CHAPTER II—

GE ELECTRONICS

SIDEBAND GENERATORS AND EXCITERS

SSB, JR.

From November-December, 1950

Presenting a 3-Tube, 5-Watt SSB Transmitter with Superior Performance

Fig. 1. Front panel view of the SSB Jr. For single-frequency operation none of the controls need be adjusted (except the audio gain control). Front-panel mounting of the controls permits a compact physical layout to be obtained.

FEATURES—

- **Simple to construct**
- **Uses inexpensive parts**
- **Has sideband-reversing control**
- **Usable as emergency, portable or home transmitter**

The SSB Jr. is a complete single-sideband transmitter—just add microphone and antenna and you are on the air. No longer must amateurs feel that single-sideband equipment is too complex to understand or too complicated to build. The SSB Jr. rig is no more difficult to build or adjust than any modern 3-tube transmitter. This rig should bring SSB within the reach of anyone that is interested.

SSB, Jr.

ELECTRICAL CIRCUIT

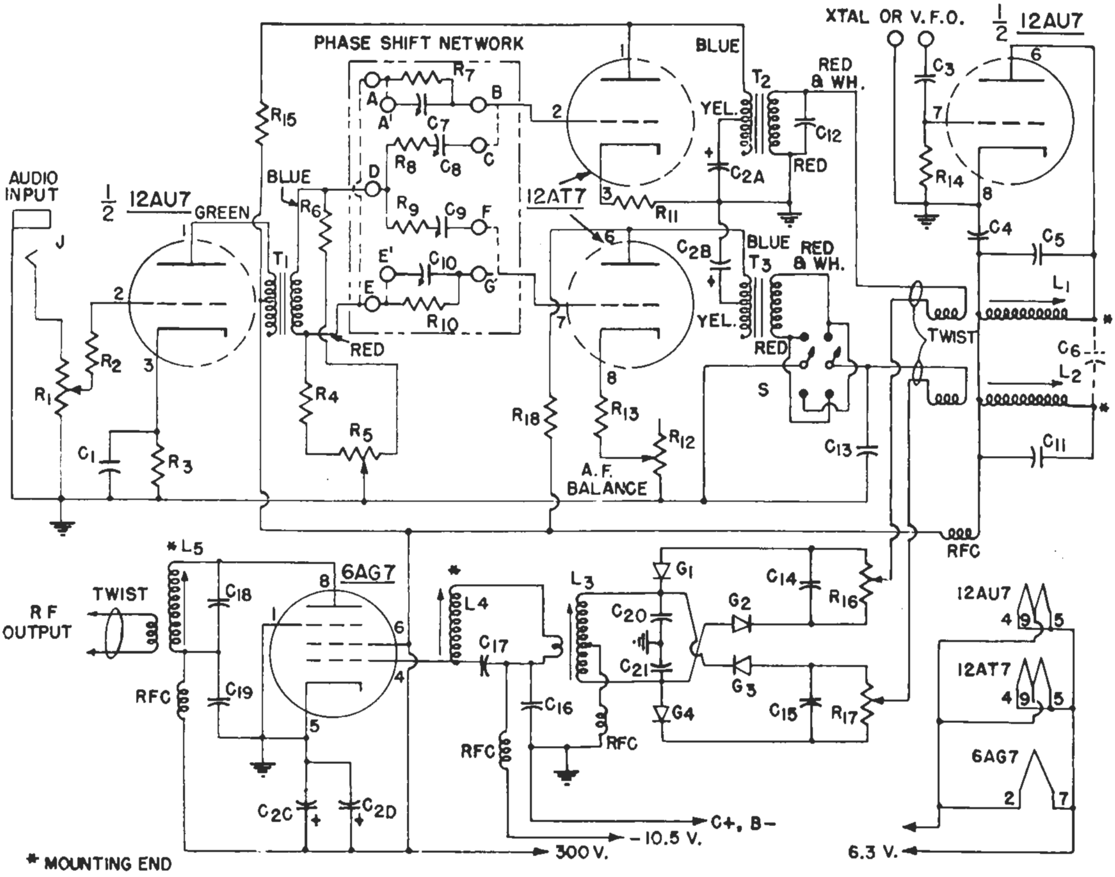


Fig. 2. Circuit diagram of the SSB Jr.

Circuit Constants

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

C_1	0.5 mf 200 volt paper
C_2	20-20-20-20 mf 450 volt electrolytic
C_3, C_4, C_{12}, C_{13}, C_{16}	1000 mmf mica or ceramic
C_5, C_{11}, C_{17}	*250 mmf mica ±10%*
C_6	May not be necessary, see text
C_7	*2430 mmf (0.002 mf mica ±5% with 170-780 mmf trimmer in parallel)*
C_8	*4860 mmf (0.0043 mf mica ±5% with 170-780 mmf trimmer in parallel)*
C_9	*1215 mmf (0.001 mf mica ±5% with 50-380 mmf trimmer in parallel)*
C_{10}	*607.5 mmf (500 mmf mica ±10% with 9-180 mmf trimmer in parallel)*
C_{14}, C_{15}	0.005 mf mica or ceramic
C_{18}	*350 mmf 600 volt mica ±10% (250 mmf in parallel with 100 mmf)*
C_{19}	0.01 mf mica or ceramic
C_{20}, C_{21}	*0.002 mf mica ±10%*
G_1, G_2, G_3, G_4	1N52 germanium diode or equivalent, see text
J	Open circuit jack
L_1, L_2	33 turns No. 21 enamel wire close wound on Millen No. 69046 iron core adjustable slug coil form. Link of 6 turns of hookup wire wound on open end.
L_3	16 turns No. 19 enamel wire spaced to fill Millen No. 69046 coil form. Tap at 8 turns. Link of 1 turn at center.
L_4	Same as L_1 except no link used
L_5	28 turns No. 19 enamel wire. Link on open end to match load. (4 turn link matches 72 ohm load.)
RFC	Radio-frequency choke 0.5 millihenry
R_1	1 megohm potentiometer
R_2	10,000 ohm, ½ watt
R_3	750 ohm, ½ watt
R_4	*430 ohm, ½ watt (±5%)*
R_5	100 ohm potentiometer
R_6	*1600 ohm, ½ watt (±5%)*
R_7, R_{10}	*133,300 ohm, ½ watt (±1%)*
R_8, R_9	*100,000 ohm, ½ watt (±1%)*
R_{11}	*510 ohm, ½ watt (±5%)*
R_{12}	500 ohm potentiometer
R_{13}	330 ohm, ½ watt
R_{14}	47,000 ohm, ½ watt
R_{15}, R_{18}	20,000 ohm, 1 watt
R_{16}, R_{17}	1000 ohm potentiometer
S	DPDT toggle switch
T_1	Stancor A-53C transformer
T_2, T_3	UTC R-38A transformer

Further, any amateur can build the SSB Jr. rig and be assured that his single-sideband signal will be second to none in quality. Performance has not been sacrificed in the interest of simplification.

The peak power output is 5 watts and the total power input, not including filament power, is 18 watts (300 volts at 60 ma.). The SSB Jr. rig features a self-contained crystal oscillator (or buffer for VFO operation), 40 db. sideband suppression, and mechanical and electrical ruggedness that make it ideally suited as a complete portable, mobile, emergency transmitter, or as an exciter for a home transmitter.

The system used in the generation of the single-sideband signal is a simplified phasing method that is daringly direct and effective. Inexpensive and easily-available components are used throughout.

All of the information necessary to construct and adjust the SSB Jr. rig appears in this article. Technical details on the new phase-shift network and the new modulator design are explained in the Designer's Corner section of this issue.

Circuit Description

With reference to the circuit diagram, Fig. 2, the first tube, a 12AU7, is a twin-triode, combination speech amplifier oscillator. A 12AT7 serves as a twin-channel amplifier in the output of the phase-shift network, and the final is a 6AG7 pentode.

Starting with the audio circuit, an input gain control potentiometer feeds the grid of the self-biased input tube, which is one-half of the 12AU7 miniature tube. The output of this tube is coupled into a newly designed audio phase-shift network by means of transformer T_1. The outputs of the phase-shift network feed separate triode sections of the 12AT7 miniature tube. These two tube sections are transformer coupled to two balanced modulators each of which employs a pair of germanium crystal diodes.

The balanced modulators are also supplied by r-f signals from the crystal oscillator, which is the other half of the 12AU7. These r-f signals are picked up by separate link windings on L_1 and L_2, which comprise portions of a 90 degree r-f phase-shift network in the plate circuit of the oscillator. The balanced modulators work into a balanced load circuit (L_3, C_{20}, C_{21}) which is link coupled to the grid circuit (L_4, C_{17}) of the class AB_1 linear power amplifier tube, a 6AG7.

This power amplifier works into a conventional tank circuit (L_5, C_{18}) that is link coupled to the load. All circuit tuning is accomplished by adjustable slug-tuned coils wound on Millen No. 69046 powdered-iron coil forms.

Sideband switching is accomplished by the reversal of audio polarity in one of the audio channels (switch S). Provision is made for equalization of gain in the audio channels, this equalization being necessary in order to achieve normal sideband cancellation. In addition, a semi-fixed control (R_7) is provided for phase-shift network adjustment. Use of this control eliminates the need for a special transformer, or the need for two non-standard precision resistors. Stable modulator balance is achieved by the balance/buffer resistors R_{16} and R_{17} in conjunction with the germanium diodes.

The audio characteristic of the SSB Jr. is designed to emphasize the intelligence-bearing frequencies from 300 to 3000 cycles per second. This feature is obtained jointly by the action of C_1 and the audio transformer T_1. Low differential phase-shift is maintained in audio circuits following the phase-shift network by means of lightly loaded output transformers which are shunt-fed to reduce harmonic distortion caused by direct current in their windings.

Constructional Details

A 5 by 7 by 2 inch chassis provides ample space, with good access, for all component parts. A cabinet, as shown, may be used, although this is not essential. It is recommended that parts layout shown in the sketches and the photographs be followed exactly. Obviously other layouts will work, but the layout shown has been carefully made and many layout problems have been eliminated.

Before starting work on the main chassis it is advisable to make the audio phase-shift network board. This is diagrammed in Fig. 3. The base material may be thin bakelite or any insulating material. The dimensions are 4 inches by 2 1/8 inches. Note that one corner is cut off to permit access to the 12AU7 tube. This board uses four fixed mica condensers which are padded with four adjustable mica trimmers, and four precision resistors (Continental Nobleloy X-1/2, plus or minus 1% tolerance). In the unit shown R_8 and R_9 are as specified, that is, they are Continental Nobleloy 100,000 ohm resistors. However, the 133,300 ohm resistors were made by taking two 150,000 ohm precision Continental Nobleloy resistors and paralleling each of them with a one-half watt 1.2 megohm (plus or minus 10% tolerance) resistor. Careful selection of the 1.2 megohm units will permit close adjustment to the desired value of 133,300 ohms. A convenient way to mount the 1.2 megohm resistors is to slip them inside the hollow body of the precision 150,000 ohm resistors.

The phase-shift network sub-assembly is mounted on three half-inch long spacers under the chassis directly below transformers T_1 and T_2. It is best to dress the leads from these transformers flat against the chassis to clear the phase-shift network. Time will be saved by installing the network sub-assembly as the last step in the construction.

Mount the phase-shift network elements as shown in Figs. 3A and 3B. The dashed connections should be omitted initially, since the detailed alignment procedure described later presumes that these connections will be made at the proper time only.

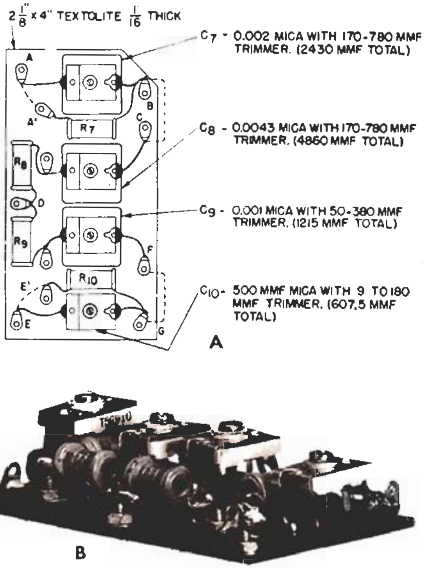


Fig. 3. (A) Mechanical arrangement of the audio phase-shift network. (B) Detail view of the audio phase-shift network

A word of caution about the coils. Make sure that the hot and cold ends are as specified on the circuit diagram—the asterisk indicates the end which is the mounting end, that is, the end with the long tuning screw.

The links on the coils are wound over the cold end, as indicated in Fig. 11. As a suggestion, wind the links with solid insulated hookup wire. This type of wire is convenient, holds on well, and makes a nice looking job. Twist the wires together when running from one coil to another coil, or to another connection point. A small terminal strip may be placed under L_1 to serve as a convenient junction point for the links coming from L_1 and L_2 and going to the balanced modulators.

The small fixed mica tuning condensers that connect across L_1, L_2 and L_3 are mounted on the coil form terminals. The coupling capacitor between L_1 and L_2 (C_6) is shown dotted in the circuit diagram, since the amount of actual capacitance needed at this point will depend on stray coupling effects in the particular unit you build. More information will be given on this later.

Note that the grid connection of the 6AG7 is above the panel from the hot end of L_4 through a hole in the chassis right next to pin number 4 (the grid terminal) of the 6AG7 socket. Direct strapping of terminals 1, 3 and 5 of this socket to the chassis is desirable to ensure stable amplifier operation. Note also that a 2 by 2½ inch brass or aluminum shield is placed between coils L_2 and L_5 below deck.

The unused transformer leads may be cut off close to the winding and forgotten. The secondary windings of T_2 and T_3 have several intermediate taps that are not used. All leads from the three transformers are fed through small rubber grommets in the chassis to circuits on the underside. All, that is, except the secondary leads from T_3 which remain above chassis. Twist these leads together before running them to the sideband reversing switch on the front panel.

Do not ground either heater lead in the chassis, as you may wish to use an a-c heater power supply or perhaps run your automobile engine while transmitting if the rig is used for mobile work.

Ample mounting space for C_1 and R_3 will be found near C_2, the four-section electrolytic condenser. With reference to C_2, one 20 mf section is C_{2A}, another is C_{2B}, etc. The heater leads that run from the 12AU7 may be cabled together with the other leads from T_1, T_2, T_3.

The germanium diodes deserve special care in handling. Do not bend the leads close to the diode unit itself. The diodes are mounted by means of their leads between the coil terminals of L_3 and the appropriate ends of R_{16} and R_{17}. Protect the germanium diodes from heat while soldering by holding the lead with cold pliers between the diode itself and the end where the soldering is taking place. Further, use only as much heat as is necessary to make a good joint.

A four-wire shielded cable brings power from the power supply to the exciter. The shield serves as the negative plate supply lead and should be connected to chassis ground. A male plug at the other end of the cable makes a convenient connection to the power supply.

Power Supply Construction

The power supply is not unusual in any respect. Any source of power supplying 300 volts and 60 mils or more may be used. It is not necessary to use electronic bias either, and a standard battery supplying 10.5 volts may be used for bias.

The power supply used with the **SSB** Jr. rig pictured is shown in Fig. 7 and the circuit diagram given in Fig. 6. A 5V4-G rectifier tube feeds a single-section filter to supply 300 volts, and a 6H6 tube acts as a bias rectifier to supply 10.5 volts. Resistor R_1 adjusts the bias voltage obtainable.

The main a-c switch is S_1, and the stand-by switch is S_2. Note that resistor R_2 acts as a low resistance bleeder to drop the positive voltage to zero quickly when the rig is turned off. A double-pole switch is employed with the switch arms tied together, as this arrangement gives the effect of a double break contact.

There is nothing critical about the power supply layout, and any arrangement may be used to suit your convenience.

Microphone Considerations

The **SSB** Jr. rig as designed requires that a high-output microphone circuit be used. A single-button carbon microphone, connected as shown in Fig. 8B is quite adequate, even desirable, if mobile operation is contemplated.

On the other hand, low-level microphones, such as the usual type of crystal or dynamic microphone, may be used if a one-tube preamplifier is provided. A suggested circuit is shown in Fig. 8A. This preamplifier may be built as a separate unit or incorporated into the **SSB** Jr. rig. Either the preamplifier shown or the single-button carbon mike circuit will provide in excess of the 2 volt (RMS) signal level required as a minimum input signal to the **SSB** Jr.

Component Parts

As is true with many transmitter designs, there are some component parts used in the **SSB** Jr. rig that must be chosen carefully. Obviously, the precision resistors specified are important. If precision resistors are not available—although you should try to get them if at all possible—you may use non-precision resistors which have been checked on a good resistance bridge. You may find that these resistors will change value after they have been used for a while, and that is why it is desirable to use precision resistors initially.

The adjustable mica trimmers used in the audio phase-shift network may be any good grade of mica trimmer. Those actually used are El-Menco mica trimmers—T52910 for the 170 to 780 mmf range; T52510 for the 50 to 380 mmf range; and T52310 for the 9 to 180 mmf range.

Resistors R_4, R_6 and R_{11} are specified as plus or minus 5% tolerance. This is because the values stated are required, and these values only come in the 5% tolerance series.

The germanium diodes are specified as 1N52 diodes. Other types, such as 1N48, 1N51 and 1N63 may be used instead. If possible, select four diodes which have about the same forward resistance. The forward resistance is the low resistance as checked on an ohmmeter. To determine approximately what it is, measure the resistance in one direction, then reverse the leads to the diode and make a second measurement. The two readings should be quite different. The lower resistance is the one of interest. Make this measurement on the four diodes you intend to use to make sure that the forward resistance of any one of the diodes is within ten per cent of the average resistance of the group.

The diodes used in the rig shown measured approximately 250 ohms on a Weston 772 analyzer when the analyzer was set to the RX10 scale. (Dif-

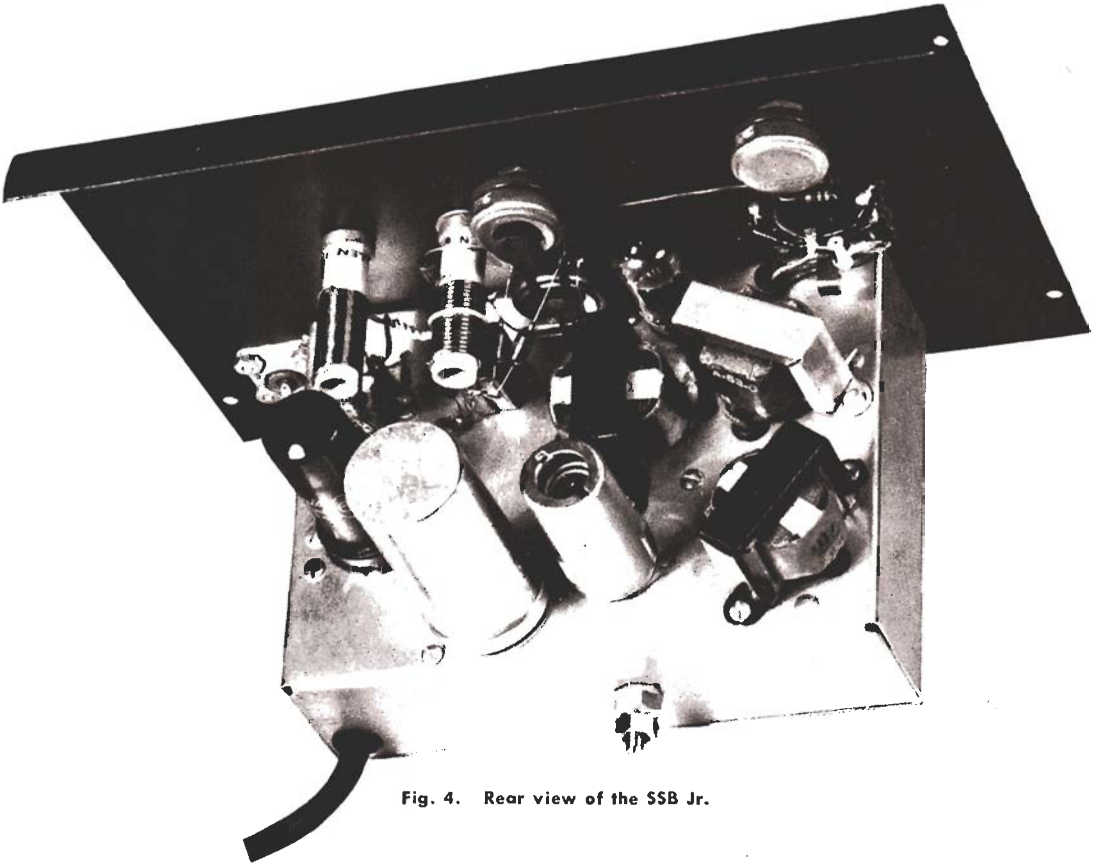


Fig. 4. Rear view of the SSB Jr.

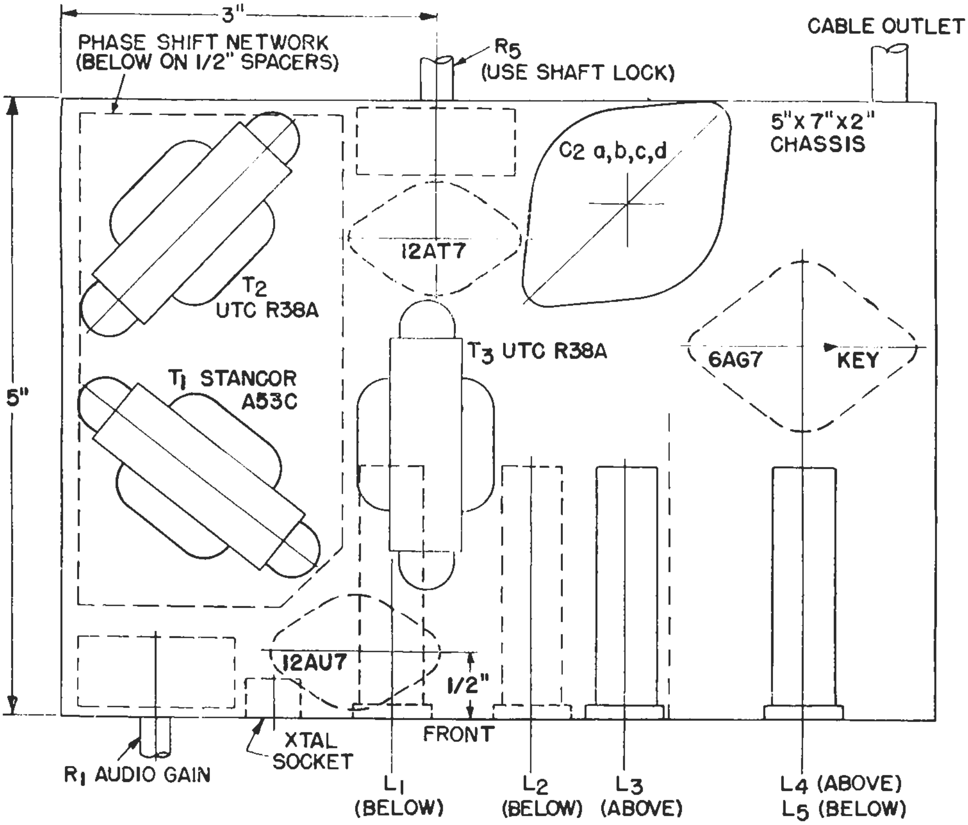


Fig. 5. Chassis layout for the SSB Jr. (top view)

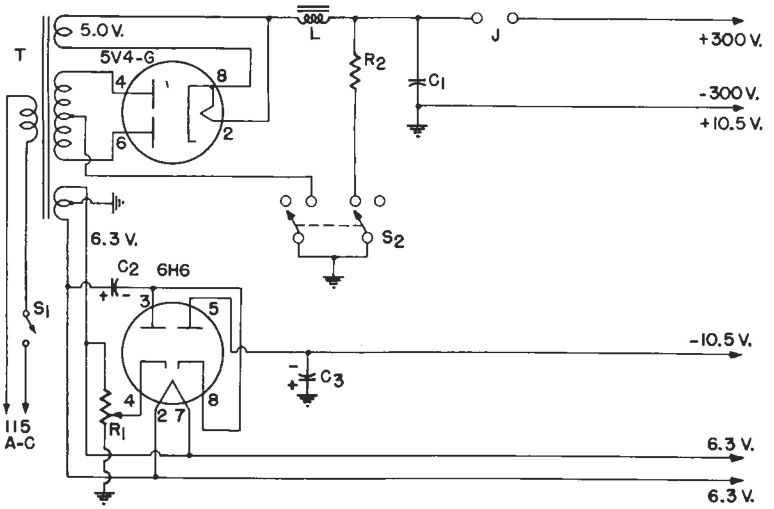


Fig. 6. Circuit diagram of the SSB Jr. power supply

Circuit Constants

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

C_1	40 mf 450 volt electrolytic	R_2	1000 ohm 1 watt
C_2, C_1	50 mf 50 volt electrolytic	S_1	SPST toggle switch
J	Closed circuit jack or terminal posts to permit metering with 0-100 mil meter	S_2	DPDT toggle switch
L	7 henry choke, 160 mils (UTC R-20)	T	Power transformer, 350-0-350 at 75 mils, 6.3 volts at 3 amperes, 5.0 volts at 3 amperes (UTC R-11)
R_1	100 ohm potentiometer		

ferent ohmmeters may give different readings, since the diodes are non-linear in nature.)

It is recommended that transformers T_1, T_2 and T_3 be as specified. Do not make any substitution unless you wish to duplicate a long series of tests to determine if the substitutes are suitable. The types indicated are standard parts, inexpensive, and easy to procure. Observe that the connections are indicated on the circuit diagram by their color code.

It is further recommended that you use Millen No. 69046 coil forms as specified. While the coils are not critical, they must have a certain inductance and distributed capacitance, and if you adhere to the specifications given you should encounter absolutely no difficulty coil-wise.

Initial Circuit Adjustments

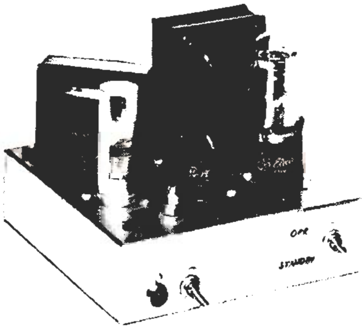


Fig. 7. SSB Jr. Power supply

The adjustment of the audio phase-shift network circuits is most easily done with the phase-shift subassembly out of the chassis. The resistors R_7 and R_8 (and R_{10} and R_9) should bear the ratio of 133,333 to 100,000, that is, 4 to 3, as closely as can be determined. If in doubt as to the ratio of the resistors you used, double-check their value on an accurate bridge. The adjustment of the phase-shift network now consists only of setting the four capacitors (C_7 through C_{10}) to their proper values. Several methods can be used. The most accurate will be described.

An audio oscillator capable of operation from 225 to 2750 cycles per second (with good waveform) is required, plus an oscilloscope. The oscillator should be carefully calibrated by the method described later. Connect the output of the audio oscillator through a step-down transformer (the Stancor A-53C will serve nicely) to a 1000 ohm or 2000 ohm potentiometer with the arm grounded.

Adjust the arm position so that equal (but opposite) voltages appear on each half of the potentiometer. A steady audio frequency signal of any convenient frequency may be used with an oscilloscope acting as a convenient voltmeter for this job. Swing the vertical deflection lead from one end of the potentiometer to the other and adjust the arm to obtain equal voltages (a true center tap). Set up a temporary double cathode-follower circuit using a 12AT7 with 500 ohms from each cathode to ground and connect as shown in Fig. 9. (It will be convenient to provide leads M, N, and 1 and 2 with clips at the ends to facilitate checking.) One may use the 12AT7 in the rig as the double cathode follower by temporarily short circuiting the plate of each tube to its respective center tap of the UTC R-38A transformers. Be sure to remove the 12AU7 and the 6AG7 at this time, and of course supply operating voltages for the

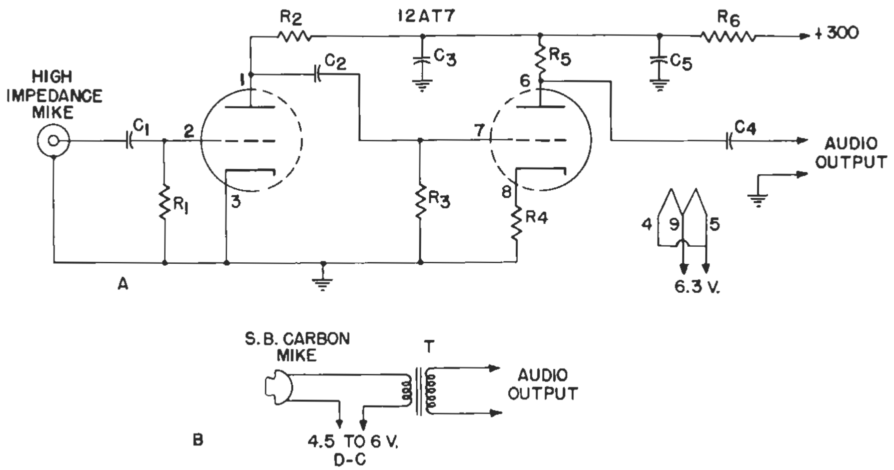


Fig. 8. **Suggested microphone circuits for use with the SSB Jr.**

Circuit Constants

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

C_1, C_2, C_4	0.05 mf 400 volt paper
C_3, C_5	8 mf 450 volt electrolytic
R_1	2 megohm, ½ watt
R_2	0.1 megohm, 1 watt
R_3	0.5 megohm, ½ watt
R_4	470 ohm, ½ watt
R_5	47,000 ohm, ½ watt
R_6	33,000 ohm, ½ watt
T	Microphone to grid transformer

12AT7. Pins 3 and 8 should connect to the H and V deflection amplifiers in the oscilloscope, and the oscilloscope common connection should be made to the chassis.

First connect lead **M** to terminal A on the phase-shift unit, and lead **N** to terminal A′. Connect leads 1 and 2 to terminal **M.** (Note that the dashed connections are missing at this stage of adjustment.) Adjust the horizontal and vertical gains on the oscilloscope to produce a line about 1½ inches long slanted at 45 degrees when the oscillator is set to a frequency of 490 CPS (an exact method of setting frequency will be described later). If the oscilloscope has negligible internal phase shift the display will be a straight line instead of a narrow slanting ellipse. If the latter display appears it is necessary to correct the oscilloscope phase shift externally by using an adjustable series resistance (a 50,000 ohm potentiometer) mounted at either the vertical or horizontal input terminal, depending on what correction is necessary.

At any rate, the objective here is to get a single straight line at 490 CPS. In some cases a series capacitor may be needed to provide the necessary correction. Try values from 0.05 to 0.0005 mf. Now shift lead 1 from terminal A to terminal B on the phase shifter. Adjust the trimmer of C_7 to obtain a circle on the oscilloscope. It will be noted that as this adjustment is made the display will shift from an ellipse "leaning" to one side through a circle or ellipse (with axes parallel to the deflection axes) to an ellipse which leans the other way. If desired or necessary, the appropriate gain control on the oscilloscope may be changed so that a circle instead of a "right" ellipse is obtained at the point of correct adjustment. After changing the gain control on the oscilloscope, check (and correct, if necessary) the phase shift in the oscilloscope by moving lead 1 back to terminal A, and then repeat the setting of C_7 with lead 1 back on terminal B.

In general, always make certain that the oscilloscope is used in a phase-corrected manner. As a double-check (if the deflection plates in the oscilloscope are skewed, for instance) connect lead 2 to terminal A′. If the circle changes to a slanting ellipse, readjust C_7 to produce an ellipse "half-way" between the ellipse (obtained by switching lead 2) and a circle. Changing lead 2 from A′ to A and back again should give equal and opposite skew to the display when C_7 is set correctly. Failure to get symmetrical ellipses (egg-shaped, or other display) is due to distortion, either in the oscilloscope, the oscillator, the transformer, or the cathode follower. Conduct the test at as low a signal level as possible to avoid distortion.

Next connect leads **M** and **N** to terminals E and E′, respectively. Connect leads 1 and 2 to E, set the oscillator frequency to 1960 CPS, correct oscilloscope phase shift as before, and move lead 1 to terminal G. Adjust C_{10} for a circle as was done for C_7, using the precautions outlined for that case.

Now connect lead **M** to terminal D, and lead **N** to terminal F. Connect leads 1 and 2 to terminal D, set the oscillator frequency at 1307 CPS, correct oscilloscope phase shift as before, and move lead 1 to the junction of R_9 and C_9. Adjust C_9 for a circle on the oscilloscope, as before.

Repeat the above procedure for the remaining R-C pair, R_8 and C_8. Use terminals D and C this time and set the oscillator for 326.7 CPS. This completes except for a final check the adjustment of the phase-shift network. Connect A to A′, E to E′, B to C, F to G, and A to E. Be certain to remove the temporary short circuiting connections between the 12AT7 plates and T_2, T_3.

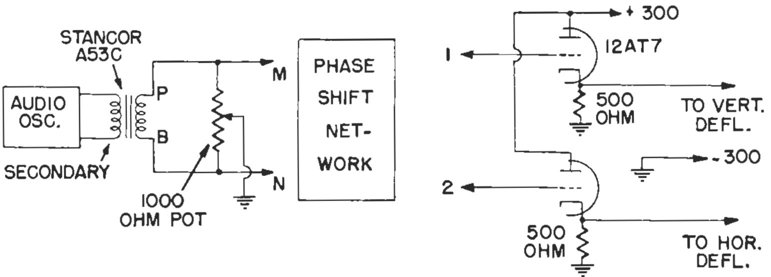


Fig. 9. Audio phase-shift network test layout

If the oscilloscope did not require changes in external compensation over the four frequencies used an over-all frequency check can now be made easily on the phase-shift network. To do this, connect lead 1 to point B, C, lead 2 to point F, G, lead M to point A, A′, E, E′, and lead N to point D. Now shift the arm of the potentiometer toward M until a circle appears on the oscilloscope screen at a frequency of 250 CPS. Then, as the oscillator frequency is varied from 250 CPS to 2500 CPS, this circle will wobble a little from one side to the other, passing through a perfect circular display at 440, 1225 and 2500 CPS.

The audio band over which the wobble indicates a plus or minus 1.3 degree deviation from 90 degrees is 225 to 2750 CPS, or 12 to 1 in range. This means that when other circuits are properly adjusted, a sideband suppression ratio of 39 db is possible at the *worst* points within this range. The average suppression ratio will be about 45 db. Proper phase-shift network operation is necessary to obtain this class of performance, so the adjustment procedures have been explained in great detail as an aid toward this goal. The phase shift network should never require readjustment, so that when you are satisfied with the adjustment you may seal the trimmers with cement.

Audio Oscillator Calibration

It will be noted that the frequency ratios are such that the 12th harmonic of 326.7 CPS, the 8th harmonic of 490 CPS and the 3rd harmonic of 1306.7 CPS are all the same as the 2nd harmonic of 1960 CPS, namely, 3920 CPS. Thus, if a stable source of 3920 CPS frequency (such as a thoroughly warm audio oscillator) be used as a reference, the frequency of the test oscillator can be set very closely to one-half, one-third, etc., of this reference frequency if both oscillators feed an oscilloscope and the resulting Lissajous figures observed.

Use of a calibrating frequency in this manner assures that the frequency *ratios* used are correct, even though the exact frequencies used are unknown. The frequency ratios (just as the resistance ratio previously mentioned) are far more important than the actual values of frequency (or resistance) used.

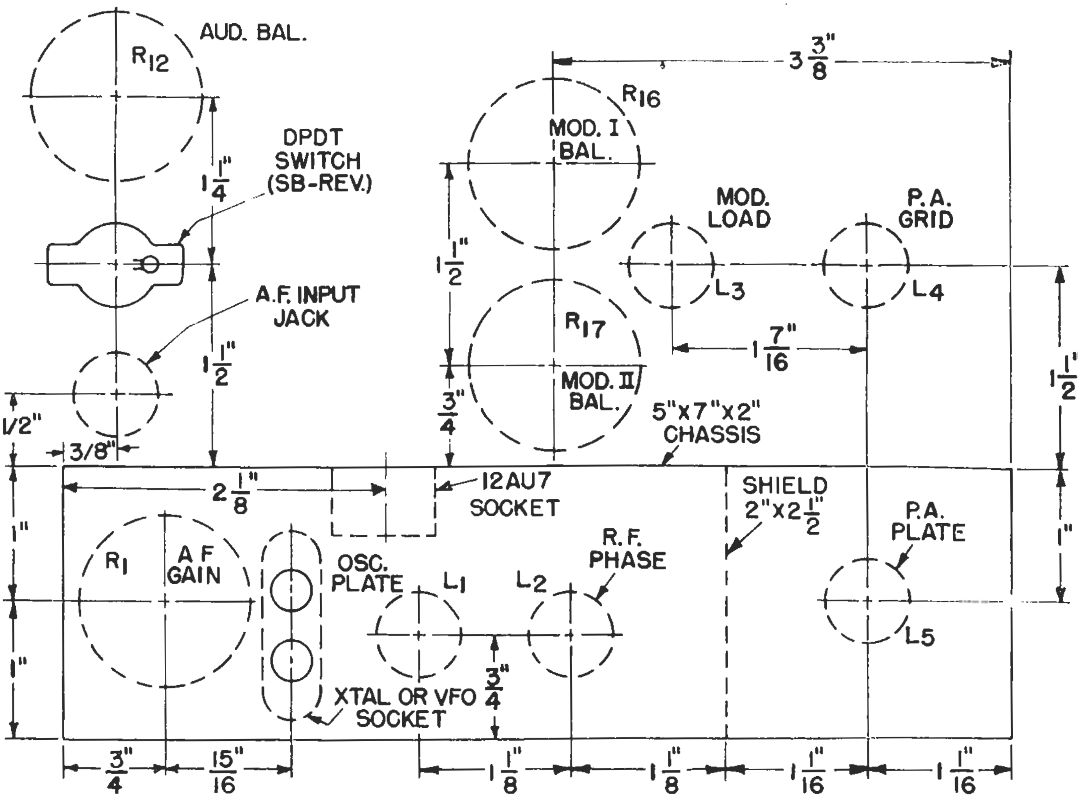


Fig. 10. SSB Jr. panel layout (front view)

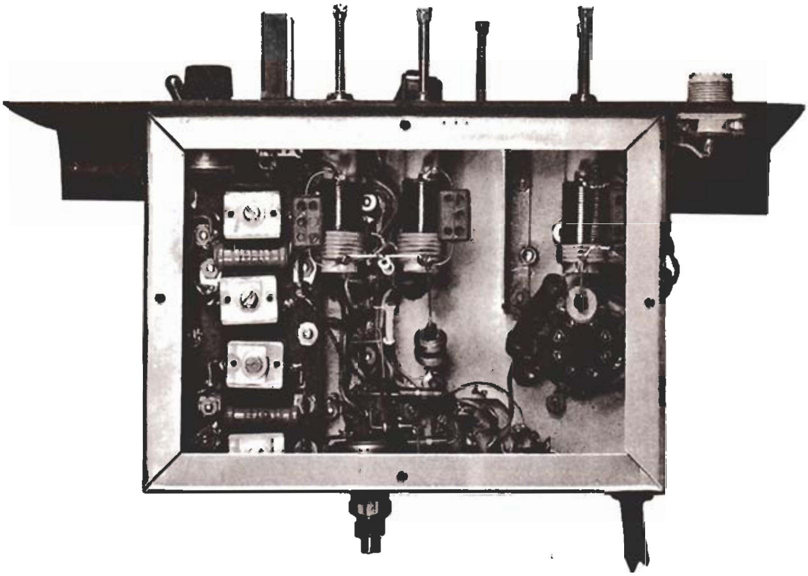


Fig. 11. Under-chassis view of the SSB Jr.

Transmitter Adjustment

Install the phase-shift network in the chassis, remove the 6AG7 output tube, plug in a crystal (3850 to 4000 KC) or supply a signal to the crystal socket from a VFO at not less than a 10 volt (RMS) level, set L_1 and L_2 for minimum inductance (slug out, counterclockwise) and apply power. The current drain should be about 35 to 40 MA at 300 volts under this condition with the oscillator operating. If the current drain is over 45 MA, turn off the B+ power, adjust L_1, reapply power, etc., until the crystal oscillates. This may be checked by means of a receiver tuned to the crystal frequency. Continue to advance the slug in L_1 with the crystal operating until oscillation ceases. Then back the slug out a few turns to assure stable crystal operation. For VFO input simply adjust L_1 for minimum total current.

Apply an audio signal of 1225 CPS to the input jack of the exciter and connect the horizontal deflection of the oscilloscope to a cathode (pin 3) of the 12AT7, and the vertical deflection to the other cathode (pin 8) after making certain that the oscilloscope is phase-compensated at the frequency of 1225 CPS. Adjust R_3 to produce a circle on the screen. Adjust R_{12} to about mid-range. This test should be made at a reasonably low audio signal level (in general, the lower the better).

Now plug in the 6AG7, after checking to see that a bias of about 10½ volts is supplied. Connect the output link on L_5 to the vertical plates of the oscilloscope (no amplifier used). Deliberately unbalance one of the modulators by setting R_{16} appreciably off-center. Adjust L_5 for maximum vertical deflection at any convenient sweep speed. This deflection may be small at first since other circuits are not yet tuned. Adjust L_3 for further increase of deflection (maximize), and then finally tune L_4 for maximum output. As this tuning is done it may be necessary to reduce the modulator unbalance to keep from overloading the output stage. Check the tuning again on L_5, L_3, and L_4, in that order. Next remove all audio input by turning R_1 to zero, and, by successive alternate adjustments of R_{16} and R_{17}, balance the modulators for zero output as seen on the oscilloscope. It will be noted that as the correct points are reached the minimum point becomes successively sharper on each control.

Next apply some 1225 CPS audio tone to the exciter by advancing R_1. Undoubtedly some RF envelope will be seen. Adjust L_2 (the RF phase control) in such a direction as to reduce the "modulation" appearing on the output. Remove the tone, check modulator balance (R_{16} and R_{17}), and repeat the adjustment of L_2. The crystal (if used) may stop oscillation during this operation due to interaction between L_2 and L_1 tuning. If so, back out the slug on L_1 until stable crystal operation is obtained. With the 1225 CPS audio signal still applied continue to adjust L_2 for minimum "modulation" or ripple on the envelope, checking modulator balance periodically. When a minimum point is reached, adjust R_{12} to still further reduce this ripple, then adjust L_2 for more reduction, etc. until a substantially ripple-free display is seen.

With L_2 tuned it is now time to check the r-f voltages applied to the modulators. Temporarily remove the audio tone and connect the vertical deflection plate of the oscilloscope to the arm of R_{16}. Always keep the common connection of the oscilloscope grounded to chassis. Note the deflection and then check the voltage on the arm of R_{17} in a similar manner. If this is appreciably lower than the first voltage (on the arm of R_{16}) more coupling capacity (C_6) is necessary between L_1 and L_2.

Usually very little capacity is required, and this can be provided conveniently by making a condenser of two pieces of insulated wire twisted together for half an inch or so. Adjust the amount of capacity by clipping off a little bit at a time to approximately equalize the RF signals appearing on the arms of R_{16} and R_{17}. (Note: check both voltages after each adjustment of capacity, since both voltages will change.) Connect the oscilloscope to read r-f output from L_5 as before, and then check modulator balance. Apply the 1225 CPS tone and make whatever slight adjustment is necessary in L_2 tuning to obtain the ripple-free display obtained before the coupling capacitor (if necessary) was installed. Remove the audio tone and check modulator balance (R_{16} and R_{17}). This completes the adjustment of **SSB**, Jr. A dummy load may now be connected, or the output used to drive a high power *linear* amplifier.

Operating Information

Note that when changing frequency, L_1, L_2, L_3, L_4 and L_5 should be readjusted, since these circuits constitute the tuning adjustments of the rig. The principal effect of mistuning L_3, L_4, and L_5 will be lower output or efficiency. *The principal effect of mistuning L_2 will be degraded sideband suppression. It is quite important, therefore, to adjust L_2 very carefully.* It may be noticed that when large audio signals are applied, the envelope develops some ripple. There are two possible causes for this action. The first is carrier unbalance (carrier shift), and the other is harmonic distortion in the audio circuits. (It is assumed that a pure sine wave of 1225 CPS is used as the input signal.) One may isolate these two effects by setting carrier balance at high-level audio operation (where these effects generally are most pronounced) to reduce the "ripple." With the carrier ripple (which is easily identified when the carrier balance controls R_{16} and R_{17} are moved) balanced out, adjust L_2 slightly (in conjunction with R_{12}) for minimum envelope ripple. The remaining ripple should be less than 5% of the display and is most probably caused by audio distortion, either in the audio source or in the audio system of the transmitter. In observing ripple, the oscilloscope should be synchronized from the 1225 CPS audio signal at a frequency of about 122.5 CPS to show ten cycles or so of carrier ripple. Unwanted sideband ripple will show twice as many peaks, and so will second harmonic audio distortion. Third harmonic audio distortion will show three times as many peaks, etc. Of course, all these distortions (and maladjustments) may occur simultaneously, so a little care and thought is advised. In the sample SSB Jrs. tested, third harmonic audio distortion is the principal component, and is easily identified at high levels.

When feeding a load the total input current will rise to about 80 MA at full level with a single tone input. With speech input the current will rise syllabically from a resting value of about 60 MA to around 70 MA, depending on the waveform. Always use an oscilloscope to determine maximum operating levels. Overload will cause degradation of the sideband suppression, and so is to be avoided. Sideband cancellation adjustments performed at about half peak level are probably the most reliable ones. Carrier balance is best made with little or no audio input. Peak level is the audio signal level which causes flattening of the peaks due to amplifier overload. A higher input level can be used when working into a load, but the overload condition should be avoided while making adjustments and later, too, when operating the rig.

The sideband selector switch is used to control which sideband (upper or lower) is generated. Find out which switch position corresponds to upper sideband by tuning the exciter output signal on a receiver with its BFO supplying carrier. Conduct a talk test and tune the receiver for normal speech output. Then tune the receiver to a slightly *lower* frequency. If the voice pitch *rises*, the upper sideband is being generated. Identify switch positions accordingly.

It takes about 15 minutes from a "cold" start to make all the adjustments described here after a little experience is gained. Do not be frightened away from single-sideband because of a lengthy description of the adjustment procedure, since the adjustments are simple to do, and you will find that the description is actually very detailed and complete. Another reason for not being frightened away from single-sideband is that extremely modest equipment affords the most reliable 'phone communication yet developed.

NOTES ON THE DESIGN OF THE SSB, JR.

> Because the **SSB** Jr. rig design is made possible by a new type of phase-shift network, and a new style modulator, it seemed desirable to have the designer, W2KUJ, explain these units in further detail for the benefit of the technically minded readers of *Ham News*.—Lighthouse Larry

The **SSB** Jr. is a superbly simple rig. Such things just don't happen by accident, however. Throughout the design many new ideas were employed to save space and reduce complication while not sacrificing performance in any way. Easy adjustment for optimum performance was a foremost point of design.

The phase-shift network is an example of simplification of this sort. Literally hundreds of laborious calculations were made along the way to the final solution. The result is a better performing network that has only eight parts and is really very easy to adjust properly. Two methods of adjustment are possible. The first (and preferred one) has already been explained in detail. The other one is obvious. Merely put in accurately measured values and call the job done. The problem here is to obtain the accuracy needed (absolute accuracy) since standards of resistance and capacity are obviously of a different nature. By making adjustments which involve both resistance and capacitance values simultaneously in conjunction with a single reference frequency, almost all sources of error are eliminated. And that is why the preferred method is preferred. All this accuracy is wasted, however, if the components used are not stable enough to hold their values after selection. This is why precision resistors are specified, and why only a small range of adjustment is provided by the trimmer capacitors, since the trimmers are the most likely circuit elements to change. In this way good stability is obtained.

A word about operating conditions necessary for the phase-shift networks. The outputs must feed very high impedance circuits. The effective source impedance should be low, and the voltage supplied to A,E must be *minus* 0.2857 times the voltage supplied to D. Incidentally, the voltage output of each section is equal to the voltage at A,E from zero frequency to a matter of megacycles. The design center frequency for the two networks (yes, there are actually two) is 800 CPS. The differential phase-shift versus frequency curve is symmetrical about this point and holds to within 1.3 degrees from 225 CPS to 2750 CPS, as indicated in Fig. 12. A slight error in setting the reference frequency (3960 CPS) will result only in shifting this band up or down by the same percentage. The operating band is adequate—even desirable for voice communication. One need not fear reports of poor quality when using this rig.

Another simplification which deserves comment is the balanced modulator used in **SSB** Jr. Let's take a few moments to consider what takes place in the circuit. Fig. 13 shows just one modulator consisting of two germanium diodes, G_1 and G_2 with associated circuits. First, suppose a high frequency signal of a few volts is applied at point R. On the positive crest of signal, current passes through G_2 into the center tapped resonant circuit and tends to pull point S in the same direction. Point T naturally tends to go negative because of the phase inverting properties of the resonant circuit, but, of course, no current flows through G_1. One half cycle later current passes through G from the source, tending to pull point T in the negative direction. But at this time point T would be at a positive potential because of the "inertia" of the resonant circuit. The net result of the battle between G_1 and G_2 to cause current to flow in the resonant circuit is a draw. No net voltage appears across this circuit at the source frequency and energy is dissipated in the balancing resistor and in G_1 and G_2. Thus far, we have currents in the resonant circuit, but none at its operating frequency. This seems like a long way to go to get nothing, but wait.

Now, let us imagine a bias applied at U. If the voltage at U is positive, G_2 will pass more current into the resonant circuit, and G_1 will pass less current. This, in effect, unbalances the circuit and a radio frequency voltage will appear across the resonant circuit, with point S in phase with the voltage at R. If the bias voltage at U is negative, G_1 passes more current than G_2, and the circuit is unbalanced in the other direction. Under this condition the voltage at T will be in phase with that at R. Obviously, if the voltage at U is an audio frequency voltage, the circuit is unbalanced in one direction or the other (at an audio frequency rate) and the resulting radio frequency voltage across the resonant circuit is actually two sets of sidebands with no carrier. When another pair of diodes (such as G_3 and G_4 of Fig. 2) is connected to feed currents into the resonant circuit from related audio frequency and radio frequency sources respectively 90° out of phase with the first, sideband currents caused by these signals flow through the resonant circuit in such a manner as to reinforce one set of sidebands and to cancel the other set. The result is a single-sideband suppressed carrier signal. In the case of **SSB** Jr., it is a really high grade one.

The function of the balancing resistors (R_{16} and R_{17} of Fig. 2) is to equalize minor differences in the characteristics of the diodes and to balance out stray couplings. Thus, any one balanced modulator is not necessarily perfectly balanced, but the action of two such modulators fed with polyphase signals allows a complete composite balance.

What about operating **SSB** Jr. in other amateur bands or at other frequencies, in general? As described, the radio frequency circuit design is for the 75 meter band, 3850 to 4000 KC. There is no reason, however, to think that equally successful performance would not be obtained on 20 or 10, or even on what is left of 160. It's simply a matter of coil design.

The unit pictured in this issue of ***Ham News*** was the second one ever built. Ten minutes after the last solder joint had cooled down, the rig was perfectly adjusted and was delivering 5 watts peak power to a 75 ohm dummy load—and I followed the adjustment procedures described in the article. Maybe it will take some people a little longer to read the instructions than it did for me (after all, I wrote them), but 1, 2, 3 procedure really does the job. I didn't peek ahead in the instructions, either.

If you get one-tenth the fun out of building and operating **SSB** Jr. as I did in designing, building and using it, you are in for the most enjoyment you have ever had in ham radio.—W2KUJ

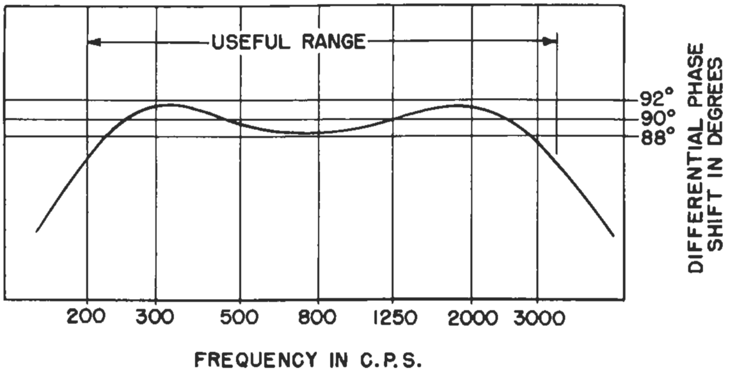


Fig. 12. Audio phase-shift network performance

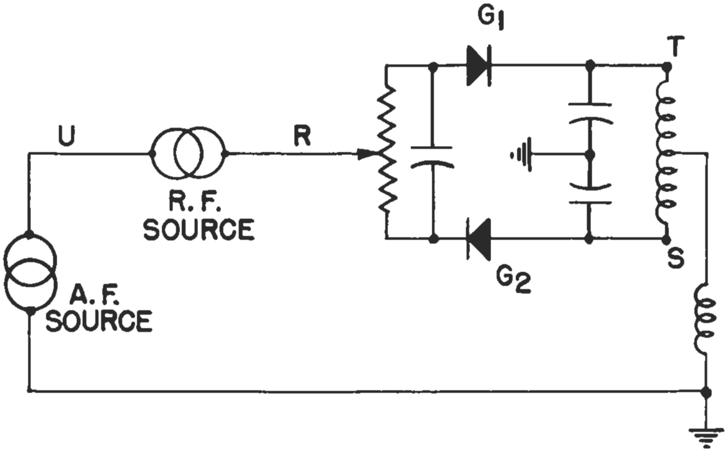


Fig. 13. SSB Jr. modulator circuit

USING THE SSB, JR. ON OTHER BANDS

The G-E HAM NEWS SSB, Jr., may be operated on other than the original design frequency by one of two methods. First, a separate set of circuit constants may be plugged or switched into the circuit for each amateur band to be covered. Second, the SSB, Jr., may be placed on a fixed frequency outside the amateur bands, then hetrodyned to the desired output frequency in a mixer stage that also is drivennby a stable oscillator having the appropriate frequency range. A low-level mixer is preferred and may be driven directly from the diode balance modulator, instead of through the 6AG7 stage.

Operation on 50 megacycles is possible by either running the SSB, Jr., directly on that band, or by using single or double conversion. When hetrodyning, the precautions outlined in the November-December, 1956 (Vol. 11, No. 6) issue of G-E HAM NEWS should be followed.

The SSB, Jr. can be placed directly on 50 megacycles by scaling down capacitors C_5, C_{11}, C_{17}, C_{18}, C_{20} and C_{21} by the ratio of frequencies involved, or 4/50 of the original values. The corresponding coils L_1 to L_5 will then have to be reduced in inductance until the circuits tune to resonance at 50 megacycles. The correct value for C_5, C_{11} and C_{17} is 10 mmf; C_{13}, 20 mmf; and C_{20} and C_{21}, 150 mmf. These values allow for the tube and stray circuit capacities that assume a large proportion of the total capacity at this frequency. Inductance L_1 to L_5 should be adjusted experimentally until all circuits tune to 50 megacycles.

A simpler method is to leave the SSB, Jr. on its fixed 4-megacycle frequency and feed the output into a frequency mixer, with 46 or 54 megacycles as the beating frequency. It will be necessary to use a double-tuned output circuit, such as used in an IF transformer, and tune traps to the 46 or 54-megacycle frequencies to prevent these from also showing up in the mixer output.

Another method is to place the SSB, Jr. on 9 megacycles, also by scaling down the capacitors and coils mentioned above, and use a 41 or 59 megacycle beating frequency in the mixer. This system will have lower spurious output than the previous one.

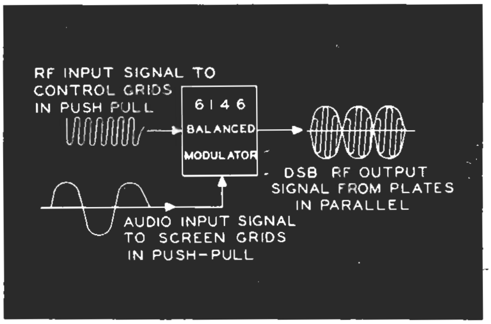
Circuit constants for 9 megacyles are given below:

These specifications apply to coils wound on the same forms used in the original model, Millen No. 69046, with iron tuning slugs. They are 1/2-inch diameter and have a winding length of 1-1/8 inches. Coil L_2 has the most critical adjustment, as it is the 180 degree RF phase shift network and will have to be retuned each time a shift of more than 5 kilocycles is made in the 9-megacycle frequency.

C_5 - 110 mmf.	L_1 - 19 turns No. 20 enameled wire spacewound 1 inch long. (2.8 uh)
C_{11} - 110 mmf.	L_2 - same as L
C_{20} - 880 mmf. C_{21} - 880 mmf.	L_3 - 9 turns No. 20 enameled wire spacewound 1-1/8 inches long. (0.6 uh)
C_{17} - 110 mmf.	L_4 - 17 turns No. 20 enameled wire spacewound 1 inch long. (2.4 uh)
C_{18} - 150 mmf.	L_5 - 14 turns No. 20 enameled wire spacewound 1 inch long. (1.75 uh)

From May-June, 1959 **ELECTRONICS**

200-WATT DOUBLE SIDEBANDER



Our DOUBLE SIDEBAND JUNIOR article a year ago sparked much interest in a more powerful double sideband transmitter with bandswitching. Now several radio amateurs at General Electric have combined their ideas in this transmitter with 200-watt peak power input capability from a pair of 6146 beam pentodes in the output stage. The complete circuit, and constructional details on the plug-in r.f. unit, is in this issue. Part II, in the July–August, 1959 issue, describes the main chassis containing audio system, power supplies and control circuits.

200-WATT
DOUBLE SIDEBANDER

Part I

***THIS DOUBLE SIDEBAND** transmitter is packed with ingenious circuits and construction features. Try them!*

THE DOUBLE SIDEBANDER was designed specifically for this mode of transmission; and, in fact, was a prototype for military double sideband and synchronous communications equipment. The frequency coverage is continuous from 2 to 30 megacycles in four bands. It has a peak power output, with sine-wave modulation, of 150 and 120 watts at 2 and 30 megacycles, respectively.

THE R.F. SECTION of the transmitter—a separately shielded and filtered unit—employs an oscillator-driver-final circuit arrangement as shown in the schematic diagram, FIG. 1. All transmitter stages are provided with protective bias to prevent damage to the tubes in the absence of excitation. In the oscillator and driver stages cathode self-bias give the necessary protection. The final stage protective circuit removes its high voltage if the r.f. drive fails.

Switch $S1_A$ in the grid circuit of the 6AH6 oscillator stage provides selection of one of the four crystals or the V.F.O. input as the frequency source. With $S1_A$ in the V.F.O. position the 6AH6 is employed as a Class A amplifier. An input from a V.F.O. of 0.5 to 1 volt r.m.s. will excite the driver stage.

All frequency multiplying is accomplished in the oscillator and the 6CL6 driver always operates as a straight amplifier. Since the pi network in the 6146 balanced modulator plate acts as a low-pass filter, sub-harmonics of the carrier frequency may appear in the transmitter output if the driver stage is operated as a frequency multiplier.

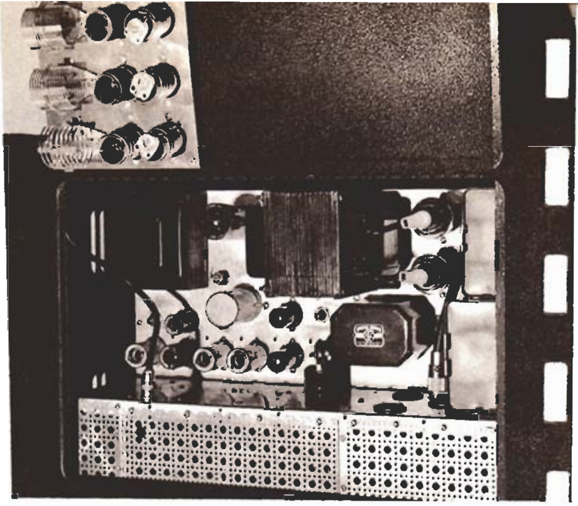
Careful circuit layout and complete r.f. bypassing stabilize the driver stage. The 15,000-ohm, 4-watt potentiometer ("PA GRID DRIVE") adjusts the 6CL6 screen voltage and, in turn, its r.f. power output.

The 6146 balanced modulator stage has the usual push-pull control grids, push-pull screen grids and paralleled plates described in several previous double sideband transmitter articles.[1] The pi-network plate circuit is designed for a 50-ohm output, but will load into impedances up to 300 ohms.

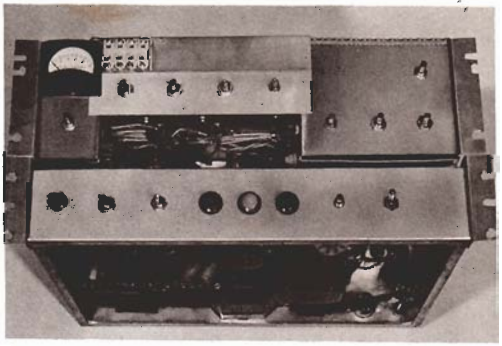
THE MODULATOR SECTION is designed for use with a low-level, high-impedance microphone (crystal, ceramic or dynamic). Low impedance microphones will require a matching transformer. The preamplifier stage (V_7) has a push-to-talk feature that cuts off the second section until closing the microphone switch greatly reduces the cathode bias. A twin diode tube (V_9) serves as an audio peak clipper. The next tube (V_8) is a matching device for the maxially-flat (Butterworth) L/C 3,000-cycle low-pass filter.

A 400-cycle phase-shift R/C sine wave oscillator (V_{10B}) and a split-load phase audio phase inverter (V_{10A}) precede the push-pull driver (V_{11}). The modulator tube (V_{12}) provides about 300 volts peak on each screen grid of the 6146 balanced modulator stage. About 8 decibels of inverse feedback in the driver and modulator stages improves balance and linearity in the 6146 stage.

(continued on page 6)



THE TRANSMITTER CABINET with the top lid open, showing the shielded r.f. compartment in the front, audio section in the middle and power supplied at the rear. Note the method of storing spare plug-in coils on an aluminum plate, on which 4 and 5-pin sockets have been mounted. Coils are changed in the exciter simply by removing four self-tapping screws which hold the shield at left-center in place.



FRONT VIEW OF THE TRANSMITTER with cabinet and panel removed. The separate chassis containing the r.f. and metering section plugs into the main chassis, containing the remaining circuits.

---

[1] See G-E HAM NEWS, March - April, 1959, for a bibliography of articles on double sideband techniques.

PARTS LIST—200 WATT DOUBLE SIDEBANDER

C_1	150-mmf mica, 500-volt rating.
C_2	10-mmf mica, 500 volt (change value if crystal is erratic).
C_3	500-volt, 10 percent mica mounted in L_1; (See coil table for values).
C_4	3—30-mmf midget ceramic trimmers mounted on L_1.
C_5	6—142-mmf variable, 0.020-inch air gap (Hammarlund HFA-140-A).
C_6	6—142-mmf per section, 2-section variable (Hammarlund HFD-140).
C_7	10—200-mmf variable, 0.024-inch air gap (Hammarlund MC-200-M).
C_8	0.001-mfd, 2500-volt mica (0.001-mfd, 5000-volt ceramic also suitable).
C_9	13.5—325-mmf air variable, 0.24-inch air gap (Hammarlund MC-325-M).
C_{10}	82-mmf, 500-volt mica (Change value to suit audio response).
C_{11}	0.0018-mfd, 500-volt mica (Value determines cutoff frequency of filter).
C_{12}	620-mmf, 500-volt mica (Value determines cutoff freqeuncy of filter).
C_{13}, C_{14}	8-mfd, 1500-volt oil-filled paper capacitors.
F_1, F_2	5-ampere type AGC fuses ond holders.
I_1	6.3-volt pilot lamp and jeweled bracket.
I_2	115-volt pilot lamp and jeweled bracket.
J_1, J_2	chassis type coaxial cable connectors (SO-239).
J_3	chassis type 2-pin recessed mole power connector.
J_4	chassis type 8-pin male power connector (Jones P-308-AB).
J_5	chossis type 2-pin female microphone connector (Amphenol 80-PC2F).
K_1	2-pole, 2 position sensitive relay, 2-ampere contacts, 10,000-ohm coil with 3- to 5-ma energizing current (Potter & Brumfield LM-11 or KCP-11).
K_2	2-pole, 2-position power relay, 5-ampere contacts, 115-volt, 60-cycle coil.
L_7, L_9	10 henry, 175-milliampere smoothing filter choke.
L_8	5—25 henry, 175-milliampere swinging filter choke.
L_{10}	3 henry, iron core inductance (toroidal type core preferable).
M_1	0—1-milliampere panel meter, 2½ inches square (G.E. DW-71 or DW-91).
P_1	8-pin coble type female power connector (Jones S-308-CCT).
RFC_1, RFC_2, RFC_3, RFC_4	2.5-mh, 100-ma r.f. choke (Notional R-100).
RFC_5	2.5-mh, 300-ma r.f. choke (National R-300 or equivalent).
S_1	3-pole, 5-position, 2-section ceramic rotary top switch (Centralab 2515).
S_2	1-pole, 4-position, 1-section 90-degree ceramic-insulated rotary tap switch, (Centralab No. 2542 or equivalent).
S_3	1-pole, 10-position, 1-section, progressive shorting ceramic-insulated rotary tap switch (Centralab P1-S wafer and P-121 index assembly).
S_4	2-pole, 11-position, 2-section rotary tap switch (Centralab 1413).
S_5	3-pole, 3-position, 1-section rotary tap switch (Centralob 1407).
S_6	2-pole, 2-position, 1-section rotary tap switch (Centralab 3122J).
S_7	2-pole, 2-position heavy duty toggle switch.
T_1	audio driver transformer; turns ratio, primary to ½ secondary: 4 to 5. (Use primary of transformer as secondary in this application.)
T_2	filament transformer: secondary, 2.5 volts ot 5 amperes; 115-volt primary.
T_3	plate transformer: 2400 volts, center tapped at 150 ma; 115-volt primary.
T_4	power transformer: secondaries, 700 volts center tapped at 150 ma; 5 volts at 3 amperes; 6.3 volts at 6 amperes; 115-volt primary.

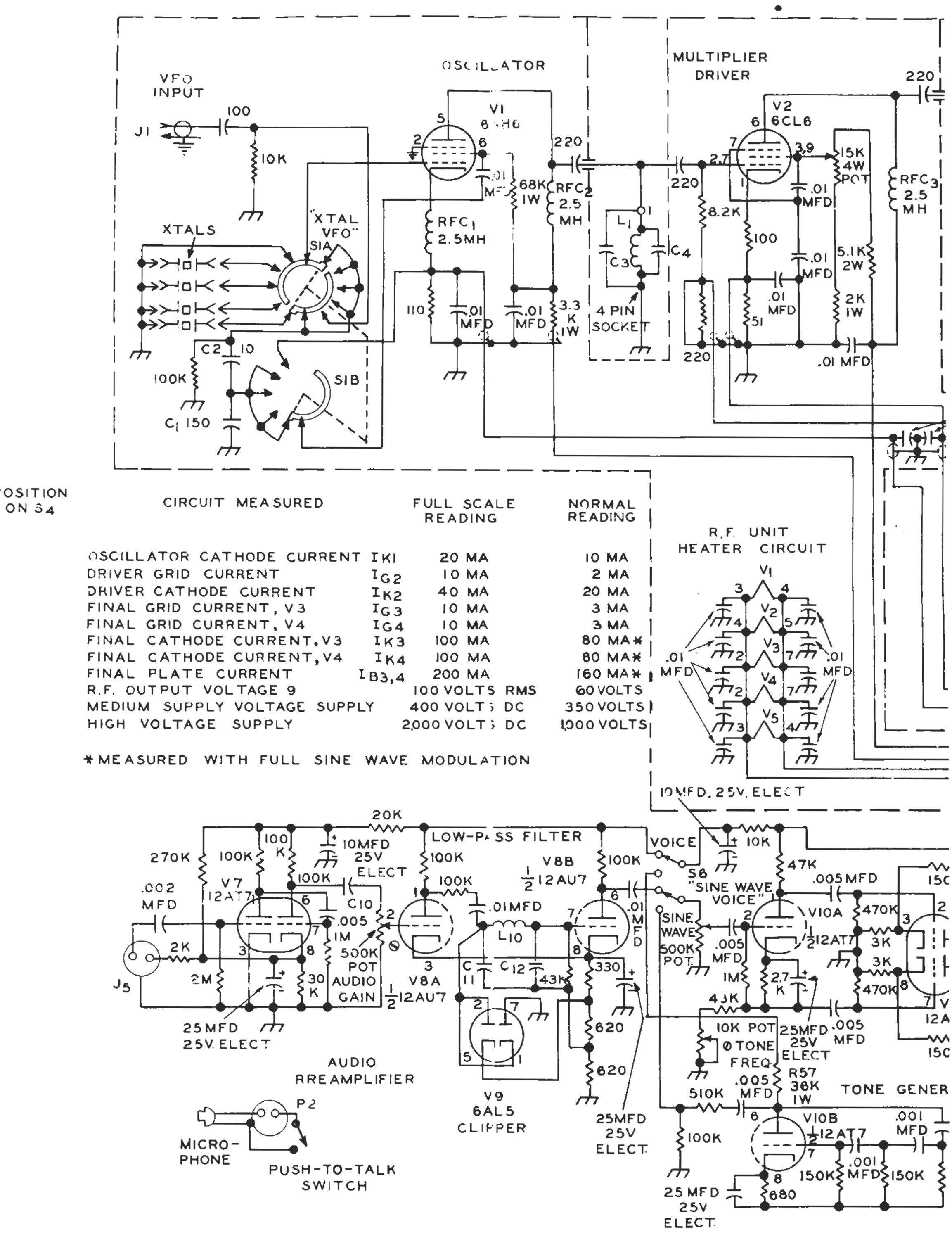
TABLE I—COIL WINDING DATA

NOTE: All coils are wound with tinned copper wire in the sizes specified below.

L_1	wound on 1-inch diometer, 4-pin plug-in forms. Winding length is 1 inch. Capacitors C_3 and C_4 are mounted inside eoch coil form.
L_2	wound on 1-inch diameter, 5-pin plug-in forms. Winding length is 1 inch. Link coil L_3 waund at graunded end of L_2 on each form.
L_4, L_5	B & W "Baby" inductors, center topped with center link coils, ond 5-pin base.
L_6	10.5 uh total, 28 turns 1½ inches in diameter, 4 inches long. Wound with 22 turns of No. 12 (7 turns per inch) and 6 turns of No. 10 (5 turns per inch) tinned copper wire, tapped at 6, 9 and 15 turns from the end with No. 10 wire.

	L_1 and L_2			L_2 Only		L_1	L_4 & L_5	L_3 Output Coil	
Band, MC	Ind., uh.	Turns	Wire Size	Turns, L_3	Wire Size	C_3 mmf.	B & W Number	Turns in Use	Ind., uh.
3.5	17.4	31	24	3	16	82	80MCL-2925	28	10.5
7	4.6	16	18	3	16	68	40MCL-2924	15	5
14	1.4	8	16	2	14	56	20MCL-2923	9	2.4
21[1]	0.75	6	16	—	—	39	——	—	—
28	0.45	4	14	2	14	27	10MCL-2921	6	1.3

[1] 28-megacycle coils tune to the 21-megacycle band. A separate 21-megacycle oscillator coil (L_1) is required only when crystals oscillating at this frequency, or a VFO having output at 21 megacycles, are used with transmitter.

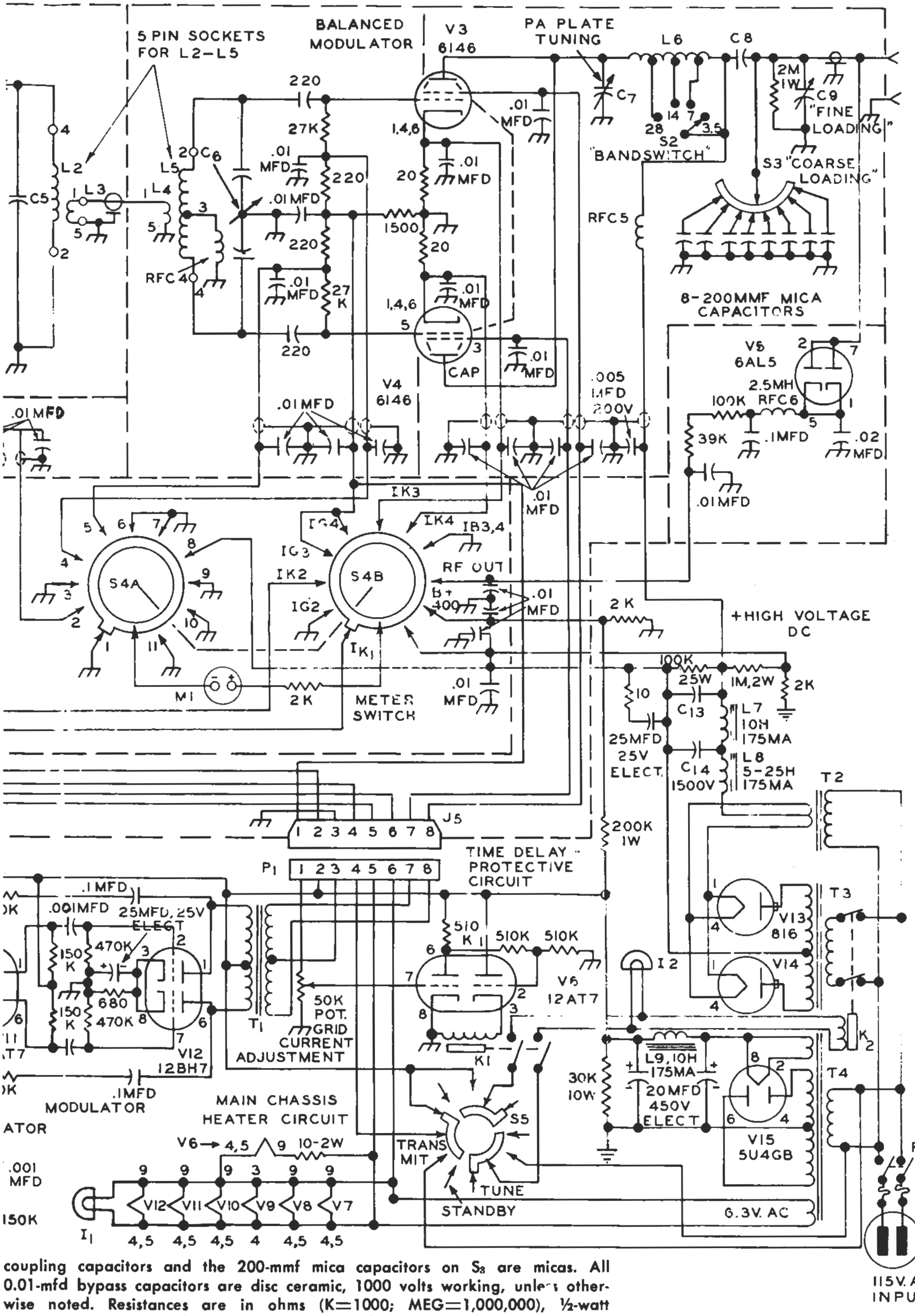


CIRCUIT MEASURED		FULL SCALE READING	NORMAL READING
OSCILLATOR CATHODE CURRENT	I_{K1}	20 MA	10 MA
DRIVER GRID CURRENT	I_{G2}	10 MA	2 MA
DRIVER CATHODE CURRENT	I_{K2}	40 MA	20 MA
FINAL GRID CURRENT, V3	I_{G3}	10 MA	3 MA
FINAL GRID CURRENT, V4	I_{G4}	10 MA	3 MA
FINAL CATHODE CURRENT, V3	I_{K3}	100 MA	80 MA*
FINAL CATHODE CURRENT, V4	I_{K4}	100 MA	80 MA*
FINAL PLATE CURRENT	$I_{B3,4}$	200 MA	160 MA*
R.F. OUTPUT VOLTAGE 9		100 VOLTS RMS	60 VOLTS
MEDIUM SUPPLY VOLTAGE SUPPLY		400 VOLTS DC	350 VOLTS
HIGH VOLTAGE SUPPLY		2,000 VOLTS DC	1,000 VOLTS

*MEASURED WITH FULL SINE WAVE MODULATION

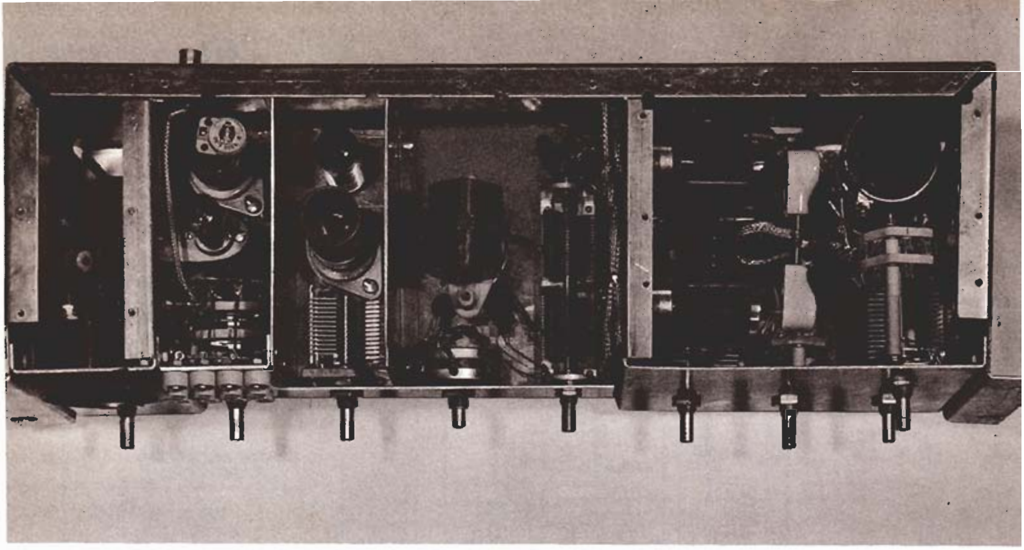
FIG. 1. COMPLETE SCHEMATIC DIAGRAM of the 200-watt double sideband transmitter. The r.f. circuit runs across the top of the diagram, with the meter switching circuit below it. The audio system is at the lower left and the power supplies at the lower right. The 12AT7 time delay-protective tube is just to the left of the power supplies.

All capacitances are in mmf, except where otherwise specified. All r.f.

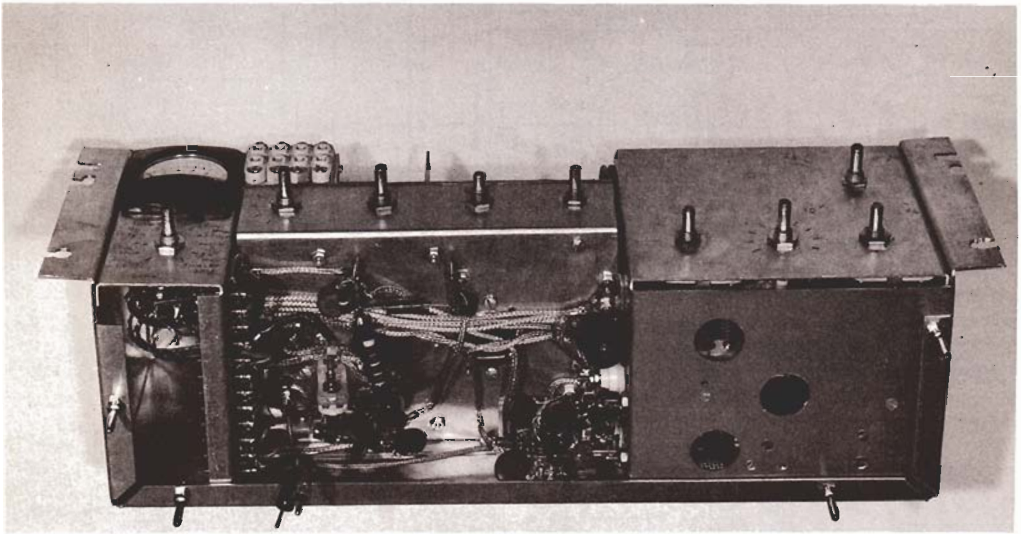


coupling capacitors and the 200-mmf mica capacitors on S_3 are micas. All 0.01-mfd bypass capacitors are disc ceramic, 1000 volts working, unless otherwise noted. Resistances are in ohms (K=1000; MEG=1,000,000), ½-watt power rating, unless a higher rating is specified.

Data for winding all the r.f. coils (L_1 to L_6) appears in the COIL TABLE below. The tube types for V_1 to V_{15} appear on the diagram. Shielded wires are indicated by dotted loops encircling the wire. Shielding around r.f. circuitry is shown in dashed lines.



TOP VIEW of the r.f. unit with shield covers removed. Note shielding partitions between stages and horizontal mounting of 6146 tubes on shield to isolate grid and plate circuits in the balanced modulator output stage. Main chassis is a 5¼-inch high panel chassis designed for relay rack mounting (Bud CB-1372, or equivalent.



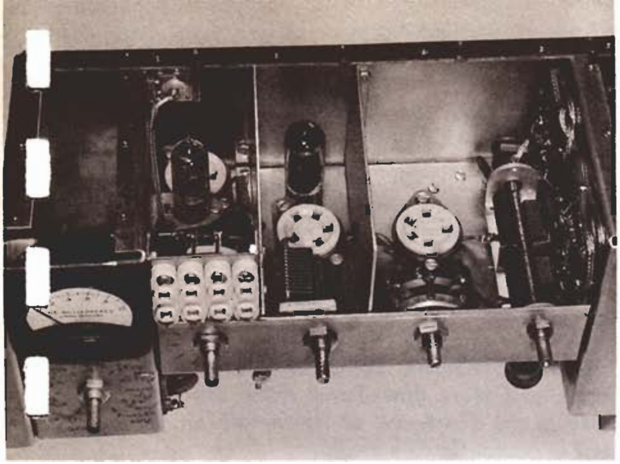
BOTTOM VIEW of the r.f. unit. The four banana plugs on the lower rim of the chassis plug into matching jacks on the main chassis. High voltage for the 6146's enters the r.f. unit via a Millen 37001 high voltage connector and the white feed-through insulator on the 6146 compartment shield. The phone-tip jack at the lower left is for plate voltage to the oscillator. Two phono plugs, connected to the row of feedthrough terminals on the meter compartment, are for the 400 and 2000-volt metering circuits. Note the liberal use of 0.01-mfd disc ceramics bypass capacitors and shielded wire for the power and metering circuits.

DOUBLE SIDEBANDER

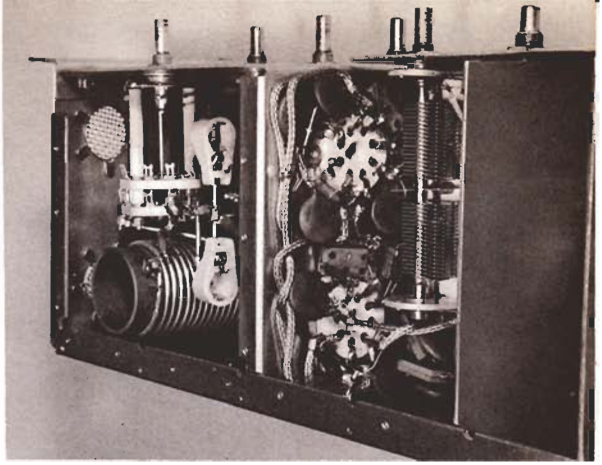
Both power supplies are of conventional design. The high voltage supply is rated at 1000 volts DC at 145 milliamperes; and the low voltage supply delivers 360 volts DC at 110 milliamperes, both continuous duty.

ADDITIONAL CIRCUITRY on the schematic diagram includes the power supply time delay and 6146 protective circuit. A 10-ohm resistor in series with the heater to this tube (V_6) increases its heating time. This prevents application of high voltage to the 816 mercury vapor rectifiers (V_{13} and. V_{14}) for 30 seconds and allows their filaments to reach operating temperature.

When no r.f. drive is applied to the 6146's the left-hand triode of V_6 has no negative bias and draws sufficient plate current through its 500,000-ohm plate resistor to nearly cut off plate current in the right-hand triode. Application of sufficient r.f. drive to the 6146's reduces plate current flow in the left-hand section of V_6. This swings the grid of the right-hand section more .positive, resulting in increased plate current flow which energizes relay K_1. This in turn energizes K_2, if S_5 is in the "TRANSMIT" position, and applies primary voltage to T_3.



DETAIL VIEW of the wiring around the 6146 balanced modulator tube sockets. The standard technique of bypassing the ends of shielded wire has been used. The 6146 plate caps were joined with No. 12 tinned wire, then connected with thin copper strips to the circuit components shown in the schematic diagram, FIG. 1.



EXCITER COMPARTMENTS in the r.f. unit. Plug-in coils have been removed to show the coil sockets mounted on metal pillars ¾ of an inch high. All partitions and shelves were fabricated from 1/16-inch thick soft sheet aluminum. The crystal sockets were mounted on a bracket drilled to match the socket holes.

METERING OF ELEVEN CIRCUITS in the transmitter is accomplished with a single 0–1-milliampere meter (M_1) and the meter switch (S_4). Switch positions—and the full-scale current or voltage reading in each position—are listed on the schematic diagram. The meter measures current by reading the voltage drop (2 volts for full-scale reading) across resistances in series with the various grid and cathode circuits.

Tube V_5 and its circuitry form a peak detector for measuring the r.f. output voltage of the transmitter. Since the meter reads 0.707 of the peak voltage, the average r.f. power output with sine-wave modulation can be calculated, if the transmitter is operated into a non-reactive load of known impedance.

MECHANICAL LAYOUT of the r.f. unit can be determined from the pictures and explanations accompanying them. Locations of the major components and approximate dimensions have been marked on each view. The usual modern r.f. construction practices have been followed: shielding, both over-all and between stages; shielded wire for all power and metering circuit connections; liberal use of bypass capacitors, etc.

Locations of the holes for the four banana plugs, shown in the bottom view, should be marked on the main chassis to insure proper alignment. Partitions and subchassis can be fastened in place with self-tapping screws; this is much easier than attempting assembly of nuts on machine screws in tight corners! The oscillator tube sits on a small angle bracket fastened to the partition between that stage and the metering compartment.

The oscillator plug-in coils (L_1) are assembled by first soldering two lengths of No. 14 tinned wire into pins 1 and 4 before winding the coil. Next the coil leads and C_3 are soldered to the wires. Finally, C_4 is soldered to the wires at the open end of the form.

TUNE-UP AND OPERATION will be described in this issue—since frequent reference is made to the schematic diagram—even though constructional details for the main chassis will be covered in the next issue. (In other words, we're tuning up the rig before you've finished building it—Ed.) The procedure is similar to any transmitter having class C amplifiers, with one exception: It is necessary to modulate the 6146 stage to obtain r.f. output.

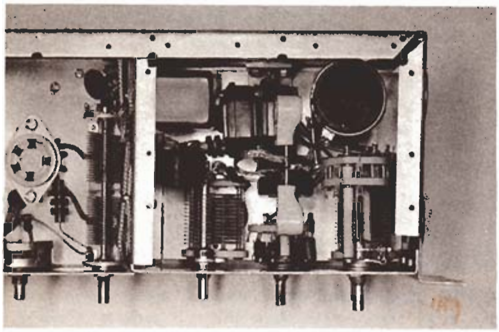
After the usual check to see that all circuits have been wired correctly, plug in the power cord, the set of coils for the desired amateur band and turn the pi-network bandswitch (S_2) to the same position. Insert a crystal of proper frequency, or connect a stable VFO to J_1 and turn S_1 to the proper position. Connect a microphone to J_5 and a 50-ohm dummy antenna load to J_2.

Turn S_7 to the "ON" position and S_5 to the "TUNE" position. With S_4 in position 2, tune C_4 (on the oscillator coil form) with a screwdriver until about 2 to 3 milliamperes of grid current is indicated in the driver stage. Detune this capacitor slightly if the grid current exceeds 4 milliamperes.

Next, turn S_4 to position 3 and tune C_5 for a dip in driver cathode current. Turn S_4 to positions 4 and 5, and adjust C_6 for maximum grid current in the 6146 balanced modulator. Adjust the "PA GRID DRIVE" control for a reading of 3 milliamperes in each 6146. Now, turn the "GRID CURRENT ADJUSTMENT" potentiometer until relays K_1 and K_2 energize, as indicated by I_2 lighting. Turn the "PA GRID DRIVE" control until the 6146 grid current decreases to 2 milliamperes and again adjust the "GRID CURRENT ADJUSTMENT" until K_1 and K_2 open. The 6146 protective circuit is now adjusted.

To tune up the 6146 balanced modulator, set S_4 on position 6, S_5 on "TRANSMIT"

200-Watt Double Sidebander—Part II



TOP VIEW of the 6146 compartment showing the positions of smaller components near the switches, capacitors and coils. The bandswitch, S_2, was modified by adding longer side rods and spacers to shorten the connections to L_6. This compartment was assembled before being fastened to the main r.f. chassis.

and S_6 on "SINE WAVE." Advance the "MOD. LEVEL" potentiometer (on main chassis) until the 6146 cathode current meter reading increases to 30 milliamperes. Tune C_7 for a dip in plate current. Turn S_4 to position 9 and adjust the "COARSE LOADING" (S_8) and "FINE LOADING" (C_9) controls for maximum output voltage on the meter. Readjust C_7 as necessary for maximum output.

Further advance the "MOD. LEVEL" control slowly to the setting at which little further increase in power output is indicated on the meter. Note this meter reading at which the balanced modulator begins to "flatten out." Next, turn S_6 to the "VOICE" position and adjust the "MOD. LEVEL" control, while talking or whistling into the microphone, until the *peak* output voltage reading on the meter reaches the maximum level noted with sine wave modulation.

Adjustment of the "AUDIO GAIN" and "CLIPPING LEVEL" controls is best made while listening to the transmitter signal, in addition to checking it for flattening of peaks on an oscilloscope. Too much clipping will introduce serious distortion. The "AUDIO GAIN" control setting will depend upon the sensitivity of the microphone and amount of room background noise in the shack.

CONSTRUCTIONAL DETAILS *of the main chassis, and more operational data, are contained in the conclusion of this article on the latest in communication media.*

The audio amplifier-modulator, control circuitry and power supplies for the 200-watt double sideband transmitter were constructed on a single 13 x 17 x 3-inch deep chassis (***Bud*** AC-4, or equivalent). If the constructor desires, the power supplies could be built on a separate chassis—say 6 x 17 x 3 inches in size and attached in back of a 7 x 17 x 3-inch chassis for the audio section, and base for the r.f. unit.

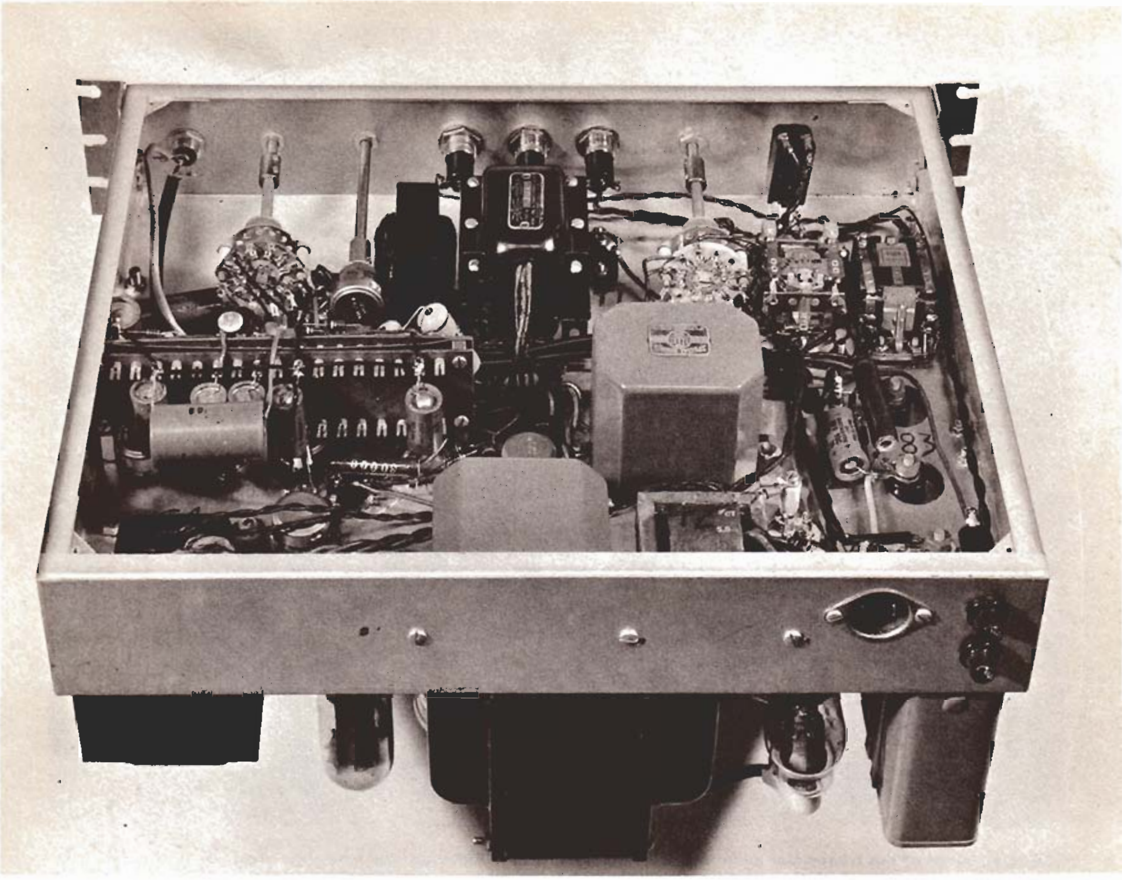
Or, some constructors may prefer to utilize separate power supplies already available. If so the standard 7 x 17 x 3 or 8 x 17 x 3-inch chassis sizes will suffice. Tubes V_6 and V_9 can then be moved over in line with the audio tubes, and the whole line of tubes extended into the area occupied by L_7.

Placement of major components on the main chassis is shown in the top and bottom views. No dimensions have been given, since the exact locations will depend on the sizes of the parts actually to be used in duplicating the transmitter. The same general configuration should be followed, since it has been found trouble-free.

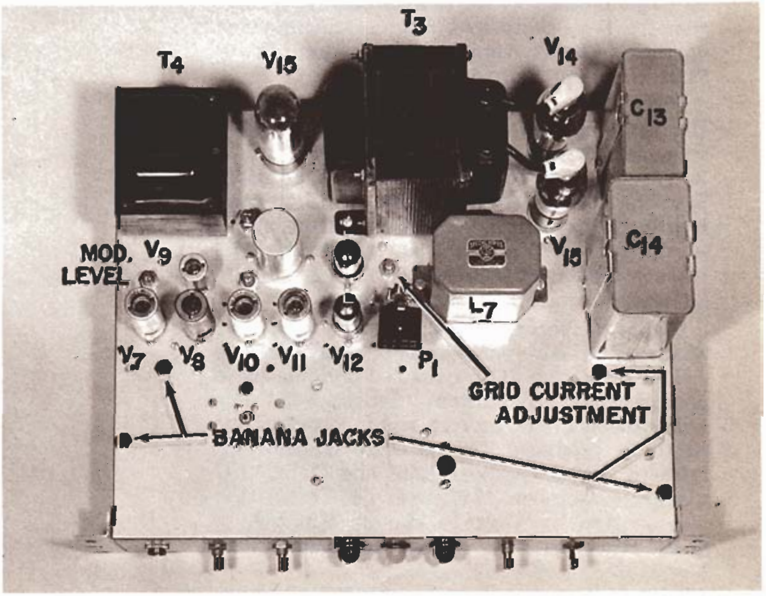
Both control relays (K_1 and K_2) were located at the right side under the chassis, near the main power switch (S_7), fuses (F_1 and F_2), and the AC power input connector (J_3), but some distance from the time delay—grid current interlock tube (V_6).

The panel controls and indicator lamps line up vertically with the control shafts on the r.f. unit—spaced 2 inches—as shown in the front view on page 3 of the May-June, 1959 issue.

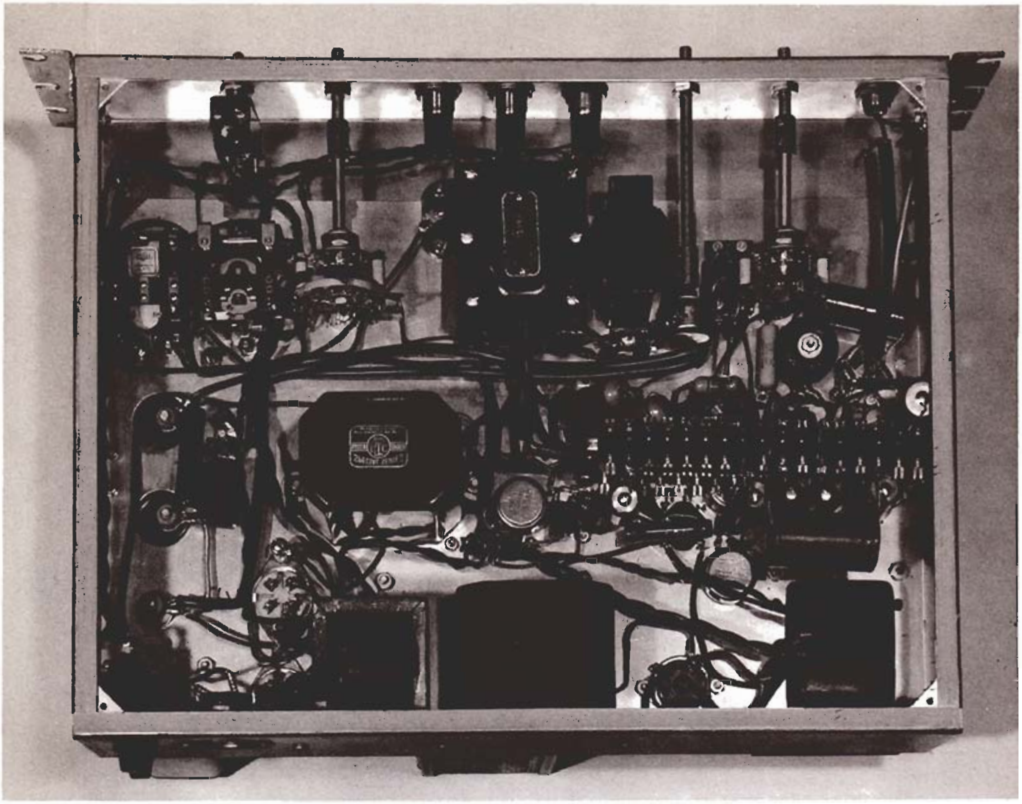
Grid and plate leads in the first few stages in the audio amplifier (V_7, V_8, V_9 and V_{10}) should be kept as short as possible to minimize hum pickup and the possibility of feed-back troubles. Medium voltage power and control circuits were wired with regular hookup wire; high voltage leads should be wire tested for several thousand volts. Pairs of wires carrying an alternating current should be twisted wherever possible.



WELL-PACKED main chassis of the double sideband transmitter. Most small parts in the audio section were mounted on the two terminal boards shown back-to-back at the left side of the chassis in this view. The power input connector (J_3) ond the fuse holders (F_1 and F_2) are on the rear apron of the chassis.



TOP VIEW of the main chassis with locations of the major parts indicated. The black jack near the front of the chassis is for high voltage to the r.f. unit. Three other jacks in front of the audio tubes are for metering circuit connections in positions 9 (r.f. output voltage), 10 (400-volt range) and 11 (2000-volt range) of the meter selector switch.



BOTTOM VIEW of the transmitter main chassis. Note the extension shafts on three of the panel controls. The doughnut-shaped coil just above the terminal boards is L_{10}, part of the audio low-pass filter. Wires carrying alternating current are twisted together wherever possible. Although the schematic diagram in the last issue showed all tube heaters operating from the 6.3-volt winding on T_4, this model has a separate transformer for all the heaters in the r.f. unit, located just to the left of T_1, and close to P_1 above the chassis.

INITIAL ADJUSTMENT and tuneup, as outlined on pages 6 and 7 of the May-June, 1959 issue, should first be completed. Normal tuneup when operating the transmitter into a dummy, or "live" antenna, is quite simple.

First, set S_5 in the TUNE position and adjust C_5 and C_6 for maximum grid current in the 6146 stage, with the meter switch (S_4) in position 4 or 5. Then, turn S_5 to the TRANSMIT position, S_6 to the SINE WAVE position, and S_4 to position 9. Adjust the 500,000-ohm potentiometer in the grid of V_{10A} so that the meter (M_1) reaches about half scale when C_7, C_9 and S_3 are adjusted for maximum meter reading.

Check the signal frequently, both with tone modulation, and with voice modulation, to ensure that the 6146 balanced modulator is operating properly without "flat-topping." For a discussion of the correct and incorrect scope patterns produced by a DSB transmitter, refer to "DSB Considerations and Data," *CQ* magazine, October, 1957, page 64. This article was written by Dale S. Harris, K3CBQ, of G-E's Heavy Military Electronics Department.

MAY-JUNE, 1959 (Vol. 14, No. 3) ISSUE--

200-WATT DOUBLE SIDEBANDER--PART I. PART II Appeared in the July-August, 1959 Issue.

COMMENTS--

This section contains a revised schematic diagram larger in size than that on pages 4 and 5 of the May-June, 1959 issue, and additional notes on components and operation of the 200-watt Doublesidebander.

A. SCHEMATIC DIAGRAM REVISIONS

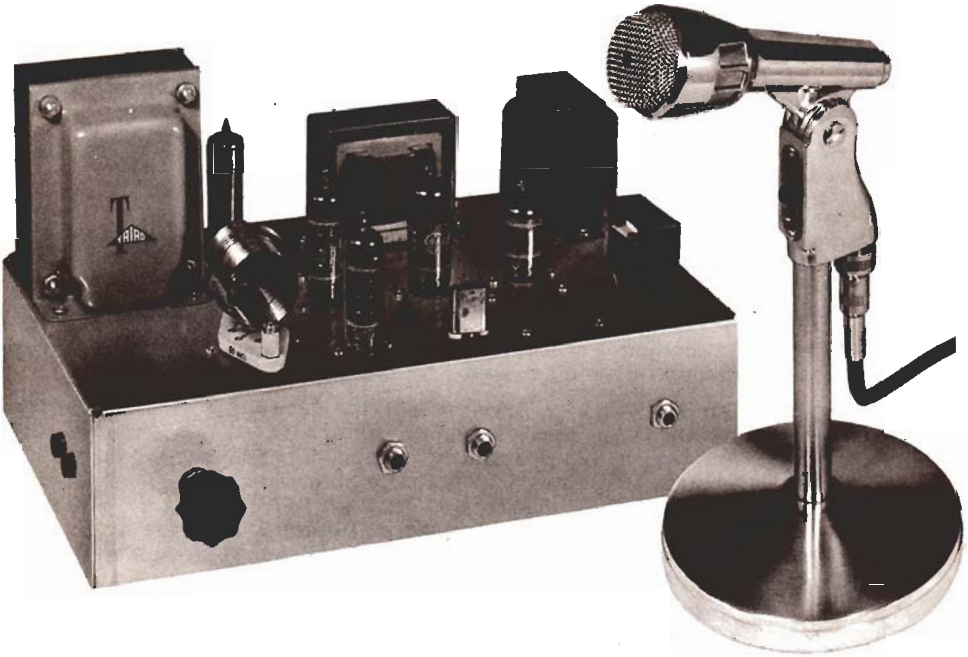
1. Both cathodes of V_8 (V_{8A} on pin 3; and V_{8B} on pin 8) should be connected together with a dot where the lines cross. This completes the DC cathode return path for V_{8A} and places the 25-mfd, 25-volt capacitor across the 330, and two 620-ohm resistors in series with the cathode return lead for V_{8B}.
2. The cathode resistor for V_{10B}, not marked on the original diagram, is 680 ohms.
3. The capacitor in the grid circuit of V_{10B}, between the 150,000-ohm resistors, not marked in value, is 0.001 mfd.
4. The resistor between the 2,700-ohm cathode resistor for V_{10A} and the 10,000-ohm potentiometer (TONE FREQ.) not marked, is 43,000 ohms.
5. The r.f. choke in series with the cathode of V_5, RFC_6 on the diagram, is 2.5 millihenries, the same value and type as RFC_1.
6. The resistor between the cathode of V_5 and the "RF OUT" tap on S_{4B}, next to a 0.01-mfd capacitor and not marked, is 39,000 ohms.
7. The resistor in the exciter plate voltage lead between L_9 and the "B+400 V." tap on S_{4B}, not marked is 200,000 ohms. (two 100,000-ohm, 1/2-watt resistors in series).
8. The full-scale current reading on the meter, M_1, with S_4 in position 3 (Driver Cathode Current) should be 40 ma., with the 51-ohm resistor in series with the cathode of the 6CL6 (V_5). For a full-scale meter reading of 50 ma., change this 51-ohm resistor to 39 ohms.
9. Only two pilot lamps, I_1 and I_2, are shown on the schematic diagram, although three lamps are shown in the front view picture on page 3 of the May-June issue. This extra pilot lamp actually was connected across the primary of T_3 and lit only when power was actually being applied to T_3. The switch S_5 was wired somewhat differently, so that when K_1 closed, I_2 would light in the "TUNE" position, indicating that sufficient grid drive to the 6146's was available to permit application of high voltage when S_5 was turned to the "TRANSMIT" position.

B. COMPONENTS

1. Any audio driver type transformer having a center-tapped primary and secondary, with a turns ratio of 4 to 5, primary to 1/2 of the secondary, and capable of handling 25 milliamperes of current in the windings, should be suitable. The winding marked as the "primary' on the transformer should be connected as the secondary, driving the 6146 screen grids in this application. The transformer actually used in this transmitter was a Merit No. A-3123. A Thordarson type 20D80 also is suitable, as is any small multi-match type driver or modulation transformer with which the proper turns ratio can be obtained.
2. A 5763 pentode can be substituted for the 6CL6 driver by changing pin connections on the socket to match those for the 5763.
3. Bandswitching could be added to the exciter instead of the plug-in coils, but this would require a complete revision of the mechanical layout. For single knob bandswitching, layouts similar to those used in some of the commercially built transmitters, with 6146's in the final, could be followed.

ELECTRONICS From March-April, 1958

DOUBLE SIDEBAND JUNIOR



A 20-WATT DSB TRANSMITTER FOR 3.8–4.0 MEGACYCLES

Get started on rapidly growing double sideband with this simple, junior-sized—but complete—transmitter designed by K2GZT (ex-WφAHM). If this little rig looks familiar, you're one of literally thousands of radio amateurs who have examined it personally at ARRL conventions, and club meetings, during the past several months.

—*Lighthouse Larry*

To say that radio amateurs have been expressing considerable interest in the double sideband, suppressed carrier communications system could easily be the understatement of the year. This has been obvious from the wealth of articles on the subject in recent electronics journals (see bibliography on page 8); also from the steady flow of requests for more information on double sideband in Lighthouse Larry's mail box.

This has resulted in the design of a simple, low-cost double sideband transmitter in which several desirable features have been included. The peak power input capability is about 20 watts, sufficient for putting a respectable signal directly into an antenna; or as a driver for a higher powered linear amplifier.

Before describing the transmitter, let's first examine double sideband as a communications system, which will reveal that the following benefits may be obtained:

1. Double sideband is a suppressed carrier system. This is another step toward eliminating hetrodyne interference—and the final amplifier power capability is not wasted on a carrier[1].
2. Since the output waveform is a replica of the modulating waveform, speech clipping may be employed to increase the average intelligence power.
3. A double sideband transmitter is quite inexpensive and simple compared to either amplitude modulated or single sideband equipment[2].
4. Modulation may be accomplished at the operating frequency.
5. Frequency diversity is inherent in the double sideband system. (The receiving operator has his choice of the more readable of two sidebands.)[3]
6. Double sideband can be received with either a single sideband or synchronous detection receiver. Therefore, it is compatible with single sideband. The synchronous receiver eases transmitter stability requirements by phase locking to the double sideband signal[4].

CIRCUIT DETAILS

In a double sideband transmitter, the modulation process occurs in an amplifier using two tetrode or pentode tubes, called a balanced modulator. Recently published double sideband modulator circuits—a typical diagram is shown in Fig. 1—have shown the RF driving signal applied to the control grids in push-pull; and the audio modulating signal to the screen grids in push-pull. The tube plates are then connected in parallel to cancel out the RF carrier. This circuit is particularly suited to high power balanced modulators, since an expensive high voltage split-stator variable capacitor is not required in the plate circuit.

Examination of the schematic diagram for the DOUBLE SIDEBAND JUNIOR transmitter, Fig. 2, will reveal that the RF output stage consists of two Type 6AQ5 pentode tubes (V_2 and V_3) with the control grids in parallel, and the screen grids and plates in push-pull. This balanced modulator circuit was chosen because a compact receiving type two-section variable capacitor (C_1) can be used in the push-pull plate tank circuit. The RF output is link coupled from the center of the plate tank coil (L_2).

The grids are driven by a crystal controlled oscillator, one half of a 12BH7 twin triode tube (V_{1A}). The other half (V_{1B}) is the audio modulator stage. The RF output stage is screen modulated with the push-pull audio signal, transformer coupled from the modulator stage. The transformer specified for T_2 is connected backwards (primary to the screen grids of V_2 and V_3; secondary to plate of V_{1B}). The RF carrier signal applied in parallel to the control grids of the 6AQ5 tubes is cancelled out in the push-pull plate circuit.

With no modulation the plate current in both final tubes will be low because of the low screen voltage. If a sinusoidal audio tone is assumed as the modulating signal, one screen is driven positive during the first half-cycle and the other is driven negative. The 6AQ5 having positive screen grid conducts and an RF current is supplied to the load by that tube. During the next half of the audio cycle, the other tube supplies RF power to the load and the first tube rests. Note that only one tube is working at any one time, except when there is no audio; then both tubes rest. Neutralization is no problem, as the balanced modulator circuit is self-neutralizing.

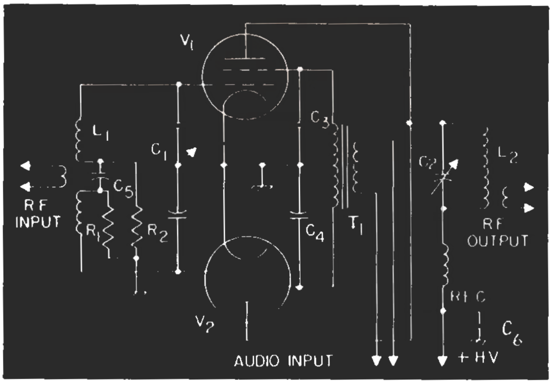


Fig. 1. Schematic diagram for the balanced modulator circuit used in most double sideband transmitter descriptions. Parts values are dependent on tube type and frequency.

A positive bias for the 6AQ5 screen grids—about 13 volts—is developed across the 2000-ohm resistor in series with the cathode-to-chassis connection for the modulator tube (V_{1B}). Current for operating a carbon microphone is supplied through the 1500-ohm resistor.

The two audio voltage amplifier stages employ a 12AU7 twin triode (V_4). The first stage is driven by a single button carbon microphone through a matching transformer (T_3). The first audio stage drives a shunt-type diode clipper circuit which clips both positive and negative audio signal peaks. The clipping level is adjusted by varying the positive bias on the clipping diodes, D_1 and D_2. This bias is obtained from a 1000-ohm potentiometer in series with the cathode-to-chassis circuit of the second audio amplifier stage (V_{4B}).

A simple pi-section audio filter (C_2, C_3 and L_3) following the clipper suppresses the audio harmonics ("splatter") generated in the clipping process. The second audio stage then drives the modulator (V_{1B}).

Push-to-talk operation of the transmitter is obtained simply by grounding the cathode of the crystal oscillator tube (V_{1A}) through a single pole, single throw, normally open push-button switch of the type found on most single button carbon microphones (war surplus T-17, or Electro-Voice Model 210-KK). If the push-to-talk feature is not desired, substitute a two conductor phone jack for the three conductor jack (J_3) shown in the schematic diagram.

Additional audio amplification will be required if a low-output crystal, ceramic or dynamic microphone will be used with the transmitter in place of the carbon microphone. This extra gain can be obtained with a 12AX7 twin triode tube in a two-stage audio preamplifier. The circuit for this amplifier, which will deliver a voltage gain in excess of 1000, is shown in Fig. 2. The arm on the 250,000-ohm gain control at the output of the second stage (V $_B$) feeds directly into the grid of V_{4A}. The transformer (T_3) and carbon microphone voltage circuit can thus be eliminated.

The transmitter may be constructed with the high voltage power supply shown in the main schematic diagram; or, any separate power supply capable of delivering 400 volts at 70 ma may be used instead. A lower plate supply voltage will result in reduced RF power output from the transmitter.

The transmitter may be operated in mobile service with a PE-103 dynamotor as a plate power supply. The microphone control circuit should be connected to switch the dynamotor rather than the oscillator.

If operation on other bands is desired, it will be necessary to change only L_1 and L_2. L_1 should be self-resonant at the crystal frequency and L_2 should be a conventional balanced tank coil for the band in use. The transmitter may be operated on two bands, as it is possible to double in the final amplifier. For example, if an 80-meter crystal and a 40-meter tank coil (L_2) are used, the output will be in the 40-meter band. This method of operation is not highly recommended, but only mentioned as a possibility.

No special effort has been made to achieve a high order of carrier suppression. However, laboratory measurements indicated 40 db of suppression in the original model. At least 30 db of carrier suppression should be obtained with reasonably symmetrical wiring in the RF output circuit. In most cases, the audio hum and noise level will be about equal to the carrier level.

MECHANICAL DETAILS

The transmitter shown on page 1 was constructed on a 7 x 12 x 3-inch aluminum chassis (Bud AC-408). A smaller chassis, or utility box, will easily hold the RF and audio components, especially if the power supply is constructed on a separate chassis. Of course, if a suitable high voltage supply already is available, utilize it instead.

The same relative locations for major parts, as shown in the chassis drilling diagram, Fig. 3, should be followed. If the audio preamplifier for low output microphones is to be included, the tube socket should be placed in the location indicated on this diagram. The

PARTS LIST—DOUBLE SIDEBAND JUNIOR

C_1	two-section variable, 7—100-mmf per section (Hammarlund MCD-100S or equivalent)
C_2	500-mmf, 500-volt mica
C_3	300-mmf, 500-volt mica
C_4, C_5, C_6	25-mfd, 50-volt electrolytic
C_7, C_8	40-mfd, 450-volt electrolytic
C_9	16-mfd, 450-volt electrolytic
D_1, D_2	1N63 germanium diodes (G-E 1N63)
J_1, J_2	two-conductor, closed-circuit phone jack
J_3	three-conductor, open-circuit phone jack
L_1	15 uh, 50 turns, No. 28 enameled wire, scramble wound ¼ of an inch long on a ⅜-inch diameter iron slug-tuned coil form (CTC LS-3)
L_2	44 uh, 48 turns, No. 22 wire, 1½ inches long, 1¼ inches in diameter, with 3-turn link at center (B&W 80JVL)
L_3	6 henry, 40-ma, 300-ohm iron core choke (UTC R-55 or equivalent)
L_4	14 henry, 100-ma, 450-ohm iron core choke (UTC R-19 or equivalent)
R_1	1000-ohm, 2-watt potentiometer
R_2	3100-ohm, 5-watt wire-wound resistor
R_3	250,000-ohm potentiometer, audio taper
RFC_1	2.5 mh RF choke
S_1	single pole, single throw toggle switch
T_1	Power transformer, 880 volts center tapped, 75 ma DC, four 6.3-volt heater windings, 115-volt, 60 cycle primary (Triad R-70A or equivalent) (6 X 4 rectifier heater should be powered from separate 6.3-volt winding on T_1.)
T_2	driver transformer, turns ratio 5.2 to 1, primary to ½ secondary; connect primary as secondary and vice versa.) (Thordarson 20D79 or equivalent)
T_3	line or single button carbon microphone-to-grid transformer, turns ratio 31.4 to 1. (Triad A-1X)
V_1	12BH7A tube
V_2, V_3	6AQ5 tube (G-E types 6005 Five-Star, or 6669 Communication series, also suitable)
V_4	12AU7 tube
V_5	6X4 tube (5Y3-GT if T_1 has 5-volt winding)
V_6	12AX7 tube (optional audio amplifier)

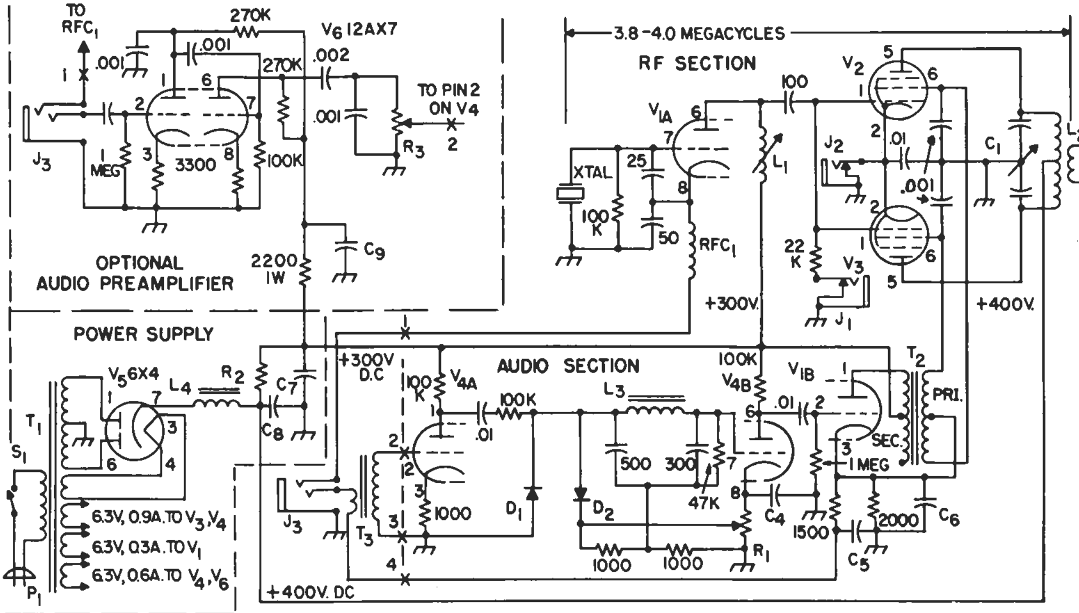


Fig. 2. Schematic diagram for the complete 20-watt double sideband transmitter. The high voltage power supply, shown within dotted lines, may be eliminated if a suitable supply already is available. The optional audio preamplifier appears in the upper left-hand corner. Capacitances given in whole numbers are mica, 500 volts working; those in decimals are disc ceramic, 500 volts working. Resistors are ½ watt unless otherwise specified.

DRILLING LEGEND

"A" drill—No. 32 for miniature tube socket hardware.

"B" drill—No. 26 for fastening terminal strips and larger components.

"C" drill—$\frac{9}{32}$ of an inch in diameter for L_1.

"D" drill—3/8 of an inch in diameter for controls, grommets, etc.

"E" socket punch—5/8 of an inch in diameter for 7-pin miniature tubes.

"F" socket punch—3/4 of an inch in diameter 9-pin miniature tubes and grommet under T_1.

"G" socket punch—1 1/4 inches in diameter for L_2.

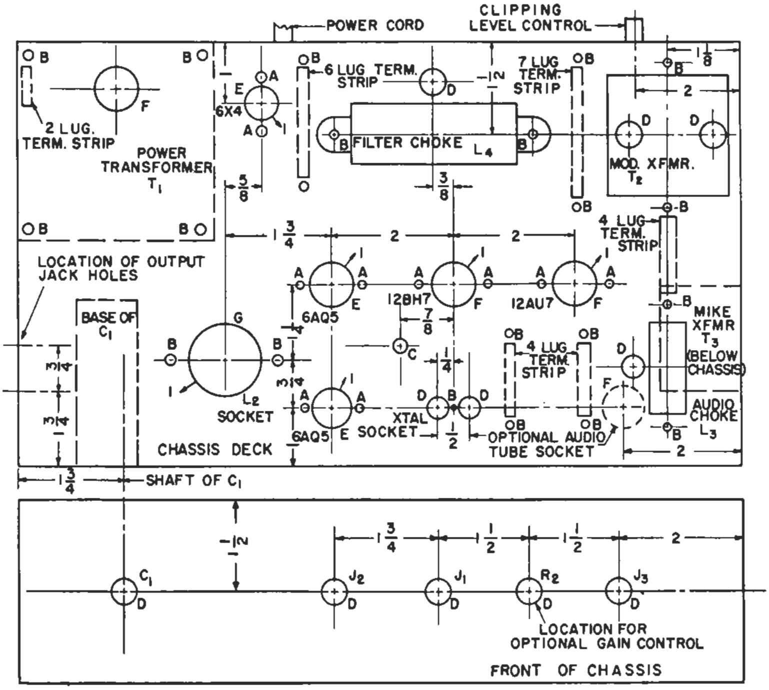


Fig. 3. Chassis deck and front panel drilling diagram for the double sideband transmitter. Dimensions are shown from the edges of a 7 x 12 x 3-inch deep chassis. Tube sockets should be mounted with pin 1 in the position indicated at each socket hole. The socket for the optional audio preamplifier tube (V_6) and gain control (R_8) are located as shown.

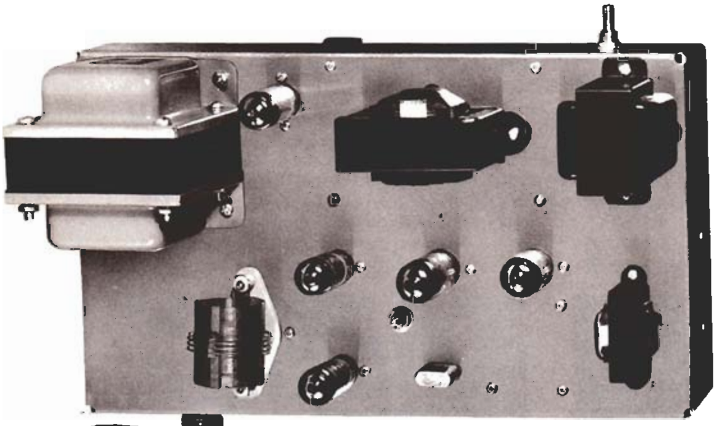


Fig. 4. Top view of the double sideband transmitter, showing the locations of major parts on chassis deck. Check to see that sufficient space is provided for components which differ in size and shape from those listed. The audio filter inductor (L_2) and the microphone transformer (T_3) should be oriented in the positions shown to prevent inductive hum pickup from the power transformer (T_1).

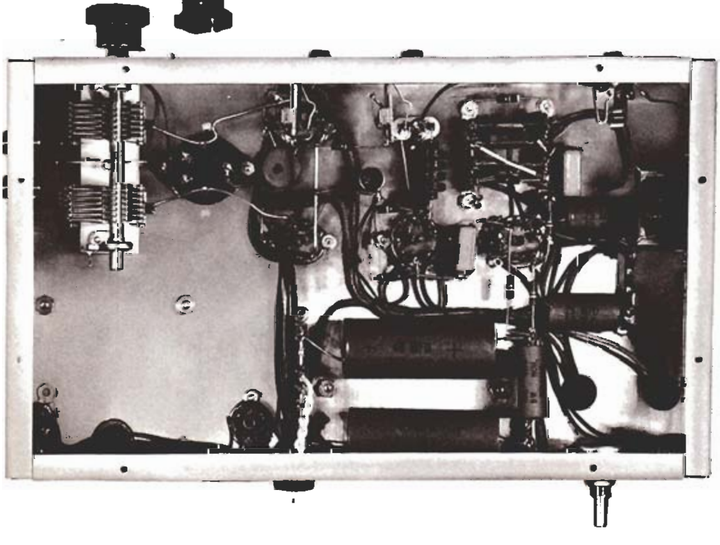


Fig. 5. Bottom view of the chassis, showing placement of smaller parts on the tube sockets and terminal strips. Power wiring is run in corners and across the center of the chassis. Wires carrying audio and RF voltages should be made as short as possible.

matching transformer for a carbon microphone, T_3, is then not required. The audio low-pass filter inductor, L_2, should be mounted beneath the chassis in place of T_3. The gain control between stages in the extra audio amplifier may be mounted midway between J_1 and J_3 on the front of the chassis, as indicated on the drawing.

Small holes for component fastening hardware should be located directly from the matching holes on each part; the drilling diagram simply indicates the presence, but not the precise location, of these holes. Rubber grommets should be placed in all chassis holes for transformer leads before these parts are assembled in the locations shown in the top view photo, Fig. 4.

The smaller parts beneath the chassis are fastened between tube socket lugs and lugs on other parts, or on lug-type terminal strips (Cinch-Jones 2000 series). Most of the audio clipper and low-pass filter components were assembled between two four-lug strips, as shown in the bottom view photo, Fig. 5. Note that the tubular type electrolytic filter and cathode bypass capacitors fit neatly into unused portions of the chassis. Use of metal can type capacitors will require crowding of some components on the chassis deck.

All power and audio circuit wiring was run with No. 20 stranded, insulated hookup wire. Heavy tinned copper wire was used for the lead between the 6AQ5 control grid socket pins; also for connecting the 6AQ5 plate lugs to the socket for L_2 and stators on C_1. Small insulated banana jacks were mounted on one end of the chassis for antenna terminals, but a suitable chassis type coaxial cable connector may be substituted.

The audio preamplifier stage, which may be added to the transmitter at any time, was constructed on a turret type 9-pin miniature socket (Vector No. 8-N-9T), as shown in the photo of Fig. 6. There is adequate room on this socket for all small parts, but the 16-mfd, 450-volt filter capacitor in the plate voltage decoupling filter should be placed in the corner behind T_3.

ADJUSTMENT AND OPERATION

Once the transmitter has been completed, it should be tested on a dummy load consisting of a 15- or 25-watt, 115-volt incandescent lamp bulb. The test procedure consists of the following steps:

1. Apply power and insert a crystal for the 3.8–4.0-megacycle phone band. Depress the microphone push-to-talk switch.
2. Adjust L_1 to resonance while observing the final amplifier grid current on a milliammeter inserted at J_1. A grid current of 3 to 4 milliamperes is required for proper operation.
3. Set R_1 to its midpoint. Adjust L_2 for closest coupling. Whistle into the microphone and adjust C_1 for maximum output power or maximum brilliance of the dummy load lamp.
4. Observe the RF output voltage with an oscilloscope. Either the bowtie or envelope presentation may be used[5]. Whistle into the microphone. Successively adjust the output coupling and clipping level (R_1) for maximum output voltage consistent with *linearity*[6].
5. Upon successful completion of testing with a dummy load, the transmitter may be connected to a transmitting antenna. The antenna should preferably be a low impedance tuned antenna, such as a dipole or folded dipole. If a long wire antenna is used, an antenna tuner should be used to transform the antenna impedance down to a value suitable for link coupling. When the transmitter is connected to the antenna, step 4 should be repeated to ensure that the output stage is properly adjusted and not overloading on positive audio peaks. The final amplifier cathode current may be metered at J_2. The plate current will have a resting value of about 20 ma and will rise to about 40 ma with modulation.

Although the basic transmitter is crystal controlled, the output of a variable frequency oscillator may be fed into the crystal socket with a short length of 300-ohm twinlead. It is important that this external oscillator have an isolating stage between it and V_{1A} to prevent frequency modulation of the signal. The VFO also should have good long-term frequency stability. Otherwise, the other participants in a round-table QSO will keep reminding you to get back on frequency.

DOUBLE SIDEBAND JUNIOR has sufficient RF output to drive a pentode linear amplifier in the one-kilowatt power class; or a triode linear amplifier in the 400-watt class, such as the LAZY LINEAR (See *G-E HAM NEWS*, July-August, 1949, Vol. 4, No. 4, for details). But even when operated "barefooted," it should have a normal working range of several hundred miles on the 3.8-megacycle band.

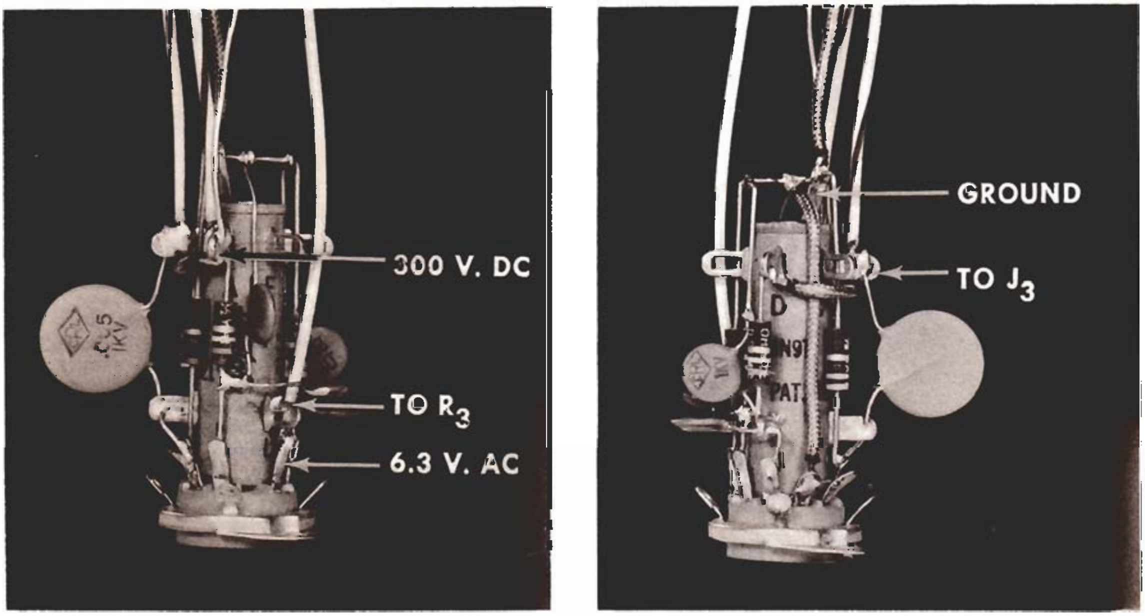


Fig. 6. Detail views of the audio preamplifier stage constructed on a turret type 9-pin miniature tube socket (Vector No. 8-N-9T). Terminals to which external connections are made have been labeled.

Added Information for Double Sideband Junior Transmitter

The following suggestions have been compiled to aid those persons who may wish to place the Double Sideband Junior transmitter on other bands, connect a VFO to it; or for those who require trouble-shooting information:

1. HEATER CIRCUIT -- The three separate 6.3-volt AC heater windings shown in the schematic diagram, Figure 1, on page 2, happened to be on the power transformer (T_1) actually used on the model transmitter. Of course, if another type of power transformer is substituted for the Triad No. R-70A, the heaters of V_1, V_2, V_3 and V_4 all can be powered from the same heater winding. The 6X4 rectifier tube heater should be powered from a separate 6.3-volt transformer winding. If the power transformer has a 5-volt winding, it probably will be more convenient to substitute a type 5U4-GB full-wave rectifier tube for the 6X4.
2. HIGH VOLTAGE POWER--Although a capacitor-input type filter may be used on the high voltage supply if a fairly low resistance bleeder resistor is used to place a fairly high static current drain on the power supply, the choke-input type filter shown in our schematic diagram is recommended. The voltage regulation of a choke-input filter is much better, resulting in improved linearity in the balance modulator stage.
3. 6AQ5 PLATE VOLTAGE -- The power output from the 6AQ5 balanced modulator stage will drop rapidly as the plate voltage is reduced below 400 volts. Actually, the DSB Jr., will deliver about 35 percent more power output with 500 volts on the plates, than with 400 volts. We cautioned users of this circuit against running more than 400 volts on the 6AQ5's in G-E HAM NEWS, but the tubes will easily handle 500 volts in DSB service. However, we have not tested the 6AQ5 stage at higher voltages -- say 600 volts -- even though they may withstand this voltage without breaking down. The combined plate dissipation of two pentode-connected 6AQ5's is 24 watts. This indicates that the tubes will handle up to 60 milliamperes of plate current with 400 volts on the plates without being overloaded, even though the tubes may not be delivering any RF output power, which might happen with the plate tank circuit tuned far off resonance. The higher-than-normal plate voltage rating follows the usual practice of operating tubes in a DSB balanced modulator at double the plate voltage rating for class C plate modulated RF amplifier service.
4. DUMMY LOADS -- The usual 50-ohm non-inductive resistors, or a 15 or 25-watt, 115-volt lamp bulb will provide a suitable dummy load resistance for the DSB Jr. With 400 volts on the 6AQ5's, a 15-watt lamp should light to nearly full brilliancy before non-linearity occurs in the 6AQ5 stage, especially when several

db of clipping is being employed in the audio circuit. A 25-watt lamp should show about 2/3 of normal brilliancy (about what it would show with 80 volts AC applied to it).

5. OUTPUT TANK CIRCUIT -- The 6AQ5 plate tank circuit, C_1--L_2, should tune to resonance at 3.8 megacycles with C_1 near maximum capacitance. If it will not tune this low in frequency, add a small padding capacitor -- a 10 mmf, 2000-volt working mica is suitable -- across the ends of L_2 on the plug-in coil base. This tank circuit should tune to the 7-megacycle band with C_1 set near 45 degrees of rotation from minimum capacitance.

6. OPERATING DSB JR. FROM A VFO -- It was possible to feed the output from a Heathkit VFO directly into the crystal socket of the DSB Jr., on the 3.8 megacycle band, with good results. The connection may be made with a short length of RG-58/U coaxial cable. The triode oscillator circuit, acting as a buffer stage, did not go into oscillation. However, instability in this stage may be encountered with other types of VFO's. Make sure that the outer shield on the coaxial cable connects to the grounded terminal on the crystal socket.

7. OPERATION DSB, JR. ON OTHER BANDS -- The following coil table has been compiled (using our trusty Lightning Calculator) as a suggested means of operating DSB Jr. on higher frequencies than the 3.8 megacycle band for which it was designed. The recommended crystal frequencies should be used for each band:

7-MC BAND --
    Crystal--7.204 to 7.296 megacycles. (In United States).
    L_1--8.5 uh; 40 turns, No. 28 enameled wire, closewound 5/8 of an inch long on a 3/8-inch diameter CTC LS-3 iron slug-tuned coil form.
    L_2--16 uh; B & W type JVL-40 manufactured coil.

14-MC BAND --
    Crystal--14.204 to 14.296 megacycles.
    L_1--3.7 uh; 27 turns, No. 28 enameled wire, closewound 3/8 of an inch long on an LS-3 form.
    L_2--2.2 uh; B & W JVL-15 coil.

21-MC BAND --
    Crystal--21.254 to 21.446 megacycles.
    L_1--2.2 uh; 18 turns, No. 24 enameled wire, closewound 3/8 of an inch long on an LS-3 form.
    L_2--2.2 uh; B & W JVL-15 coil.

28-MC BAND --
    Crystal--28.504 to 29.696 megacycles.
    L_1--1.2 uh; 10 turns, No. 24 enameled wire, closewound 5/16 of an inch long on an LS-3 form.
    L_2--1.2 uh; B & W JVL-10 coil.

8. The DSB, Jr. 6AQ5 balanced modulator circuit should work on 50 megacycles when driven by a small crystal controlled exciter, such as those described in the May-June, 1958 issue, under "PACKAGED VHF EXCITERS".

9. About plus 10 volts should be measured at the junction of C_5 and the 1,500-ohm resistor in the cathode of the 12BH7A modulator tube. This supplies excitation voltage for a carbon microphone, and may drop to about plus 5 volts with a microphone plugged into J_3.

K2GZT'S 6146 DOUBLE SIDEBAND TRANSMITTER

There have been many requests received from radio amateurs for information on the 7-megacycle DSB transmitter using a pair of 6146's, as mentioned on page 8 of the March-April, 1958 issue of G-E HAM NEWS. The schematic diagram below shows the balanced modulator circuit he is using, with the major component values marked thereon. The operating conditions for the 6146 tubes are listed below. Note that the plate voltage--1200 volts--is much higher than the usual maximum rating, but is in line with the usual practice in a DSB balanced modulator of operating the tubes at a DC plate voltage twice the recommended plate voltage for plate-modulated class C amplifier service. Thus, the 1200-volt value is equal to the positive peak modulating voltage.

AUDIO MODULATOR CIRCUIT -- A two-stage modulator circuit is shown in Fig. 1. Inverse feedback voltage from the plates of the 12BH7 push-pull output stage is fed into the cathodes of the 12AT7 driver stage to reduce audio distortion. The 12AT7 should be preceded by a phase-splitter stage having about 1 volt peak-to-peak output. Audio clipping and low-pass filtering, as shown in the original DOUBLE SIDEBAND JUNIOR circuit, may be used for increased average power output from the 6146 balanced modulator.

MECHANICAL LAYOUT, 6146 DSB BALANCED MODULATOR--The usual practice of short leads in the RF circuitry should be followed during construction of the modulator stage. The final amplifier layout for any of the popular 100-watt class transmitters (DX-100, Valiant, etc.) may be used as a guide for this circuit.

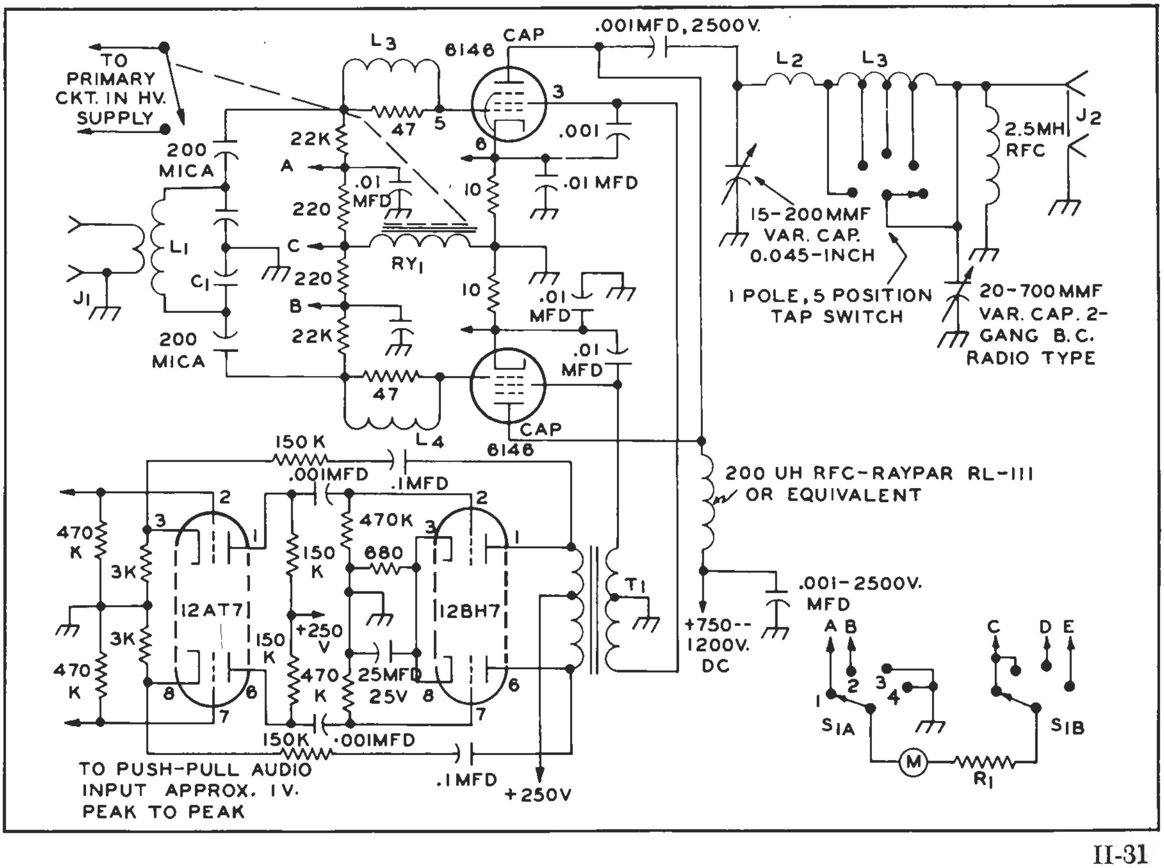


TABLE I — PARTS LIST

C_1-------10--100-mmf per section, two-section receiving type variable.

J_1, J_2----chassis type coaxial cable connectors.

L_3, L_4----VHF parasitic suppressors; 6 turns, No. 16 enameled space wound on 1/4-inch diameter, 47-ohm, 2-watt resistors.

M--------low-range milliameter, see TABLE I.

R_1-------Value depends upon full-scale current rating of meter, see TABLE I.

RY_1------SPST relay with 3-ma DC coil.

S_1--------two-pole, four position tap switch.

T_1-------audio driver transformer, turns ratio 5.2 to 1, primary to 1/2 secondary (Thordarson No. 20D79); connect primary as secondary, and secondary as primary.

TABLE II — COIL TABLE

BAND	L_1	L_2
3.5 MC:	B & W MCL-80 coil:	L_2---6.5 uh, 18 turns, No. 16 wire, spacewound 8 turns per inch, 2.1/4 inches long, 1 1/2 inches in diameter.
7 MC:	B & W MCL-40 coil:	L_2---3.2 uh, 13 turns, No. 16 wire, spacewound 6 turns per inch, 2 1/6 inches long, 1 1/2 inches in diameter.
14 MC:	B & W MCL-15 coil:	L_2---1.6 uh, 9 turns, No. 14 wire, spacewound 4 turns per inch, 2 1/4 inches long, 1 1/2 inches in diameter.
21 MC:	B & W MCL-15 coil:	L_2---1.08 uh, 7 turns, No. 14 wire, spacewound 4 turns per inch, 1 3/4 inches long, 1 1/2 inches in diameter.

TABLE III — METER RANGES

METER RANGE	R_1	FULL SCALE READINGS	
		GRID	CATHODE
0--1 ma.	1000 ohms	4.5 ma.	100 ma.
0--1 ma.	470 ohms	2.2 ma.	50 ma.

TABLE IV — 6146 OPERATING CONDITIONS — DSB MODULATOR

DC Plate Voltage	1200 volts
DC Screen Voltage	0 volts
DC Control Grid Bias	0 volts
DC Plate Current (no audio signal on screens)	25 milliamperes
DC Plate Current (maximum for good linearity)	100 milliamperes
Peak Envelope Power Input	170 watts
Peak Envelope Power Output	125 watts

(Continued on page II-35)

The trend by more and more amateurs to suppressed carrier phone communications is one of the greatest things that has ever happened to amateur radio. It is really a pleasure to operate in the segments of the bands which the sidebanders have pretty well taken over.

DSB offers a very easy way for anyone to try out suppressed carrier operation and it is hoped that this discussion will encourage more of you to try it. Let us not get off into any AM versus SSB versus DSB arguments—those arguments are for the professionals and the average amateur should steer clear.

Several DSB articles have appeared in recent issues of CQ showing the basic tetrode balanced modulator circuits used to suppress the carrier. These circuits may have either of two configurations:

1. Push-pull grids with parallel plates, or
2. Parallel grids with push-pull plates.

In either case, the screens are modulated with push-pull audio. Generally, the first configuration will be the best one to use since the push-pull components will be small and a pi-tank can be used in the output, the advantages of which are well known.

Hi-Level vs Linear

There are two approaches to medium or high power DSB. One is to make your final a high power balanced modulator. The other would be a low-power balanced modulator driving a linear amplifier. Unless you already have a *linear* amplifier (and know how to keep it linear) the high level approach is definitely recommended. If you do use a linear, don't forget that a single audio tone to the DSB exciter is a two-tone signal into the linear amplifier!

Most CW exciters have plenty of output to drive even the big tetrodes in a DSB final. Anyone with a two tube final (either push-pull or parallel) will only have to modify one RF circuit and split the screen grids to put the final on DSB.

Most any tetrodes may be used in the balanced modulator circuit and a tabulation of the recommended variables for the more common tubes is presented later. The general considerations of how to operate different tubes are best discussed one circuit at a time.

Grid Circuit

Each tube should definitely have its own grid bias resistor. Attempts at using a common bias resistor have resulted in aggravating any off-balance tendencies the tubes may have. The grid circuits should be operated as for normal class C Plate Modulated operation. The normal bias resistors for class C are used. The grid current is run up to normal values. It has considerable effect upon the resting plate current.

Bias may be partially from a battery, but should not be all battery bias. Partial battery bias will be found very handy if you want to include voice control operation.

Screen Circuit

The dc bias applied to the screens through the modulation transformer secondary has two effects. Most important is its effect upon the bow tie pattern crossover point. Just enough negative bias should be used to give a clean crossover and limit the resting plate current. Any further negative voltage will cause the two halves of the pattern to separate apart indicating distortion. The screen bias is necessary on some tubes to hold down the resting plate dissipation requirements. The bias battery or supply should have good regulation and should be by-passed heavily with several microfarads of capacitance. The smaller tubes (807's, 6146, etc.) work nicely with zero screen bias.

The screens must be by-passed for rf but not for audio, so the by-pass condensers should not be larger than .001 mfd and should be mica. The audio swing of the screens determines the amount of plate current the tubes can draw. As a conservative estimate of how much audio voltage you will need, take the normal plate modulated screen voltage and double it. Your audio *peaks* should hit this value (from center tap of mod. xfmr to screen) If you really want to run to full tube capability, you can check by heavily loading the final and running up the audio voltage till the RF no longer increases with increasing audio. At this point you are flattening on peaks because of emission limitation. Exceeding that audio voltage will only cause distortion. This maximum screen swing will be the same for a given tube type regradless of what plate voltage you run.

The screen modulator needs relatively small power output, but to modulate the larger tubes, voltage swings of about 800 volts peak are required. This is best accomplished with a step-up transformer. A pair of 6L6's in Class AB1 will modulate most any tubes, but step-up transformers with push-pull primary and secondary are a scarce commodity. The best solution available now seems to be to use a 10 or 20 watt class B driver transformer of 5:1 (pri to ½ sec) step down ratio. Using it backward will give you 1:1.25 primary to one-half secondary.

Before long perhaps the transformer manufacturers will make available more suitable transformers.

Another possibility is to use a single 6L6 into the 117 volt winding of a small power transformer. This will give you roughly a 1:3 step up to half of the HV winding and works quite well.

Clipper-filter

While talking about modulators, it should be pointed out that speech clipping can be used to good advantage in DSB and is a very worthwhile feature to put in the speech amplifier. Clipping will give you a big boost in average talk power. Just remember to reduce low frequency response before the clipper-filter, and preserve both lows and highs after the clipper-filter.

Plate Circuit

As previously mentioned, the plate current of the DSB stage is pretty well determined by the audio swing on the screens. The way to more power then is obviously higher plate voltage. Bearing in mind that on normal AM the plate voltage swings up to twice the dc plate voltage, you can use up to twice the AM plate voltage on your DSB stage, and up to that value, the higher the better. Any given tube will work satisfactorily at its normal plate voltage, but it's a similar situation to linear amplifiers, if you really want to sock them, you must run up the plate and screen voltages.

This means that you have the following choices based on voltages available:

400-600 volts	6L6's, 2E26's, 6V6's, 6Y6's
600-1200 volts	807's, 1625's, 6146's
1200-1600 volts	?
1600-3000 volts	813's
2000-4000 volts	4-125A's, 4-250A's

Paralleling tubes on each side of the balanced modulator offers a powerful little package (four 807's give 300 watts p.e.p. *output*), but the paralleled output capacitances may make it difficult to get above 20 meters with four tubes.

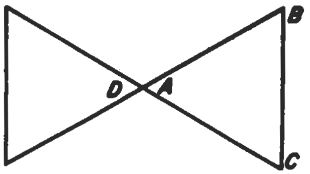
Since the plate current swing depends largely on the screen voltage swing, the best way to tune the DSB stage is not by plate current dip but by tuning for maximum output. With the tank circuit resonated, increase your loading to the maximum output point and stop. That's all there is to it. Some tank circuit conditions will cause greater plate current readings but reduced output.

The plate current meter, of course, does not read peak plate current, so if you want to figure your peak envelope power you must apply a factor. For sine wave modulation, the meter reading should be multiplied by 1.58 (1/.636). This figure and your plate voltage will give you peak envelope power input; you multiply by about 75% efficiency to get your peak envelope power output. If you are running relatively high plate voltage on your tubes you can estimate your peak output as four times the carrier output rating for AM phone service. This is conservative estimating, however, since with the low duty cycle of speech you can get a little better than this before distortion sets in from emission limiting or instantaneous downward plate voltage hits the screen voltage level.

Half of your peak power appears in each sideband which means a 3db disadvantage compared to SSB. The ability to select the best sideband at the receiving end buys some of this back, and clipping buys even more.

Checking Patterns

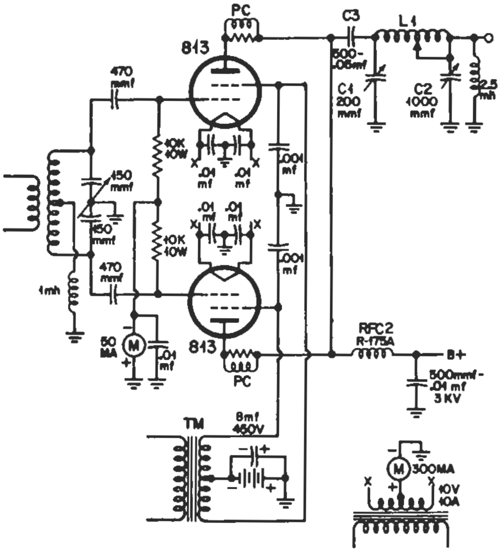
Just as in AM and SSB, it's always best to check your signal with an oscilloscope. The handiest pattern for checking DSB is the familiar bow tie. Apply audio on your horizontal amplifiers and rf direct on the vertical plates. This procedure is described in the handbooks. It is recommended that the audio be taken off the secondary of the modulation transformer for minimum phase shift. The audio voltage here will be way too much for your scope input though, so rig yourself a voltage divider of 1 megohm in series with a 10K resistor and pick audio off across the smaller resistor. Your bow tie should look like *fig. 1*.



Line AB and AC should be nice and straight. The A end of these lines has a tendency to bulge slightly with too much grid drive and may become concave with too little drive, so experiment here. If you have negative bias on the screens, there will probably be a little kink near A where the screen goes through zero, but this does not cause bad distortion. Peaks at B and C should be nice and sharp. If they are rounded you are flattening and probably due to overdriving the screens. If points A and D are separated so the points don't meet, you have too much negative bias on the screens. With high plate voltage you will find it easier to get a good bow-tie pattern. If your tubes are not balanced, one half of the pattern will rise higher on peaks than the other side. One half of the pattern represents each tube, but has no relationship to the upper and lower sideband. The side-bands will be identical in any case.

The bow-tie pattern won't show up audio distortion so you will find it interesting to

	6V6	6BQ6/ 6DQ6	807/ 1625	6146	813	813	813	4-250A
Plate Volts	500	600	1250	1000	1500	2000	2600	4000
Screen Volts	0	0	0	0	–22.5	–67.5	–90	–65
Plate Current Resting	10	25	30	25	100	55	60	80
Plate Current Full Whistle	50	150	100	125	205	245	265	300
PEP Output	30	100	150	150	380	600	840	1500



shift to an rf envelope pattern by switching to internal sweep on your horizontal axis. By using a steady audio note you can synchronize and see how well your audio is doing.

If you have established the proper conditions you will have a good bow-tie shape and you will be pleased to note that the tuning controls don't affect the shape much. If you detune anything, about all that happens is you get less than maximum output.

Fig. 2 is a complete circuit diagram for 813's. Exactly the same circuit is applicable for all tetrodes—you can use lower voltage components for smaller tubes of course.

Table 1 shows DSB operating conditions for some of the more common tubes. Don't worry if you don't have the exact voltages called for, these are the ones tried by W2CRR, W2HNH, W2SBI, and K2KID. Pick out the tubes you want and have a go at DSB. You'll like it!

OPERATIONAL NOTES

(Continued from page II-32 *)*

EXCITER FOR 6146 DSB MODULATOR -- Approximately 4 to 5 watts of driving power should be available for the balanced modulator, even though the 6146's actually do not require all of this power for proper operation. The exciter output should be relatively free of spurious output frequencies, and have excellent frequency stability. Preferably, any variable frequency oscillator used with the DSB modulator should have not more than 1-kilocycle of warmup drift during the first few minutes of operation, and should be capable of staying within 50 cycles of the desired operating frequency after the initial warmup.

AUTHOR OF DSB JR. ARTICLE

MEET THE DESIGNER—John K. Webb, K2GZT, took a busman's holiday from his profession as electrical design engineer on synchronous and other communications systems at our Light Military Electronic Equipment Department in Utica, New York. Result—the DOUBLE SIDEBAND JUNIOR transmitter in this issue!

Some measure of Jack's enthusiasm for double sideband can be garnered from his many presentations on this subject at trade shows, amateur radio conventions, hamfests, and club meetings. Of course, this little transmitter usually accompanies him as his favorite "conversation piece."

First licensed as WϕAHM in Kansas during 1947, Jack's association with electronics includes AM broadcasting and the U.S. Army Signal Corps, before joining General Electric. Although he has tried 'em all—CW, FM, AM and SSB—Jack can now be found on 14-megacycle phone pushing a pair of GL-6146's in a—you guessed it—double sideband rig!

BIBLIOGRAPHY OF ARTICLES ON DOUBLE SIDEBAND

Costas, J. P., "Synchronous Communications," *Proceedings of the I R.E.*, December, 1956.

[2] Costas, J. P., "Single Sideband: Is It Really Better Than Amplitude Modulation?", CQ, January, 1957.

[3] Costas, J. P., "Discussion of the Single-Sideband Issue," *Proceedings of the I.R.E.*, April, 1957.

[4] Webb, J. K., "A Synchronous Detection Adapter for Communications Receivers," CQ, June, 1957.

[5] Harris, D. S., "DSB Considerations and Data," CQ, October, 1957.

[6] Webb, J. K., "Modulating the DSB Transmitter," CQ, March, 1958.

Eaton, R. C., "Two Sidebands for Less than the Price of One," CQ, September, 1957.

Najork, Jack, "A 100 Watt DSB Mobile Transmitter," CQ, March, 1957.

Stoner, D. L., "Double Sideband with the Heath DX-100," CQ, April, 1957.

Jones, F. C., "Low Cost DSB-AM Amplifiers," CQ, November, 1957.

Costas, J. P., "Phase-Shift Radio Teletype," *Proceedings of the I.R.E.*, January, 1957.

HETRODYNE EXCITER WITH 6BU8 TWIN PENTODE BALANCED MIXER

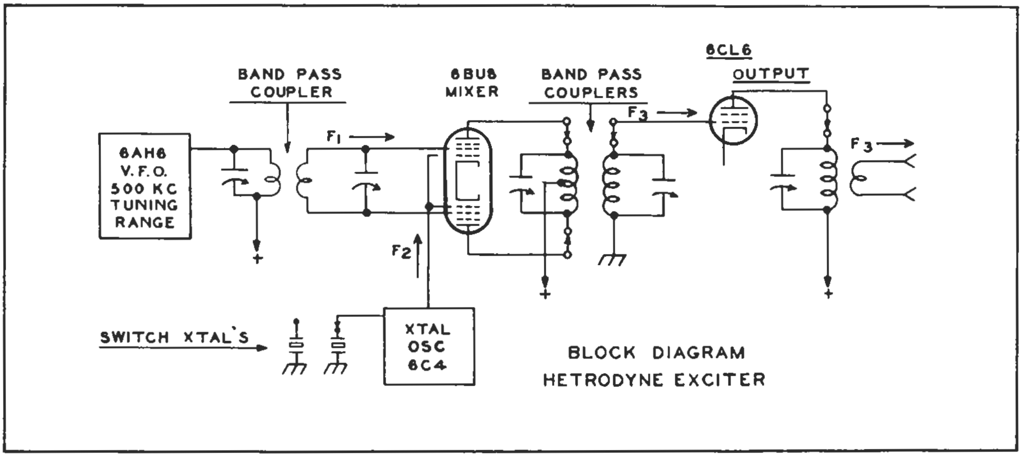
HETRODYNE EXCITER ADVANTAGES:

1. No more complex than many conventional exciter circuits having a tunable oscillator, following by an isolating stage and a series of frequency multipliers.
2. Oscillator drift is the same on all bands. Drift is not multiplied as the exciter is operated on the higher frequency amateur bands, as is the case in a conventional exciter, where frequency drift at 28 megacycles can be up to 8 times higher than at 3.5 megacycles.
3. The tuning rate is the same for all bands. No switching of parallel and series capacitors is necessary in the tunable oscillator frequency determining circuits to prevent the higher frequency amateur bands from being squeezed into a small portion of the oscillator tuning dial scale.
4. Chirpless keying is simplified. Both the crystal and tunable oscillators can run continuously, but no signal will appear at the output frequency when the mixer stage is made inoperative by the keying system.
5. An adjustable negative bias can be fed to the mixer through a potentiometer, making possible setting the "zeroing in" signal in the receiver to a level which does not block or over-ride incoming signals.
6. The hetrodyne exciter can be easily adapted to single sideband operation by adding a sideband generator unit between the crystal controlled oscillator (F_2) and the mixer stage.

HETRODYNE EXCITER CIRCUIT:

The exciter, as summarized in the block diagram, consists of the solid high-c tunable oscillator signal (F_1), feeding through a link-coupled bandpass push-pull r.f. transformer into the separate No. 3 grids of a 6BU8 miniature twin pentode tube, operating as a balanced mixer. The hetrodyning signal (F_2) from a crystal controlled oscillator is capacitance coupled to the common control grid for both pentode sections in the 6BU8 tube.

The two plates of the 6BU8 are connected to a push-pull tank circuit, tuned to either the sum or difference of the two input signal frequencies ($F_1 + F_2$; or, $F_1 - F_2$), and amplifies the mixer output signal (F_3). This signal drives a 6CL6 miniature pentode, operating in class A or class AB_1. The 6CL6 will deliver about 2 to 4 watts output, depending upon the output frequency.



BLOCK DIAGRAM
HETRODYNE EXCITER

The preliminary schematic diagram of the crystal oscillator, mixer and amplifier is shown next page. Note that a ganged bandswitch (S_1A THROUGH S_1F) selects the proper crystal, oscillator plate tank coil, mixer plate circuit, and 6CL6 output circuit for the amateur bands from 3.5 to 29.7 megacycles. For simplicity, only one set of interstage coupling and output circuit coils are shown in the diagram. There are, of course, actually five sets of coils connected to switch sections S_1C, S_1D, S_1E and S_1F.

Parts values for the experimental hetrodyne exciter are given in TABLE I. The chart of tunable oscillator, crystal oscillator and output frequencies for each popular amateur band are given in TABLE II. Coil data for operation of the experimental exciter on the 14-megacycle amateur band is given in TABLE III. Final coil data for L_5, L_6 and L_7, for the other amateur bands has not yet been determined, but persons interested in winding such coils should scale up and down the coil data given for 14 megacycles, keeping approximately the same L/C ratio in each tuned circuit.

The power output from the 6CL6 amplifier stage is sufficient to drive one or two of the popular 20 to 30 watt plate dissipation class beam pentode tubes in class AB_1, class B, or class C as a power amplifier (6CA7/EL34, 6DQ5, 6DQ6B, 6L6-GC, 5881, 6146, 7027, 7581, etc.). Class AB_1 operation of this 50 to 150-watt linear amplifier stage is recommended for those applications where not more than 40 watts of driving power is required by a high power amplifier stage which may follow the complete exciter. This will reduce harmonic output, as compared to operating the 50--150-watt amplifier in class C, and thus help prevent interference to nearby television receivers.

Table II · FREQUENCY CHART

(For 12-Megacycle Tunable Oscillator)

OUTPUT BAND, MC, (F_3)	TUNABLE OSC. RANGE (F_1) MC.	CRYSTAL FREQ. MC (F_2)	MIXER
3.5 - 4.0	12.0 - 12.5	X_1 = 8.5	$F_1 - F_2 = F_3$
7.0 - 7.3	12.0 - 12.3	X_2 = 5.0	$F_1 - F_2 = F_3$
14.0 - 14.35	12.0 - 12.35	X_3 = 2.0	$F_1 + F_2 = F_3$
21.0 - 21.45	12.0 - 12.45	X_4 = 9.0	$F_1 + F_2 = F_3$
28.0 - 28.5	12.0 - 12.45	X_5 = 16.0	$F_1 + F_2 = F_3$
28.5 - 29.0	12.0 - 12.5	X_6 = 16.5	$F_1 + F_2 = F_3$
29.0 - 29.5	12.0 - 12.5	X_7 = 17.0	$F_1 + F_2 = F_3$
29.5 - 29.7	12.0 - 12.2	X_8 = 17.5	$F_1 + F_2 = F_3$

The final working version of this hetrodyne exciter, designed, constructed and tested for a full year on all bands by W2FBS, is published in the July-August, 1961 issue of G-E HAM NEWS. It is a complete transmitter/exciter, with built-in power supply and differential keying system, and a single 7581 beam pentode in the power amplifier stage.

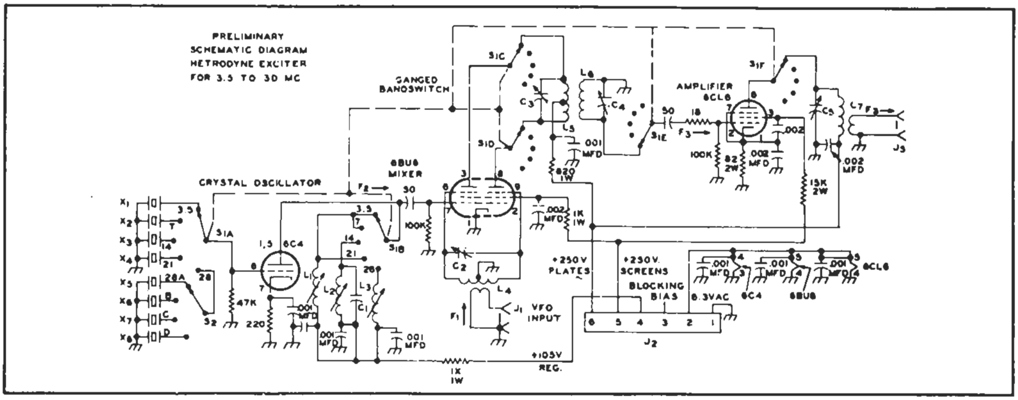

PRELIMINARY SCHEMATIC DIAGRAM HETRODYNE EXCITER FOR 3.5 TO 30 MC

Table I · PARTS LIST

C_1	150-mmf mica capacitor[1]
C_2, C_3, C_4	4--40-mmf adjustable mica trimmer capacitor [2] (ICA No. 611).
C_5	4--50-mmf air variable capacitor[2] (Hammarlund APC-50, or equivalent).
J_1, J_3	chassis type coaxial cable connector; or, midget phonotype jack.
J_2	6-pin power socket; or, 6-lug terminal strip.
L_1 to L_7	See (Table III) COIL TABLE for details.
S_1	6-pole, 5 position ceramic insulated rotary tap switch (Made from Centralab P-123 index assembly and three Centralab "R" shorting type wafers spaced to suit parts layout of exciter).
S_2	1 pole, 4-position ceramic insulated rotary tap switch (Centralab No. 2500 6-position switch with stop set for 4 positions).
X_1 to X_8	Quartz crystals; frequencies as indicated in Table II.

[1] Value across L_2 for 2-megacycle crystal, for 14-megacycle operation.

[2] Value required for 14-megacycle opeation; capacitance will be larger for 3.5 and 7 megacycles, and smaller for 21 and 28 megacycles.

TABLE III · COIL TABLE

(For 12-megacycle tunable oscillator and 14-megacycle output)

L_1	6---13 uh, coil scramble wound on 3/8-inch diameter combination iron/brass slug tuned coil form (Cambion LS-3, 10 MC coil).
L_2	30--70 uh coil scramble wound on same form as L_1. (Cambion LS-3, 5-MC coil).
L_3	1.5--3.0 uh, 18 turns, No. 24 enameled wire closewound 3/8 of an inch long on same form as L_1.
L_4	5.4 uh, 32 turns, No. 24 tinned wire spacewound 32 turns per inch, 1 inch long and 1/2 of an inch in diameter (air-dux No. 432) and centertapped with 2-turn link coil at center, wound with No. 20 insulated hookup wire.
L_5	2.8 uh, 18 turns, same coil stock as L_4, center tap.
L_7	2.8 uh, same as L_6 with 2-turn link at bypassed end, wound from No. 20 insulated hookup wire.

HETRODYNE VFO FOR 9-MC. SSB GENERATORS

There has been much interest in our publishing an article on constructing a hetrodyne VFO for 9-megacycle type SSB exciters, so that the proper injection frequencies for output on 1.8, 7, 21 and 28 megacycles (and even 50 megacycles) can be obtained from these exciters. Most persons now have suitable VFO's which they use to provide the proper injection frequencies (5.0 to 5.5 megacycles for operation of the exciter on the 3.9 and 14-megacycle bands.

The block diagram shows a suggested method of taking the output from a stable VFO tuning the 5.0 to 5.5-megacycle range (F_1) and feeding it into another mixer, into which a crystal oscillator signal (F_2) also is fed. The mixer output (F_3), either the sum or difference of the two input frequencies, is used as the injection frequency (F_3) into the SSB exciter. On the block diagram, all blocks above the dashed line are inside the SSB exciter. The signal designated F_4 is from the 9-megacycle SSB generator, and the F_5 signal is the desired output signal on the amateur bands.

An experimental hetrodyning unit for a stable 5-megacycle VFO has been constructed and is being tested on a Central Electronics 20A exciter. Details will be published in a future issue of G-E HAM NEWS.

Block Diagram of Hetrodyne VFO
For SSB Exciters with 9-megacycle Sideband Generator
(CENTRAL ELECTRONICS 10A, 10B and 20A,
Lakeshore and W2EWL Exciters)

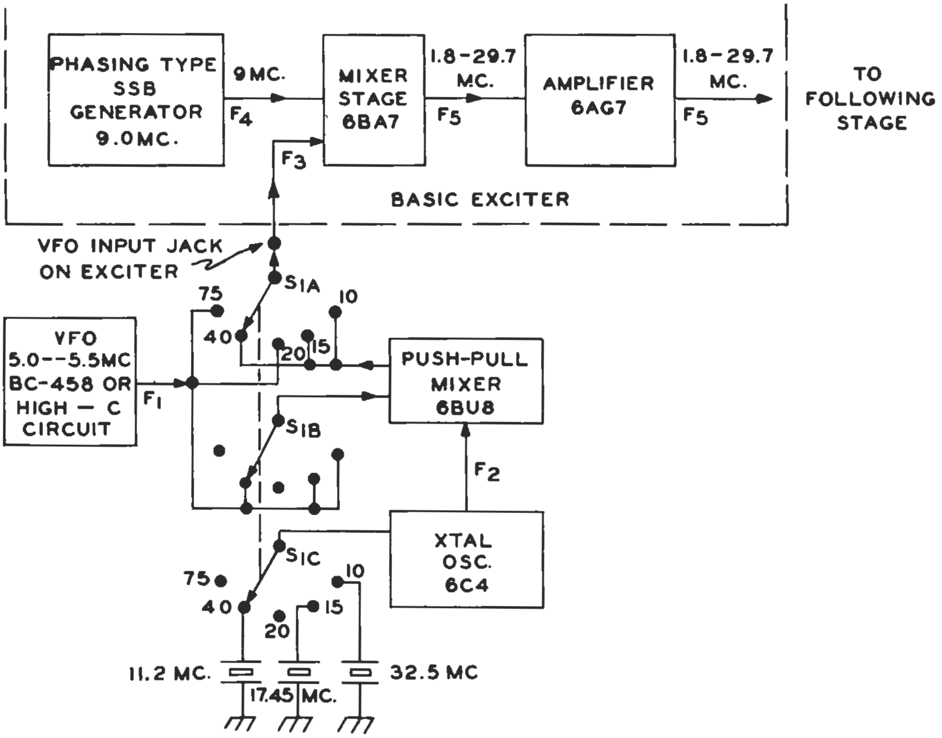


Table IV · FREQUENCY CHART

For Hetrodyne VFO for 9-megacycle Single Sideband Generators

OUTPUT BAND, MC. (F_5)	SSB GEN. FREQ. (F_4)	EXCITER INJECTION FREQ, MC. (F_3)	CRYSTAL OSC. FREQ, MC. (F_2)	TUNABLE OSC. FREQ, MC. (F_1)
3.5 -- 4.0	9.0	5.5 -- 5.0	None	5.5 -- 5.0
7.0 -- 7.3	9.0	16.0 -- 16.3	11.0	5.0 -- 5.3
14.0 -- 14.35	9.0	5.0 -- 5.35	None	5.0 -- 5.35
21.0 -- 21.45	9.0	12.0 -- 12.45	17.0	5.45 -- 5.0
28.0 -- 28.5	9.0	37.0 -- 37.5 (19.0 -- 19.5)	32.0 (24.5)	5.0 -- 5.5 (5.5 -- 5.0)
28.5 -- 29.0	9.0	37.5 -- 38.0 (19.5 -- 20.0)	32.5 (25.0)	5.0 -- 5.5 (5.5 -- 5.0)
29.0 -- 29.5	9.0	38.0 -- 38.5 (20.0 -- 20.5)	33.0 (25.5)	5.0 -- 5.5 (5.5 -- 5.0)
29.5 -- 29.7	9.0	38.5 -- 38.7 (20.5 -- 20.7)	33.5 (26.0)	5.0 -- 5.5 (5.5 -- 5.0)

OTHER IDEAS:

The basic hetrodyne exciter circuit has several possibilities, among them:

1. A hetrodyne exciter for CW or AM operation, as shown on the previous three pages.
2. A single sideband exciter, by adding a suitable sideband generator at the crystal oscillator frequency.
3. A hetrodyne VFO unit for use with filter or phasing type single sideband generators operating on a fixed frequency outside the amateur bands (such as 9 megacycles, used in the Central Electronics 10A, 10B and 20A, Lakeshore Phasemaster, and W2EWL exciter described in QST).
4. A hetrodyne exciter for the higher frequency amateur bands, such as 21, 28 and 50 megacycles.
5. A converter unit with which to convert a single sideband signal from an exciter with output on 14 or 21 megacycles, to the 50 and 144-megacycle amateur bands, making SSB operation practical on those bands.

These projects are being investigated by the G-E radio amateurs who build equipment and write articles for G-E HAM NEWS and will be reported in future issues.