we are dealing with a relatively high loaded *Q*, so losses in the strip-line tank-circuit components must be kept very low. To this end, small diameter Teflon rods are used as mechanical drive for the tuning capacitor and for physical support as well as mechanical drive for the output-coupling capacitor. The tuning vane or flapper capacitor is solidly grounded, through a wide flexible strap of negligible inductance, directly to the chassis in close proximity to the grid-return point. A flexible-strap arrangement, similar to that of the tuning capacitor, is used to connect the output coupling capacitor to the center pin of a type N coaxial connector mounted in the chassis base. Ceramic (or Teflon) pillars, used to support the air strip line, are located under the middle set of plate-line dc isolation bushings. This places these pillars well out of the intense rf field associated with the tube, or high-impedance end of the line. In operation, plate tuning and loading is quite smooth and stable, so a high-loaded *Q* is apparently not bothersome in this respect.

In this amplifier, output coupling is accomplished by the capacitive probe method. As pointed out by Knadle[1] "Major advantages of capacitive probe coupling are loading linearity and elimination of moving contact surfaces."

Capacitive-probe coupling is a form of "reactive transformation matching" whereby the feed-line (load) impedance is transformed to the tube resonant-load impedance (R_o) of 1800 ohms (at the 2-kW level) by means of a series reactance (a capacitor in this case). At the 1-kW level, R_o is approximately twice that at the 2-kW PEP level. Therefore, the series coupling capacitor should be variable and of sufficient range to cover both power levels. Formulas to calculate the transformation values have been presented in *QST*.[2]

The electro-mechanical method of probe coupling used in this amplifier is easy to assemble and provides good electrical performance. Also, it has no moving-contact surfaces and enables placement of the output coupling, or loading, control on the front panel of the amplifier for ease in adjustment.

The grid- and cathode-metering circuits employed are conventional for cathode-driven amplifiers. The multimeter, a basic 0-1 mA movement, is switched to appropriate monitoring points.

An rf-output monitor is a virtual necessity in

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[1] Knadle, "A Strip-Line Kilowatt Amplifier for 432 MHz," *QST*, in two parts: Part I, April, 1972, p. 49; Part II, May, 1972, p. 59.

[2] Belcher, "Rf Matching Techniques, Design and Example," *QST*, October, 1972.

The placement of input-circuit components and supporting bracket may be seen in this bottom view. When the bottom cover is in place, the screened air inlet allows the blower to pull air in, pressurizing the entire under-chassis area. The Minibox on the rear apron is a housing for the input reflactometer circuit.

vhf amplifiers to assure maximum power transfer to the load while tuning. Most capacitive-probe output coupling schemes presented to date do not lend themselves to built-in relative-output monitoring circuits. In this amplifier, one of these built-in circuits is achieved quite handily. The circuit consists of a 10:1 resistive voltage divider, diode rectifier, filter and adjustable indicating instrument. Two 7500-ohm, 2-watt carbon resistors are located in the plate compartment connected between the type N rf-output connector and a BNC connector. A small wire was soldered to the center pin of the BNC connector, inside a Minibox, with the 1500-ohm, 1-watt composition resistor and the rectifier diode joined at this point. Relative output voltage is fed, via feedthrough capacitors, to the level-setting potentiometer and multimeter switch.

A calibrated string of 2-watt composition resistors, totaling 5 megohms, was installed to facilitate "on-the-spot" determination of power input, and to attest to the presence or absence of high voltage in the plate tank circuit. A full-scale range of 5000 volts is obtained with the 0-1 mA meter. If desired, the builder may use ten 500-K-Ω, 2-watt, 1-percent resistors for the string and reasonable accuracy will be obtained. Of course this monitor feature may be eliminated if other means are used to measure and monitor plate voltage.

The amplifier is unconditionally stable, with no parasitics. To verify this, a zero bias check for stability was made. This involved shorting out the Zener diode in the cathode return lead, reducing bias to essentially zero volts. Plate voltage was applied, allowing the tube to dissipate about 885 watts. The input and output circuits were then tuned through their ranges with no loads attached. There was no sign of output on the relative output meter and no change in the plate and grid currents. As with most cathode-driven amplifiers, there is a slight interaction between grid and plate currents during normal tune-up under rf-applied conditions. This should not be misconstrued as amplifier instability.

Tolerances of the Zener diode used in the cathode return line will result in values of bias voltage and idling plate currents other than those listed in Table I. The 1N3311, a 20-percent tolerance unit, is rated at 12 volts nominal but actually operates at 10 volts in this amplifier (within the 20-percent tolerance).

All testing and actual operation of this amplifier was conducted with a Raytrack high-voltage power supply used in conjunction with the author's 6-meter amplifier. The power supply control and output cable harness was moved from one amplifier to the other, depending on the desired frequency of operation.

Drive requirements were measured for plate power-input levels of 1000 and 1600 watts with a Bird Model 43 Thru Line Wattmeter and a plug of known accuracy. Output power was measured simultaneously with drive requirements at the 1000 and 1600 watt plate power input levels. A second Bird model 43 with a 1000-watt plug was used to measure amplifier output into a Bird

The tube and plate line is in place, with the top and side of the compartment removed for clarity. The plate-tuning vane is at bottom center. A bracket is attached to the side panel to support the rear of the Teflon rod supporting the tuning vane. The coil at the opposite end of the plate line is RFC1, connected between the high-voltage-bypass plate and the top section of the plate-line sandwich. Items outside the tube enclosure include the filament transformer, blower motor, relays, and a power supply to operate a VOX-controlled relay system.

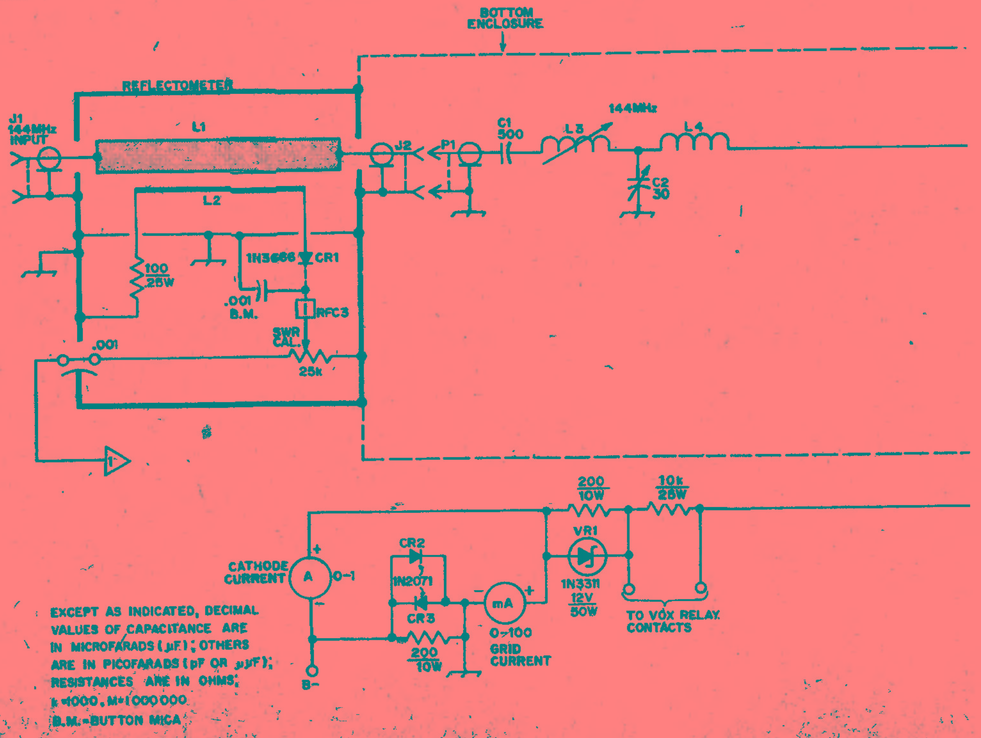
1000-watt Termaline load. A 2500-watt plug would be necessary to determine output power at the 2-kW input level, so I stopped at the 1000-watt output point and worked backwards to calculate apparent stage gain and efficiency.

Efficiency measurements also were made employing the "tube air-stream heat-differential" method. Several runs were made at 885 watts static dc and normal rf input. Apparent efficiencies of 62 to 67 percent were noted. These values were about 5-percent higher than the actual power output values given in Table I. Both efficiency measurement schemes serve to confirm that the amplifier is operating at the upper limit of the theoretical 50-60-percent efficiency range for typical Class AB2 amplifiers.

To commence routine operation, the variable capacitor in the input circuit should be set at the point where lowest input VSWR was obtained during the "cold-tube" initial tube-up. The ability of the plate tank to resonate at 144-145 MHz with the top cover in place should be verified with a grid-dip meter, via a one-turn link attached to the rf output connector. Top and bottom covers are then secured. *As with all cathode driven amplifiers, excitation should never be applied when the tube*

Fig. 1 — Schematic diagram of the amplifier. Included is information for the input reflectometer used as an aid to tuning the cathode circuit for low SWR. C7, C8, and C9 are fabricated as described in the text and Fig. 2.

B1 — Blower. Fasco 59752-IN or Dayton 2C610. Wheel diameter is 3-13/16 inchas.
C2 — 5- to 30-pF air variabla. Hammerlund HF-30-X or equiv.
C3, C4, C5, C6 — 0.1 µF, 600-V, 20-A feedthrough capacitor. Sprague 8OP3 or equiv.
J1, J2, J6 — Coaxial chassis-mount connectors, type BNC.
J3 — Coaxial connector, type N.
J4 — Coaxial panel jack, UG-22B/U (Amphenol 82-62 or equiv.).
J5 — HV connector (James Millen 37001 or equiv.).
L1 — Double-sided pc board, 1-1/4 × 4-7/16 inches.
L2 — 4-1/4 inches of No. 18 wire. L1 and L2 are part of the input reflectometer circuit described in the text under the heading of "Support Electronics."
L3 — 6 turns No. 18 enam., 5/8-in. long on 3/8-in. dia form (white slug).
L4 — 3 turns No. 14 enam., 5/8-in. long × 9/16-in. ID. Lead length to L3 is 5/8-in. Lead length to cathode bus is 3/4-in.
L5 — Air-dialectric strip lina. See text and Fig. 2.
P1 — Coaxial cabla connector, type BNC.
P2 — Coaxial cable connector, type N.
R1 — Meter renge multiplier. Ten 500-K Ω, 2-watt composition rasistors in serias.
RFC1 — 7 turns No. 16 tinned, 1/2-in. ID × 1-in long.
RFC2 — 18 turns No. 18 enam., close wound on 1-megohm, 2-watt composition resistor.
RFC3, RFC4 — Each 2 ferrite beads on component leads.
RFC5, RFC6 — 10 turns No. 12 enam. bifilar wound, 5/8-in. dia.
S1 — Single-pola, three position rotary switch, non-shorting contacts.
T1 — 5-V, 10-A secondary, center tap not used. (Stancor P-6135 or equiv.).
VR1 — 12-V, 50-watt Zener diode.



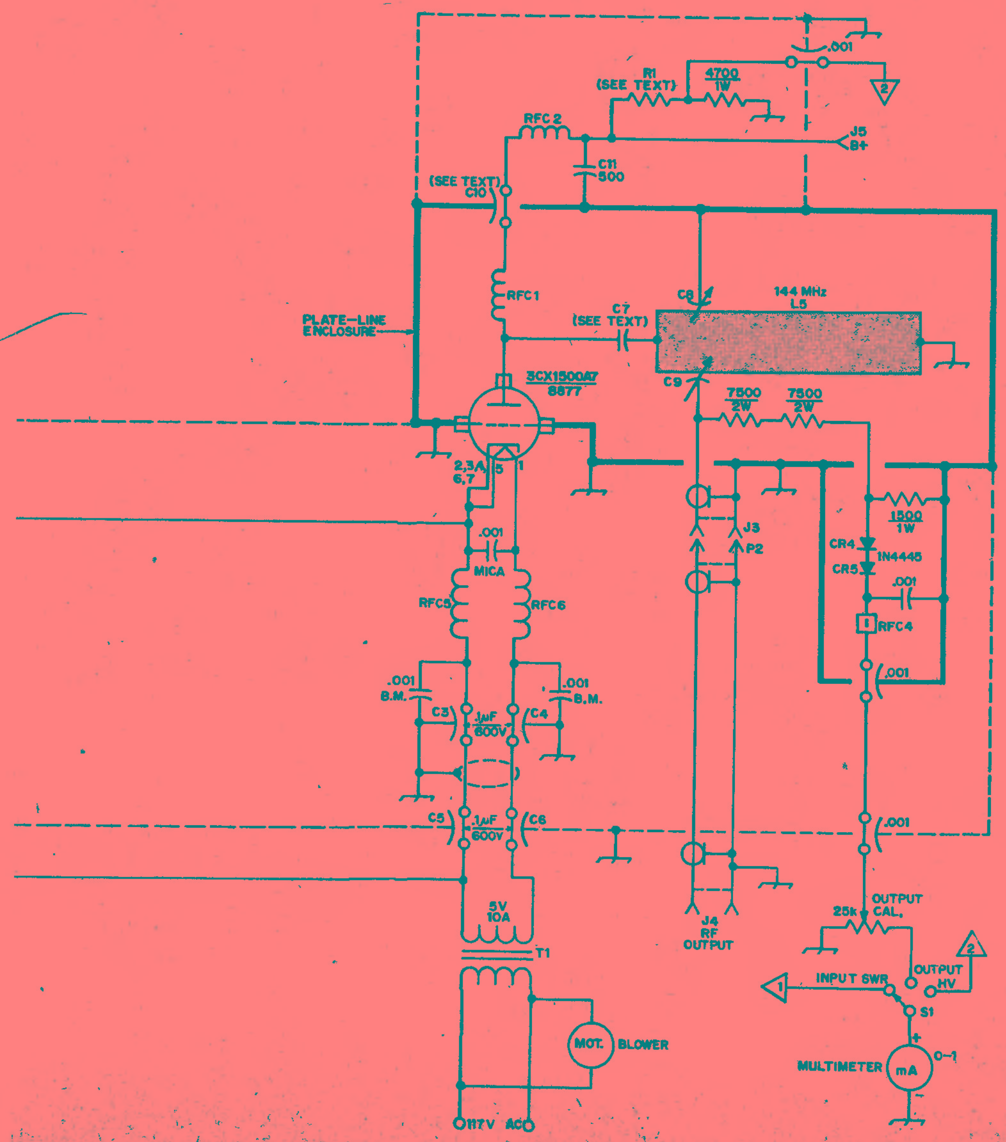
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k=1000, M=1000 000
B.M.=BUTTON MICA

heater is activated and plate voltage is removed. Next, turn on the tube heater and blower simultaneously, allowing 90 seconds for warm-up. Plate potential between 2400-3000 volts then may be applied and its presence verified on the multimeter. The power supply should be able to deliver 800 mA or so. With the VOX relay actuated, resting current should be indicated on the cathode meter. A small amount of drive is applied and the plate tank circuit tuned for an indication of maximum relative power output. The cathode circuit can now be resonated, tuning for minimum reflected power on the reflectometer, and not for maximum drive power transfer. Tuning and loading of the plate-tank circuit follows the standard sequence for any cathode driven amplifier. Resonance is accompanied by a moderate dip in plate/cathode current, a rise in grid current and a considerable increase in relative power output. Plate-current dip is not absolutely coincident with maximum power output but it is very close. Tuning and output-loading adjustments should be for maximum efficiency and output as indicated on the output meter. Final adjustment for lowest VSWR at amplifier input should be done when the deisred plate input-power level has been reached.

Table I

Performance Data

Power input, watts	1000	1600
Plate voltage	2600	2450
Plate current (single tone)	385 mA	660 mA
Plate current (idling)	50 mA	50 mA
Grid bias	−10 V	−10 V
Grid current (single tone)	35 mA	54 mA
Drive power, watts	18	41
Efficiency (apparent)	59.5%	61.8%
Power gain (apparent)	15.2 dB	13.9 dB
Power output, watts	595	1000



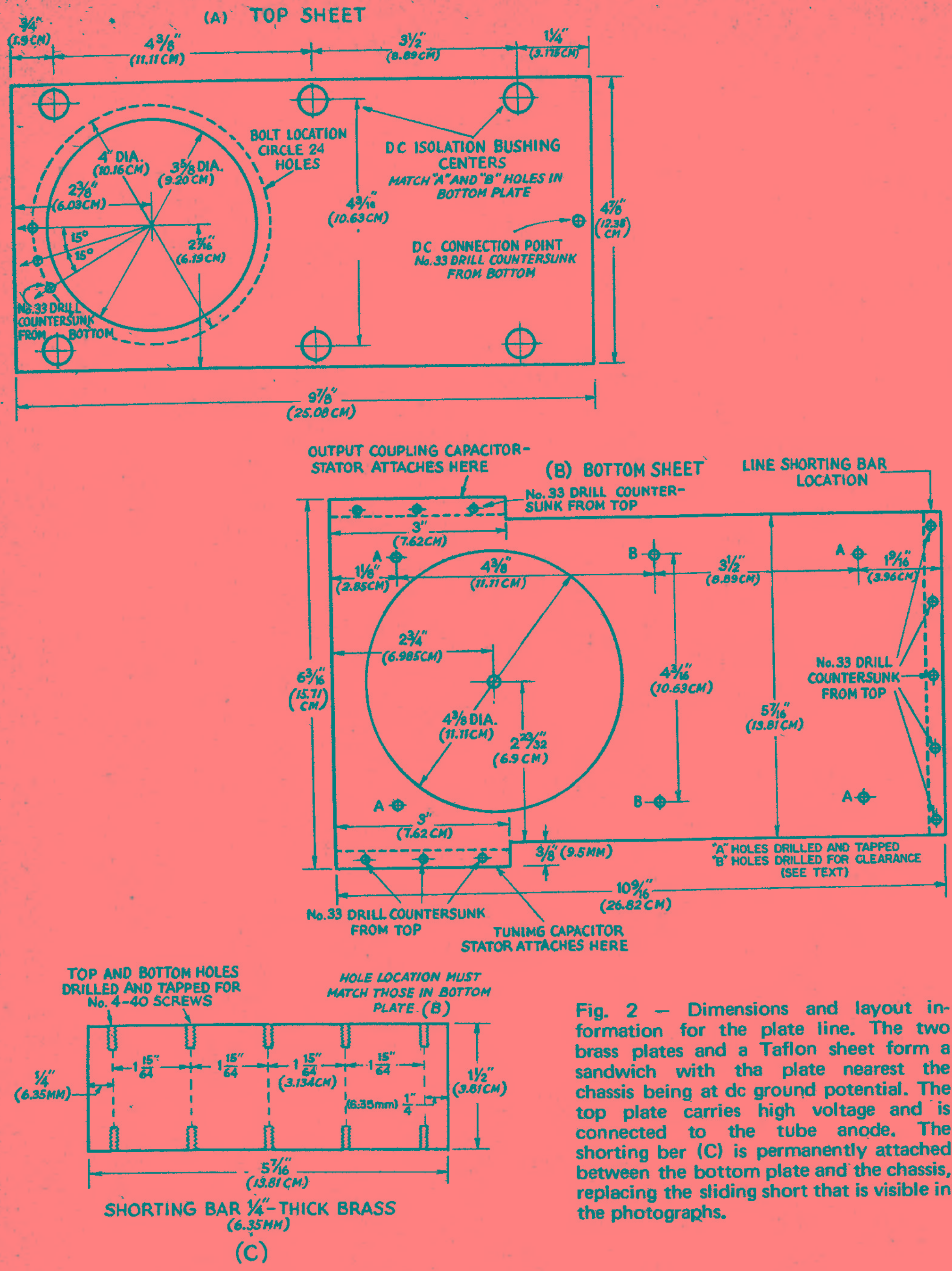


Fig. 2 — Dimensions and layout information for the plate line. The two brass plates and a Taflon sheet form a sandwich with tha plate nearest the chassis being at dc ground potential. The top plate carries high voltage and is connected to the tube anode. The shorting ber (C) is permanently attached between the bottom plate and the chassis, replacing the sliding short that is visible in the photographs.

A RESONANT-CAVITY AMPLIFIER FOR 432 MHZ

This highly-efficient 4CX250 amplifier operates at approximately 63-percent efficiency when used with a plate supply of 1750 volts and a screen supply of 255 volts. It can be operated with higher voltage on its plate, but at reduced efficiency. It provides power levels up to 500 watts input on cw and fm.

The grid circuit of the amplifier is as shown in Fig. 7-39 and is pretty much a duplication of the one shown in the 2nd Edition of *The Radio Amateur's VHF Manual* (ARRL), page 257. The plate side of the circuit is a resonant cavity and is shown in representative form in Fig. 7-39. Detailed information on how the plate circuit is built is given in Fig. 7-40.

Fig. 7-37 — View of the top of the assembled amplifier. Teflon bushings hold the square capacitor plate in place on the wall of the cavity. One bushing is not shown. The high voltage and rf choke connect to that bushing's screw when it is in place. Plate-tuning adjustments are made from the bottom of the cavity. The shaft for C3 is accessible on the bottom wall of the cavity. This amplifier was designed and built by H. E. Holshouser, Jr., K4QIF.

Fig. 7-38 — Inside view of the amplifier. The grid circuit and filament transformer are inside the chassis. Plate and output-tuning adjustments are made from the bottom of the cavity (far right).

Construction

Much of the information concerning the way the amplifier is built can be taken from the photos. The dimensions of the plate cavity are given in Fig. 7-40. The cavity is constructed, cylindrical fashion, from 1/8-inch thick copper or brass stock and has an inside diameter of 6 1/4-inches. The wall height of the cylinder is 1 1/2 inches. Both end plates are fashioned from 1/8-inch thick copper or brass stock. A firm bond is essential between the end plates and the cylinder to assure maximum efficiency. It would be wise to have the cylinder milled flat on each end to assure a good fit, then use a liberal number of machine screws to hold the end plates in place. Mechanical rigidity is imperative with this type of structure, thus assuring good continuity at the high-current points of the cavity, and to enhance the tuning stability of the plate circuit.

The tube and socket are mounted 5/8 inch off center from the center of the cavity. The hole in the top plate of the cavity should be large enough in diameter to assure a 3/16-inch clearance all around the anode of the tube. Care should be taken to smooth the edges of the hole lest arcing occur during operation. The home-built capacitor, C6, is formed by making a 3 7/8-inch square copper or brass plate of 1/8-inch thick stock and placing a sheet of 10-mil teflon insulation between it and the cavity top plate. The plate has a clearance hole for the anode of the 4CX250 and is ringed with finger stock so that it contacts the tube's anode. Insulating bushings of teflon are used at each corner of the capacitor plate to secure it to the wall of the cavity, Fig. 7-37.

An Eimac SK-600 tube socket is used, and no chimney is needed. The socket has built-in bypass capacitors on the screen and filament terminals. These are not shown on the schematic diagram. The bottom of the tube socket projects into the main chassis where the grid circuit is located. The output link, L3, is a straight piece of 1/16-inch

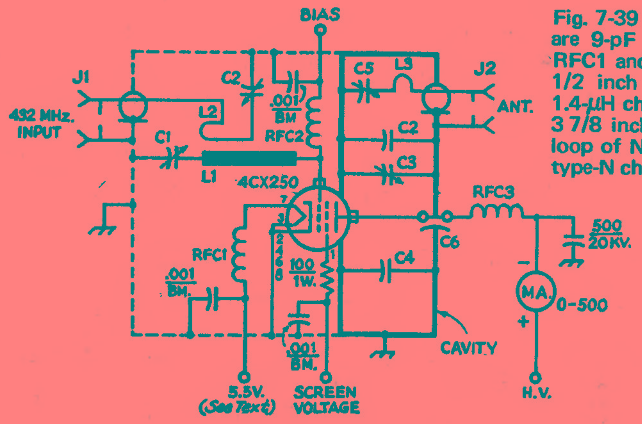


Fig. 7-39 — Schematic of the amplifier. C1 and C2 are 9-pF miniature variables (Johnson 160-104). RFC1 and RFC2 are each 8 turns of No. 16, enam, 1/2 inch diameter and 1 inch long. RFC3 is a 1.4-μH choke. L1 is a brass strip, 1/16 inch thick, 3 7/8 inches long, and 1 1/4 inches wide. L2 is a loop of No. 12 wire, 6 inches overall. J1 and J2 are type-N chassis connectors. B.M. = button mica.

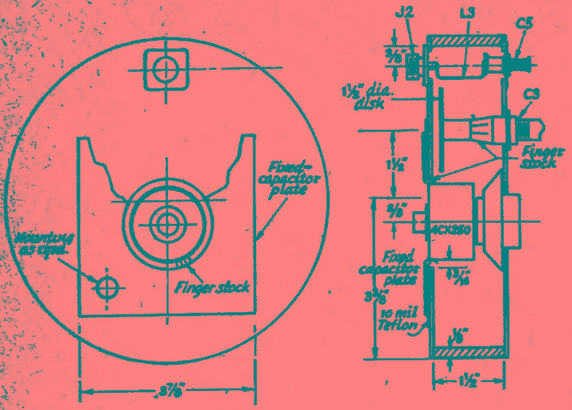


Fig. 7-40 — Mechanical layout of the plate cavity and its dimensions.

Fig. 7-41 — Inside view of the K4QIF amplifier cavity. The stationary capacitors, C2 and C4, are located on either side of the 4CX250 socket.

thick brass or copper, 1/8 inch wide, shaped as shown in Fig. 7-40.

Two fixed capacitors are shown in the schematic diagram, C2 and C4. These capacitors are not indicated on the mechanical drawing of Fig. 7-40 as they were added as a modification when some models of this amplifier showed a tendency toward arcing between the disk of C3 and the cavity wall. C2 and C4 are disks of copper which are 1 1/4 inches in diameter. They are spaced approximately 1/8 inch from the top wall of the cavity. They are supported from the bottom wall of the cavity by means of 3/8-inch diameter brass posts and are positioned generally as shown in Fig. 7-41. *A word of caution:* The tuning shaft of C3 should not pass through the grid compartment of the amplifier. The cavity assembly is offset on the main chassis so that the shaft is accessible outside the grid compartment.

The output tuning capacitor, C5, is a glass piston trimmer with a maximum capacitance of 10 pF. Do not try to use a plastic piston trimmer here as it will be destroyed because of its poor dielectric properties. Neutralization of this amplifier was not found to be necessary as no tendency toward instability was noted.

Operation

It is suggested that a 0.5-ampere fuse be used in series with the high-voltage lead to protect the plate meter should an arc or short circuit occur. The screen current should be metered so that at no time an excessive amount of current will be permitted to flow. Heed the manufacturer's ratings at all times.

The amplifier must always look into a nonreactive load if damage is not to occur. It is designed to work into a 50-ohm load, but a 75-ohm load will be acceptable if the SWR is kept low. *Warning:* The anode of the 4CX250 should be covered with a perforated box of some type to prevent accidental contact with the high voltage. It should allow the free passage of air from the forced-air cooling system, which is piped into the grid compartment. The grid compartment should be made as air-tight as possible to assure a heavy flow of air through the socket and the anode fins of the tube.

The heater voltage for this type of tube is 6.0 and not 6.3. It is satisfactory to use the 6-volt figure at the low frequencies, but at 432-MHz, the voltage should be reduced to 5.5 to compensate for the back-bombardment that the cathode is subjected to. The latter causes overheating, which in turn causes drifting of operating conditions and shortened tube life. Other operating voltages and currents for this amplifier must be chosen for the class of operation desired. It is best to consult the manufacturer's published ratings for this information.

GROUNDED-GRID AMPLIFIER FOR 1296 MHZ

There are few tubes available that will provide the radio amateur with low-cost construction while at the same time delivering moderate power output in the 1215-MHz region. One popular low-cost tube is the 2C39. Also available are its newer brothers the 2C39A, 2C39B, 3CX100A5, and 7289. All look pretty much alike, but only the early versions have appeared on the surplus market. This amplifier uses 2C39As in a cavity assembly and is capable of delivering 100 watts or more as a linear amplifier, with a gain of 6 to 10 decibels.[1] It can be built with simple hand tools.

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[1] Described in January 1968 *QST*.

Amplifier Details

Uhf circuits, particularly those involving cavities, do not lend themselves well to conventional schematic presentation, but the circuit diagram, Fig. 7-43, may aid the reader in identifying the components and understanding their functions. The structural features of the amplifier are not all apparent from the photographs, so are described in some detail, using component designations of Fig. 7-45 in referring to the various parts.

This is a grounded-grid amplifier. The large square box visible in the pictures houses the cathode input circuit. The whole assembly is shown from the top in Fig. 7-42, and from the bottom in Fig. 7-44. Details of the principal metal parts are given in Fig. 7-45. It will be seen that the bottom cover of the cathode compartment (part D in Fig. 7-45) is cut diagonally to permit access to the cathode circuit for adjustment purposes. The tuned circuit, L1-C2, is effectively a half-wave line, tuned at the end opposite to the tubes. The inductance, part E in Fig. 7-45, is tuned by means of a beryllium copper spring finger, visible in the lower left corner of Fig. 7-44. It is actuated by an adjustment screw running through a shoulder nut mounted in the removable cover plate. Input coupling is capacitive, through C1, a small glass trimmer at the center of the line, between the tubes. An approximate input match is established by adjustment of this capacitor.

The plate circuit, L2-C3, is a square tuned cavity not visible in the pictures. It is made by bending part G into a square, and soldering it to the top of part C and to the bottom of part B, with all lined up on a common center. The *outside* of the cavity is at rf ground potential. The tubes are mounted on a diagonal, at equal distances from the center. The plate tuning capacitor, C3, is coaxial. Its movable element is a 6-32 screw, running through a shoulder nut in the top plate of the bypass capacitor, C4, soon to be described. The fixed portion is a metal sleeve 5/16 inch inside diameter and 5/8 inch high, soldered to the top side of part C. It is centered on a 6-32 binder-head screw, threaded into the center hole in part C. This screw also holds a 3/8-inch insulating spacer that supports the cathode inductor, part E. Output coupling is by means of a fixed loop, L3, on a BNC or TNC coaxial fitting mounted in the 3/8-inch hole in part G, the cavity wall.

The bypass capacitor, C4, consists of the top cover of the plate cavity, part B, a layer of 0.02-inch Teflon sheet, and the top plate, part A. This combination does not act as a pure capacitance, because of the large size of the plates in terms of wavelength at 1296 MHz. It is important not to make substitutions here, as variations in size of the plates or thickness of the insulation may cause the capacitor to become resonant. The plates are held together with nylon screws. Metal screws with insulating sleeving, and insulating shoulder washers, may also be used. Nylon screws and other insulation, other than Teflon, may melt if the bypass capacitor becomes resonant. Nylon is very lossy at 1296 MHz.

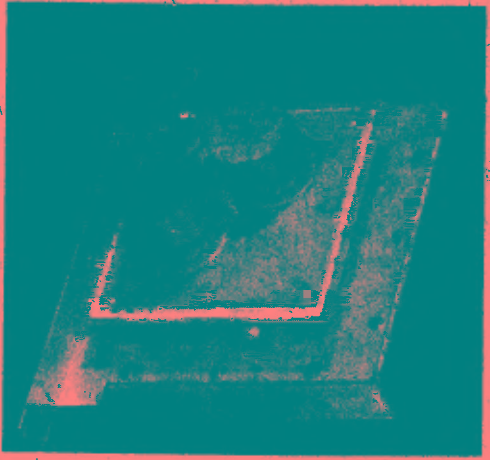

Fig. 7-42 — The 2-tube 1296-MHz amplifier. Two 2C39As are used in this grounded-grid setup. The large square base unit houses the cathode input circuit. The plate cavity is not visible, as it is obscured by the plate-bypass assembly seen here. *(Built by W6IQM)*

Construction

Major sheet-metal parts are cut from 0.04- or 0.05-inch sheet-brass. The cutting, bending and soldering can be done with hand tools. The soldering is done readily over a kitchen stove, or with a 300-watt or larger soldering iron. Silver plating is recommended, to assure good rf contact throughout. Several methods usable in the home are outlined in *The Radio Amateur's VHF Manual.* All sheet-brass parts are shown in Fig. 7-45, with dimensions and hole locations. Note that the bottom plate of the cathode assembly, part D, is cut diagonally, and fitted with spring finger stock to assure good electrical continuity when the assembly is closed.

On the smaller part of D is a 6-32 screw that runs through a shoulder nut soldered into the sheet, with the head of the screw on the outside when the cover is in place. The end of the screw bears on the beryllium copper spring finger, 5/8 inch wide, bent so that its position with respect to the cathode circuit varies with the position of the screw. Its position and approximate size should be evident from Fig. 7-44. The bottom end is soldered to the inside of part C. The free end should be wrapped with smooth insulating tape, so that the cathode bias will not be shorted out if the capacitor is closed down too far.

Spring finger stock is used to provide flexible low-inductance contact with the plate, grid and cathode elements of the tubes. Finger stock numbers are given for stock obtained from Instrument Specialty Co., Little Falls, N.J. The material used for tube contact purposes is No. 97-380. That on the triangular cover plate is 97-134. If tubes with recessed grid rings are used (example: the 7289) it is necessary to solder a small piece of brass against the bottom of the grid finger stock, to prevent the tube from being

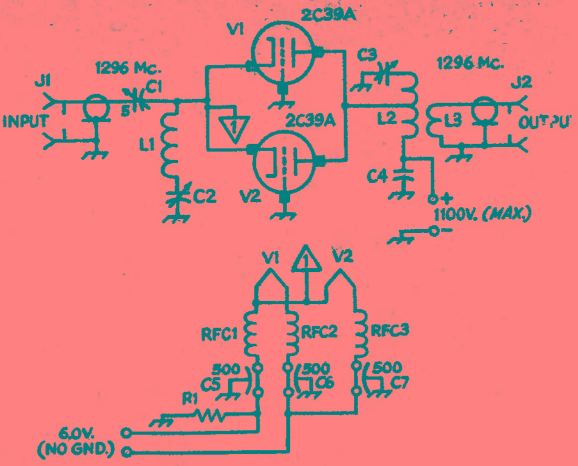

Fig. 7-43 — Representative circuit of the 1296-MHz cavity amplifier. The plate cavity and tuning device are indicated by L2,C3, the cathode inductance and tuning capacitor by L1,C2. Note that the heater supply must not be grounded.

C1 — 5-pF glass trimmer.
C2 — Beryllium-copper spring finger; see taxt and Fig. 7-44.
C3 — Coaxial plate capacitor (see text)
C4 — Plate bypass capacitor, composed of parts A and B, Fig. 7-45 separeted by 0.02-inch Teflon sheet. See text.
C5, C6, C7 — Feedthrough bypass, 500 pF.
J1, J2 — Coaxial jack, BNC or TNC typa.
L1 — Cathode inductor, part E, Fig. 7-45. See text and Fig. 7-44.
L2 — Plate cavity, composed of parts C, B and G of Fig. 7-45. See text.
L3 — Copper strap 3/B inch wida, from pin of J2 to top side of part C.
RFC1, RFC2, RFC3 — 10 turns No. 22 enamel, 1/8-inch dia, 1 inch long.
R1 — 50 to 100 ohms, 2 watts (see taxt).

pushed in too far. Otherwise it is impossible to remove the tube without damage to either the finger stock or the tube. The finger stock used in the grid, plate and cathode holes should be preformed to fit, and then soldered in with a 200-watt or larger iron. That on part D is soldered to the outside of the plate. It may be necessary to strengthen the cover plate with a strip of brass soldered to the inside, opposite to the finger stock to prevent bulging. This should protrude about 1/16 inch from the edge of the cover plate. Any intermittent contact here will detune the input circuit severely.

The finger stock in the plate bypass should be flush with the sheet metal on the side facing the cavity. With the grid and cathode connections the stock may protrude somewhat. The soldering of the cavity parts should be done first. The parts should be lined up carefully, clamped together, and then soldered in place over a gas flame for preheating, doing the actual soldering with a small iron. Check alignment prior to final cool-down. The output BNC fitting can be soldered in at this time, adding the coupling loop later. It is merely a strip of copper or brass, 3/8 inch wide, soldered between the center pin of J2 and the cavity bottom. The strip should rest against the Teflon shoulder of the fitting, and extend 1/4 inch beyond the center pin before being bent 90 degrees down to the cavity bottom. Solder solidly to part A, and to the full length of the pin on J2. Now put in the finger stock. If a small iron is used, preheating with the gas flame, the heavy brass parts will not come loose. The top cover of the plate cavity, part B, is then soldered in place, using a clamp as before.

In cutting the Teflon insulation for the plate bypass, make tube holes only just large enough to clear the tube. There should also be some area of insulation around the outer edges of the top plate. These precautions are helpful in preventing arc-over.

Connection to the tube heaters is made by bending a U-shaped piece of beryllium copper or spring bronze to make a snug fit in the heater cup at the end of the tube. The air-wound rf choke is connected directly to this, with the other end running to the feedthrough bypasses. The heaters being brought out separately permits a check on condition of tubes, by turning off the heaters one at a time. Leaving the tube in place, but cold, does not detune the system, and a comparison of the tubes may be made in this way. Note that neither side of the heater circuit can be grounded.

Fig. 7-44 — Bottom (or back) view of the cathode circuit and housing showing the divided cover plate, part D in Fig. 7-45. Inside are the cathode inductance, part E, and the spring-finger tuning capacitor plate, C2. The heater and cathode feedthrough bypasses and the input coaxial fitting are on the cover plate, near the center. The outside surface of the removable cover plate is shown.