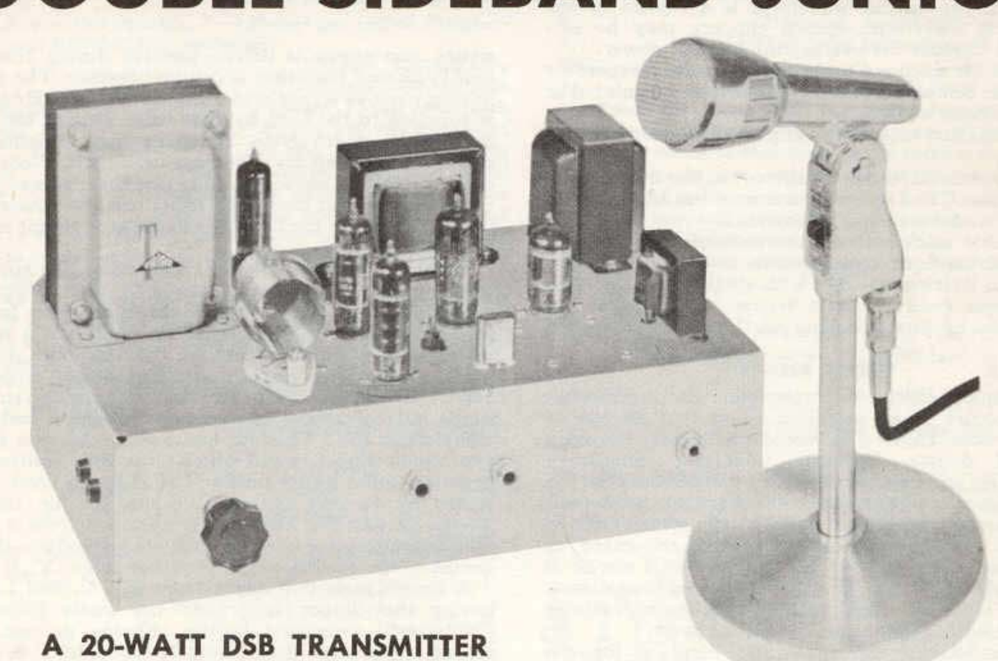
GE TUBES

HAM NEWS

SPECIAL REPRINT
OF MARCH-APRIL, 1958
(Vol. 13, No. 2) FOR

MARS
MILITARY AFFILIATE RADIO SYSTEM
U.S. ARMY • U.S. AIR FORCE

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*

CONTENTS

DOUBLE SIDEBAND JUNIOR

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

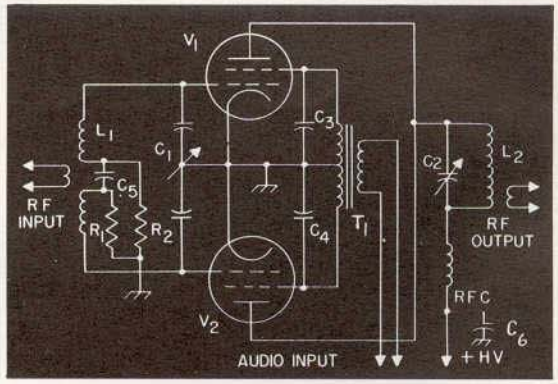


Fig. 1. Schematic diagram for the balanced modulator circuit used in most double sideband transmitter descriptions. Parts values are dependent on tube type and frequency.

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.

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_2) 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)

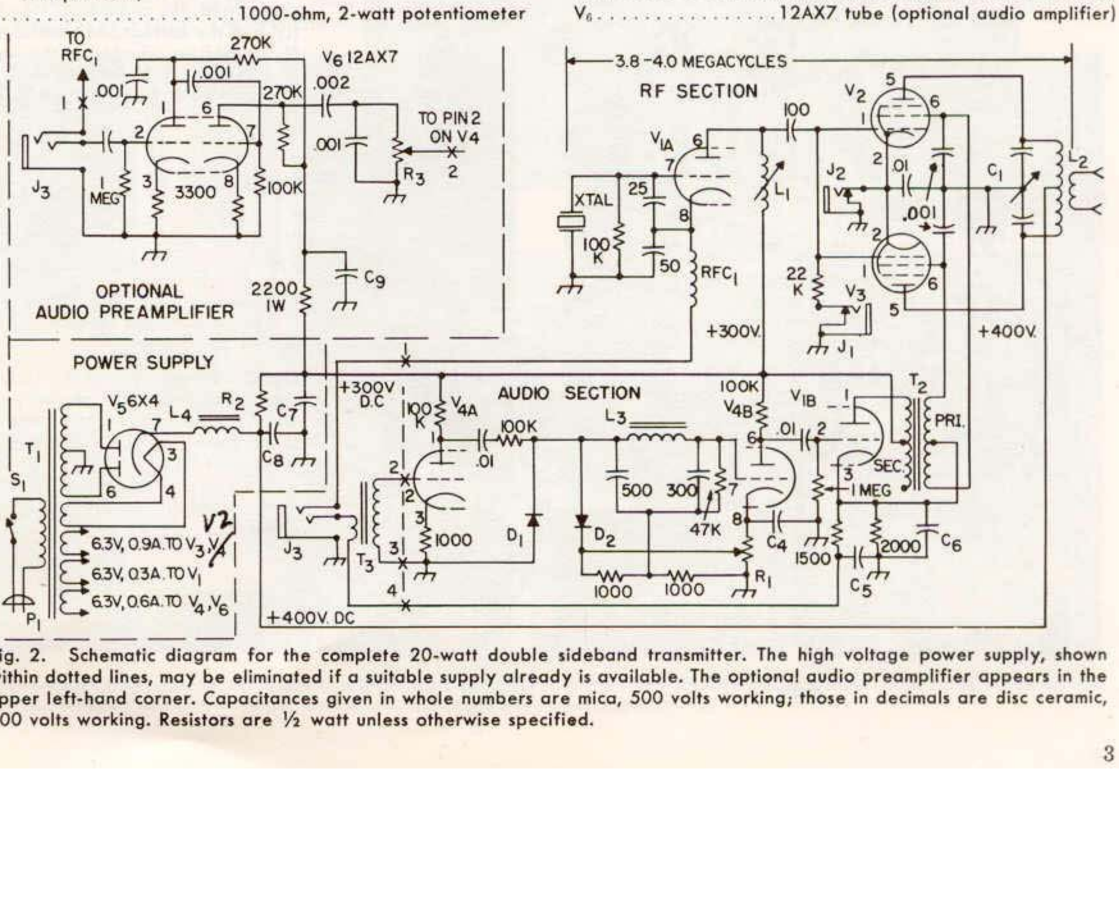
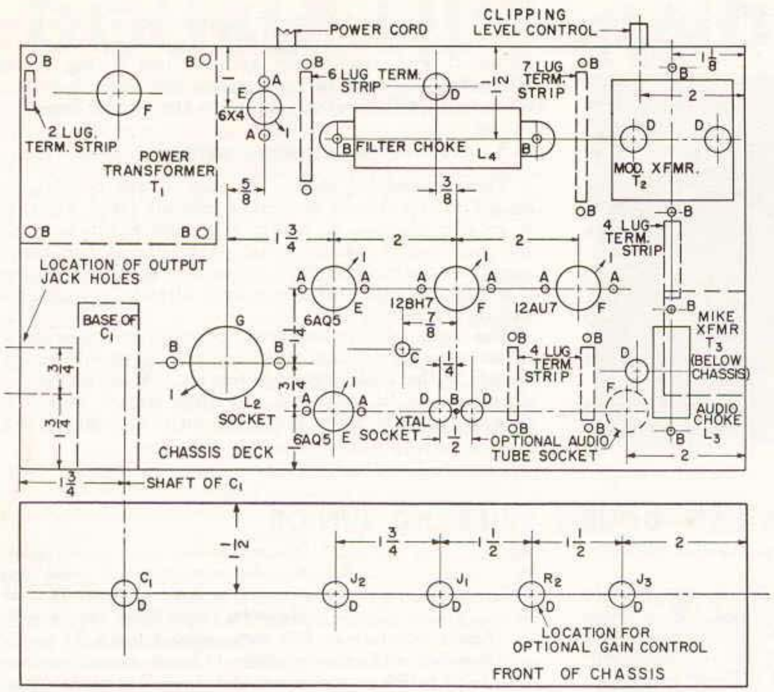


Fig. 2. Schematic diagram for the complete 20-watt double sideband transmitter. The high voltage power supply, shown within dotted lines, may be eliminated if a suitable supply already is available. The optional audio preamplifier appears in the upper left-hand corner. Capacitances given in whole numbers 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_3) are located as shown.

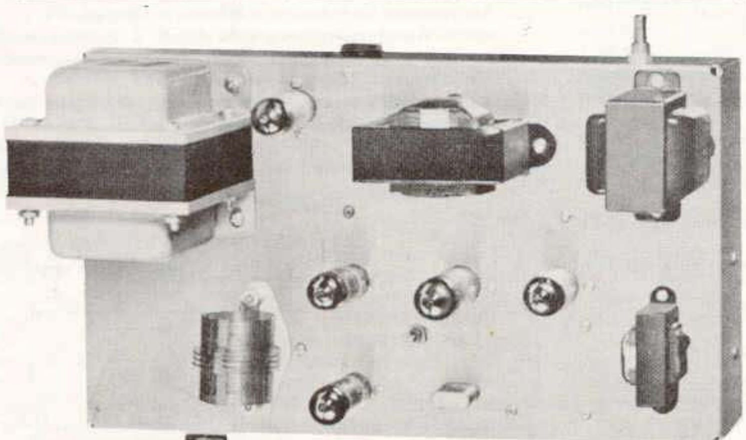


Fig. 4. Top view of the double sideband transmitter, showing the locations of major parts on chassis deck. Check to see that sufficient space is provided for components which differ in size and shape from those listed. The audio filter inductor (L_2) and the microphone transformer (T_3) should be oriented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

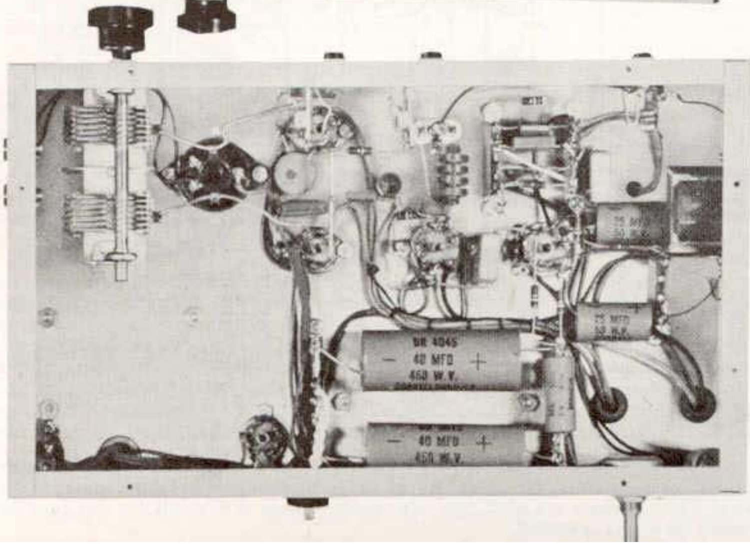


Fig. 5. Bottom view of the chassis, showing placement of smaller parts on the tube sockets and terminal strips. Power wiring is run in corners and across the center of the chassis. Wires carrying audio and RF voltages should be made as short as possible.

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.

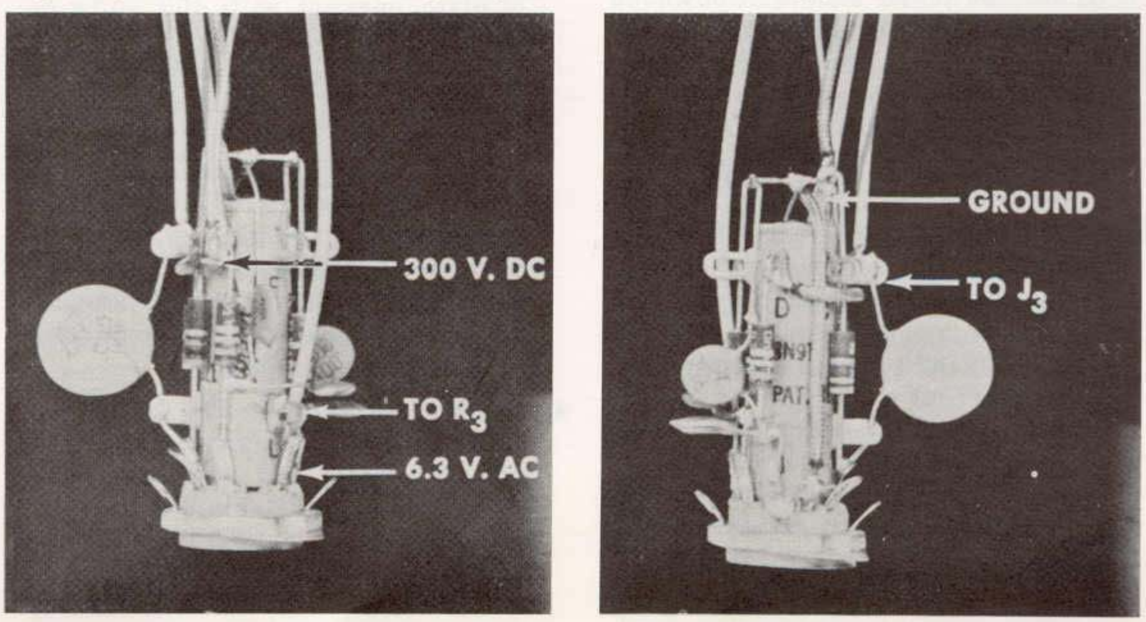


Fig. 6. Detail views of the audio preamplifier stage constructed on a turret type 9-pin miniature tube socket (Vector No. 8-N-9T). Terminals to which external connections are made have been labeled.

EXTRA 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.

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.

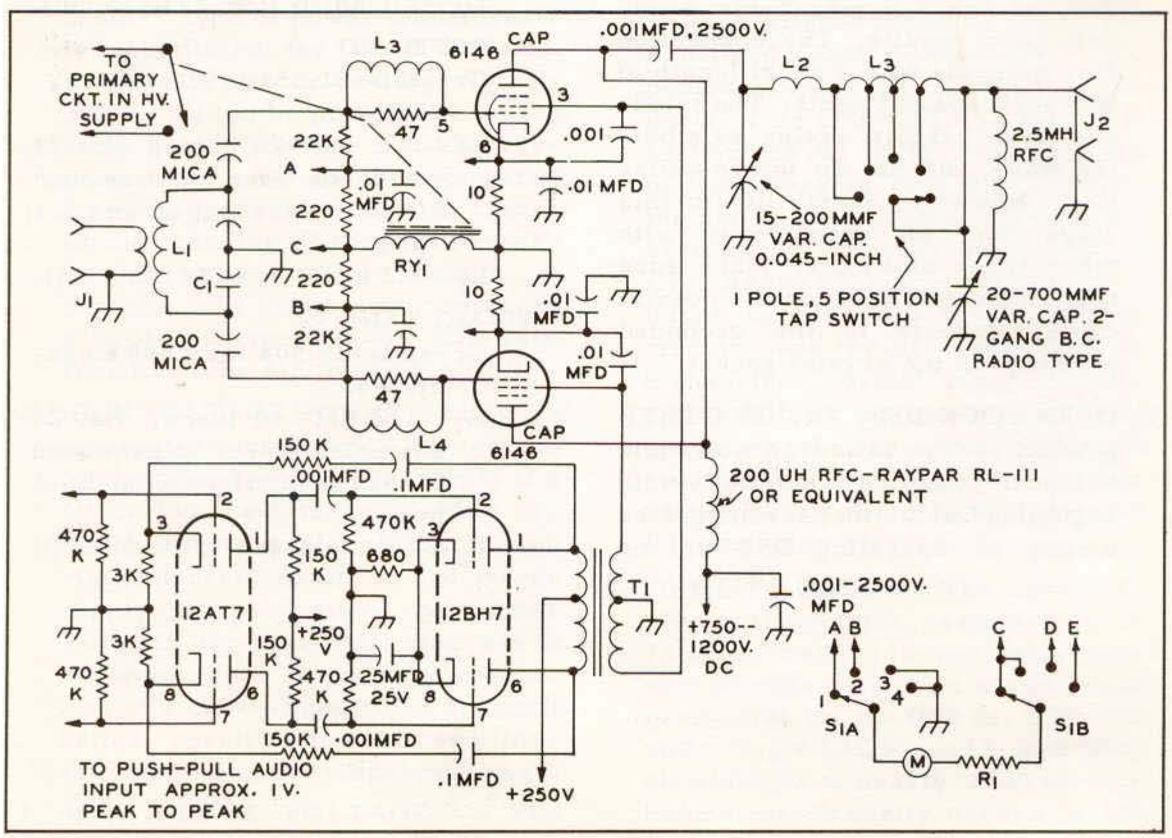


TABLE I — PARTS LIST

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, space-wound 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, space-wound 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, space-wound 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, space-wound 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 12)

DSB Considerations and Data

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.

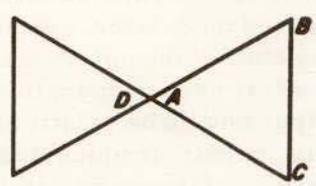
Since the plate current swing depends largely on the screen voltage swing, the best way to tune the DSB stage is not by plate current dip but by tuning for maximum output. With the tank circuit resonated, increase your loading to the maximum output point and stop. That's all there is to it. Some tank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

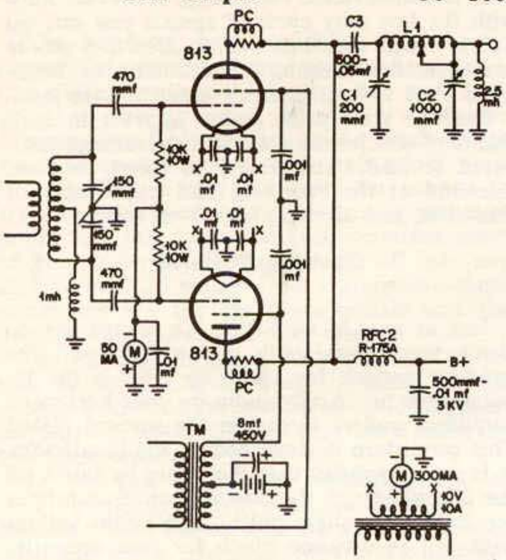
Just as in AM and SSB, it's always best to check your signal with an oscilloscope. The handiest pattern for checking DSB is the familiar bow tie. Apply audio on your horizontal amplifiers and rf direct on the vertical plates. This procedure is described in the handbooks. It is recommended that the audio 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 (Cont'd. from page 9)

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

[1] 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.