A Unique Suppressed Carrier Transmitter

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W8KP has constructed an experimental d.s.b. transmitter using a 6AR8 balanced modulator. The entire unit, described here, is nicely packaged on a Command transmitter chassis. The unit is ideal for use as a spare, emergency or mobile transmitter.

MANY writers are hesitant when it comes to writing articles about double sideband transmitters in the present era of single sideband. However, the described transmitter is unique and the author feels sure that many amateurs will be interested and may visualize many applications of the underlying principle.

Comparisons

There are a number of ways to look at suppressed carrier double sideband transmitters. One may compare the system with a.m., in which case it can be shown that for equal tube capacity, the system is equal to or equivalent to approximately two a.m. transmitters operating simultaneously with the advantage of economy and compatibility with single sideband. Or, one may further compare the system with single sideband techniques and observe that for all practical purposes it is only down approximately 3db when received on either of its two sidebands and this at reduced bandwidth. However, the comparison that the writer prefers is that it makes an excellent low cost "second car" and possesses, for emergency or mobile operation the assurance of being heard, regardless of the sideband position of the listener's receiver, plus economy and portability.

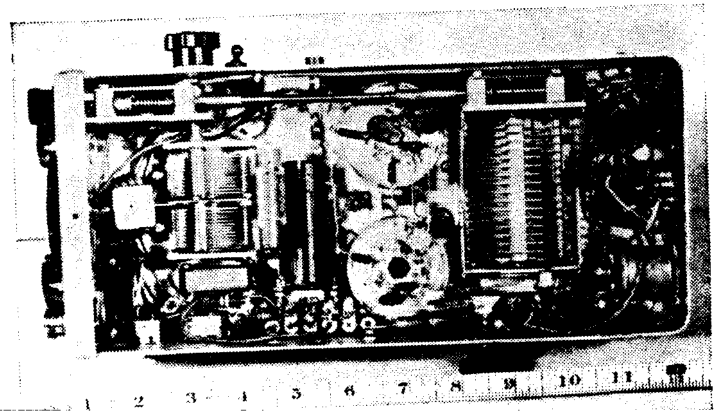
Circuit Analysis

As one can see from the schematic diagram the unit is composed of a total of six tubes (less power supplies). Namely, the oscillator (3-4 mc), using the original 1626 as found in the BC-696 Command transmitter, a 6AR8 balanced modulator, a pair of 6550's (Hi-Fi audio tubes) and finally a pair of 12AX7's for the entire audio system.

The selection of tubes may concern some readers. But let's make it clear that the described transmitter is experimental and was originally intended for single band operation for the purpose of simplifying portable amateur equipment. The 6AR8 was selected to eliminate the necessity for a buffer between the oscillator and balanced modulator and further, that it requires practically no audio power as the audio energy merely deflects the electron beam by electrostatic fields. The 6550's were selected for the final as they are ideal for linear amplifier applications and capable of 100 watts average power in class AB1 operation with 600 volts on the plate. The relatively low plate voltage reduces power supply requirements. It is interesting to note, and possibly you have already guessed, three of the tubes may be transistorized, i.e., the oscillator, and the audio tubes which of course, would further reduces the overall size and weight.

Multiplication

How does the system multiply the reference frequency without a multiplication of the sideband components? The answer to this question is incorporated in the inherent characteristic of



Bottom view shows location of the two gang tuning capacitor for the balanced modulator plate tank on the left. To the right of it is the modulator plate coil, 2 sections of B&W coil stock. The 6AR8, shielded, is just to the right of the coil. The neutralizing capacitor is located between the two 6550 sockets.

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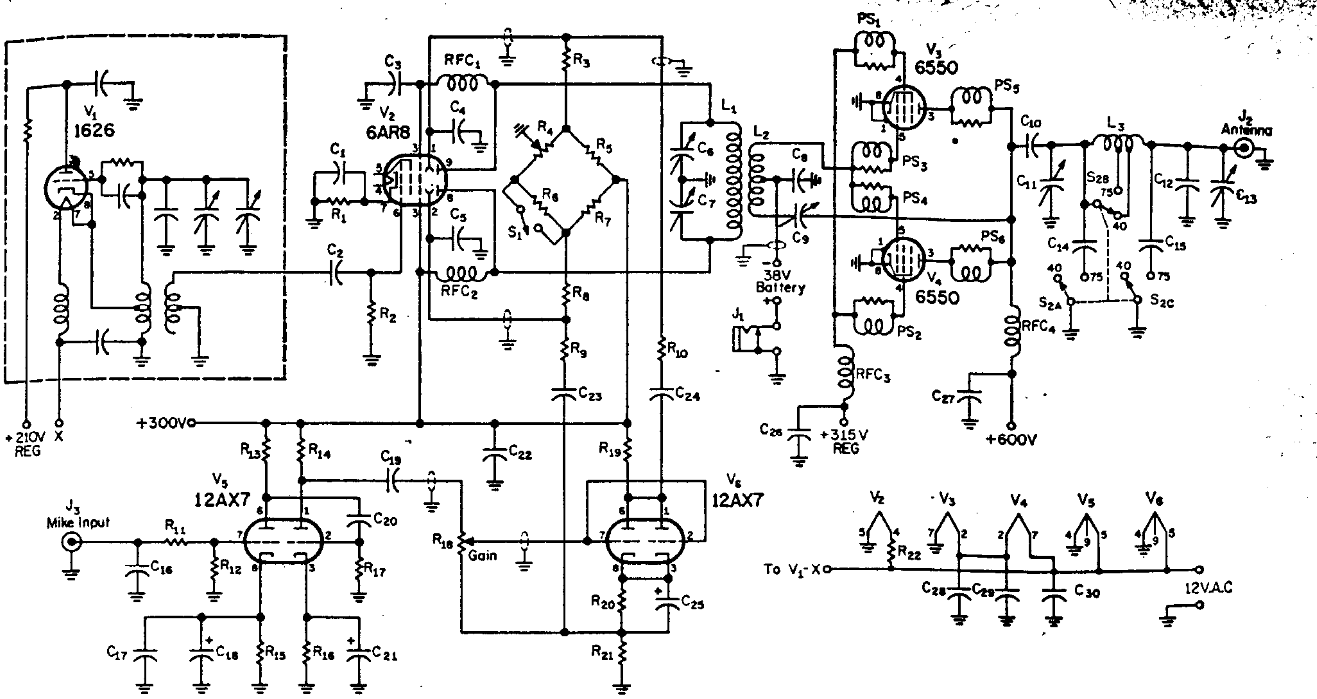


Fig. 1—Circuit of a d.s.b. transmitter built around a Command set. The 6AR8 tank circuit can tune to 80, 40 and is not too efficient from 9 to 12 mc.

C_1—.01 mf
C_2—500 mmf
C_3—.01 mf
C_4—100 mmf
C_5—100 mmf
$C_{6, 7}$—420 mmf two gang variable
C_8—.01 mf
C_9—1.5 to 5 mmf, Johnson 5M11
C_{10}—500 mmf
C_{11}—200 mmf variable
C_{12}—500 mmf
C_{13}—200 mmf variable
C_{14}—100 mmf
C_{15}—500 mmf
C_{16}—100 mmf
C_{17}—.005 mmf
C_{18}—5 mf, 25 v.
C_{19}—.005 mf
C_{20}—.005 mf
C_{21}—5 mf, 25 v.
C_{22}—.01 mf
$C_{23, 24}$—.0015 mf
C_{25}—5 mf 25 v.
C_{26}—.002 mf
C_{27}—.01 mf
C_{28}—.005 mf
C_{29}—.005 mf
C_{30}—.005 mf
R_1—390 ohms
R_2—10K
R_3—150K
R_4—5K pot.
R_5—220K
R_6—50K
R_7—220K
R_8—150K
$R_{9, 10}$—10K
R_{11}—4700 ohms
R_{12}—1 megohm
$R_{13, 14}$—500K
$R_{15, 16}$—4.7K
R_{17}—500K
R_{18}—500K pot.
R_{19}—56K
R_{20}—2.4K
R_{21}—56K
R_{22}—21 ohms
RFC_1—2.5 mh
RFC_2—2.5 mh
RFC_3—5 to 10 μh
RFC_4—1 mh, 600 ma, National 154-U
PS $_{1}$ to $_{6}$—Type used in command transmitter
L_1—53t, ½" diam. B&W (32 tpi)
L_2—27t, ⅝" diam. B&W (32 tpi)
L_3—Antenna tuning coil from BC-459
11t for 40M.
16t for 75M.

the 6AR8 Balanced Modulator.

As most amateurs know, the energy delivered from the oscillator tube in the command transmitter represents a considerable power level (3-4 watts). For example, in the original design of these transmitters the oscillator was capable of driving a pair of 1625 (807's) into Class C operation with the 1625's self-biased with a 15K grid resistor. The grid current of the 1625's was well above 5 milliamperes. Let's say for our purpose the value was exactly 5 ma. This value of current through the 15K grid resistor represents 75 volts. So one notes immediately the 6AR8 is being driven into the positive grid area and thus into a form of class C operation. The positive grid current waveform takes on the shape of a pattern some place between an ideal rectified sine wave pulse and a hybrid square wave due to clipping. A Fourier spectrum analysis indicates immediately that the harmonic content increases to relatively large values and almost equals the strength of the fundamental energy on the desired harmonics.

Thus the electron beam of the 6AR8 contains more than a single frequency. In this particular experimental unit the fundamental, 3-4 mc, and the second harmonic 6-8 mc, were very strong while the 9-12 mc energy was lower due to the unfavorable L/C ratio (at these frequencies) in circuit.

Modulation

The reader must keep in mind these frequencies are contained within the beam of the 6AR8 and represents beam intensity. Due to the structure of the tube the audio is applied on two electrodes whose action is purely a deflection technique of the beam similar to the deflection plates of an oscilloscope. They do not change the intensity of the beam but add, through the plate tank of the 6AR8, the audio energy on a one to one basis, simultaneously to each frequency present in the beam. The output circuit of the 6AR8 is used for selecting the desired frequency band.

Construction Details

It was not the intention of the writer to devise another modification for Command transmitters but the chassis lent itself very well to the construction of the experimental transmitter.

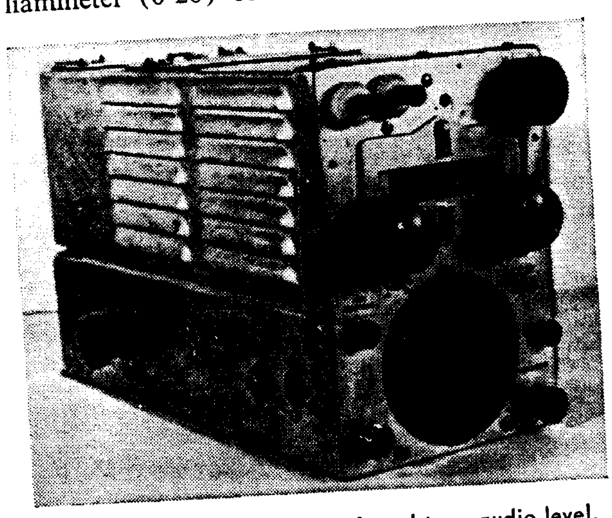
The oscillator system is very stable if one regulates the plate voltage. No other changes were made in this section. It may be of interest to some readers that in many of the Command transmitters the oscillator variable capacitor is constructed with invar plates. Invar has a very low temperature coefficient of expansion and while expensive, is ideal for stable oscillators. One may determine if the unit is so constructed by checking the plates with a permanent magnet.

It is worthwhile to select oscillator tubes; many of the 1626's are rather bad drifters; but it is not difficult to find one, out of several, that performs with good stability. The stability is important because in this circuit the reference frequency is multiplied and the higher the multiplication the more important the stability requirement. A 12A6 works quite satisfactorily and the socket connections require only a slight modification. By grounding pin #1 the metal shield of the 12A6 becomes effective and eliminates "hand" effect commonly experienced because of the glass envelope of the 1626's.

The excitation of the balanced modulator (6AR8) is obtained by using one-half of the original excitation coil as may be observed in the schematic.

Balancing

The resistive network composed of 150K, 50K, (normally shorted), 5K (variable), 150K, 220K resistors as shown in the schematic are for the purpose of extablishing equal d.c. potentials on the audio deflectors to eliminate the carrier. The variable resistor, 5K, is adjusted for maximum carrier rejection by observing a milliammeter (0-20) connected in series with the



The controls on the side are, from l to r; audio level, carrier rejection and 2 circuit connector for an antenna relay. The front panel controls are; lower right, oscillator tuning; center right, final tank capacitor; upper right, pi-network bandswitch; lower left, mike input connector; center left, loading capacitor; upper left, antenna terminals.

6550's gried return circuit. The 6550's, during this adjustment, have the filaments operating but without control grid, screen or plate voltage applied. The correct setting for the 5K resistor is for a minimum deflection. The experimental transmitter indicated practically zero grid current under these conditions. Greater carrier rejection is possible by the incorporation of a phase adjustment in addition to the amplitude control. However, measurements indicated approximately 40 db rejection of the carrier so a phase adjuster was not incorporated in the experimental transmitter. To this date no listener, during several months on the air tests, was able to report hearing the carrier.

The switch shown across the 50K resistor is used to unbalance the d.c. potential on the audio deflectors to shift the electron beam to one plate of the 6AR8 thereby producing a carrier signal for determing in the correct setting of the pi-network for the antenna system and signal frequency used.

The photographs clearly show the radio frequency transformer that couples the 6AR8 to the Class AB1 6550's linear amplifier. The ⅝ inch B&W. Miniductor Coil is carefully slid over the ½ inch B&W Miniductor.

As noted in the schematic diagram the linea[r] amplifier operates with 600 volts on the plate 315 volts on the screen, and approximately 3[…] volts (negative) bias from a battery source. Th[e] fixed capacitors shown by dotted lines in the pi network are switched into the network whe[n] operating on the 75 meter phone band. Th[e] values selected are designed for optimum op[…] erating condition into a dipole antenna of ap[…] proximately 75 ohms impedance.

The audio system is self explanatory but f[or] those interested the microphone used was [a] Model 729 Ceramic Cardioid manufactured [by] Electro-Voice, Inc.

Balanced Modulator Adjustments

One may quickly observe that the oscillat[or …] balanced modulator and the audio system [a…] working satisfactorily by observing the g[rid] current flow through the grid return circuit [of] the 6550's. The current is observed with [the] grid bias, plate and screen voltages disconnec[ted] from the linear amplifier and with the swi[tch] across the 50K resistor in the open position. [The] tuning adjustment, under these conditions, [of] the balanced modulator is for maximum [grid] current flow. (Approximately 11-12 ma for 40 meters and 12-13 ma on the 75 meter ba[nd.)] Following this adjustment, the switch (ac[ross] the 50K resistor) is closed and the ampli[tude] balance adjustment (carrier rejection) is [m…] for minimum grid current flow. No furthe[r ad-] justments will then be required. If one de[sires] at this phase of the testing, the signal qu[ality] may be checked in a monitoring receiver.

The balanced modulator tank circuit, fo[llow-] ing its adjustment for maximum grid cu[rrent] flow, will not require further adjustment u[nless] the operator desires to exceed a band

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coverage of ± 5 kc in which case, a slight adjustment will be required and may be made by observing the maximum average plate current reading on the linear amplifier with carrier temporarily inserted.

Neutralization

Before any attempt is made to excite the linear amplifier, it is of utmost importance to adjust the neutralizing capacitor. This adjustment is made using a radio frequency galvanometer (a diode shunted across a sensitive 0-500 microammeter movement) connected across the output terminals of the pi-network (antenna connection). The procedure is as follows: Set the oscillator to 7.25 mc. (Dial setting, 3.625 mc.) Plate, screen and bias voltages are disconnected (short out battery connection points) and, *most important,* the heater circuits to the 6550's must be disconnected.

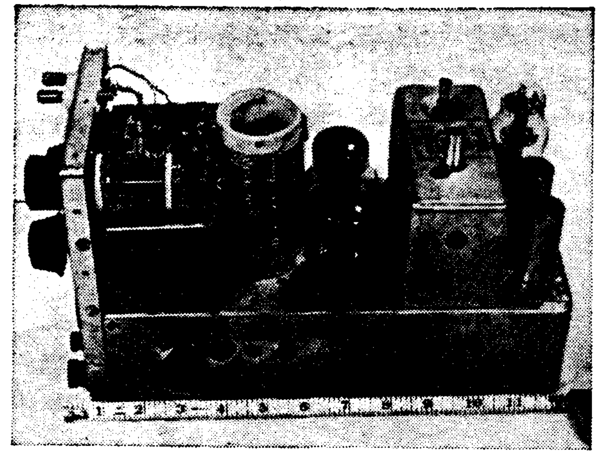
Just prior to disconnecting the 6550's heater circuit the balanced modulator tank is peaked for maximum drive by checking for maximum deflection with a 0-20 ma meter in the grid return circuit. The pi-network is also adjusted, observing the radio frequency galvanometer for maximum deflection, and at the same time being careful not to damage the movement by excessive deflection. Now disconnect the filaments of the 6550's. The neutralizing capacitor is then adjusted for minimum deflection on the r.f. galvanometer. This adjustment should result in a meter deflection very close to zero. Now check the system by varying the oscillator between 7.2—7.3 mc during which the galvanometer should remain very close to zero. Readjust the balanced modulator circuit to the 75 meter band (3.8—4 mc) and check the neutralization on this band. The system should still be satisfactorily neutralized.

The next step is to replace the heater circuits, plate, screen, and grid voltages. Place a 100 watt lamp across the antenna terminals as a dummy load. With no carrier inserted the idle plate current should be approximately 75 to 85 ma. With carrier inserted the plate current should rise to between 300 to 325 ma. Always check the tuning adjustment (excitation) of the balanced modulator for maximum power output, of course, not to exceed a maximum of 325 ma.

The tuning of the pi-network is conventional. Should minimum plate current and maximum power output not occur at the same point on the tuning dial, the linear amplifier is incorrectly neutralized. Recheck the neutralization procedure and the difficulty will be eliminated.

Frequency Modulation

At this point in the testing program it is advisable to make a check for frequency modulation difficulties. It is doubtful if oscillator pulling will be experienced because of the type of tube structure (6AR8) and technique involved in the modulation process. However, it is advisable to check the loading effect of the power amplifier because of a change of plate current from 85 ma



Controls on the side flange are, from l to r; balanced modulator tuning (upper mark is 40 m and lower 75), carrier insertion switch, 6550 grid return jack. Tuning capacitor on the left is for the final and the switch directly above is the bandswitch for the pi-network. The pi-network coil (standing upright) is salvaged from a BC-459. To the right of the coil are the two 6550's. The tubes on the right are from f to b; 12AX7, 12AX7 and 1626. The plate r.f. choke is mounted directly behind the pi-network coil and is not visible.

to 325 ma represents a husky variation in load. This check is accomplished by inserting the carrier, adjusting the transmitter to maximum power output into a dummy load (100 W lamp). With a stable receiver, Zero beat the transmitted signal. Vary the output by varying the drive. Varying drive is accomplished by a slight adjustment of the balanced modulator output tuning capacitor. If no change in frequency is observed everything is satisfactory. Should some deviation be noted, the main power supply is possibly causing trouble through the power mains, affecting the plate voltage to the oscillator. An improved power main or better voltage regulation of the oscillator is required to correct this type of frequency deviation.

Operating

A few words should be mentioned regarding the general operating procedures on the air. While utilizing the 75 meter phone band, the frequency dial is read directly in accordance with its original frequency calibration. After the operator has selected the frequency of transmission (75 meter phone band) and the required switching is accomplished, the class AB1 stage with no grid drive indicates a plate current of approximately 85 ma. Carrier is inserted momentarily and the drive and pi-network are adjusted. The carrier is then suppressed by turning the CARRIER INSERTION switch to the off position. Talking into the microphone circuit then produces the suppressed carrier double side band signal.

The 40 meter operation is similar however, the pi-network components are changed by the pi-network switch for this particular band.

The balanced modulator is tuned to the new

[*Continued on page 106*]

For further information, check number 25, on page 126

Tube Tester *[from page 47]*

adjusted so that the listed plate current value is not exceeded. The shunt control and the bias (control "R") setting required for a GOOD indication should be recorded for future use.

Construction

The actual construction, physical size and tube sockets used will depend on your own requirements. Use of loctal and acorn tubes might not be anticipated as well as the large 7 pin tubes such as the 829B or 832. Subminiature sockets might be included. An extra set of banana jacks might be added for GRID 3 if desired.

The unit was constructed on a sheet of aluminum 6″ x 9″ but might also be built on a strong phenolic or bakelite sheet. This would eliminate the need of insulating the banana jacks.

Locate and mount the banana jacks as shown in the schematic of fig. 1. When the aluminum chassis is used be sure to insulate the jacks and employ grommets for the grid leads. Number and label all the leads and jacks with decals. Also be sure to make the leads long enough to reach any of the jacks on the panel. ■

Suppressed Carrier *[from page 51]*

frequency for the drive requirements.

The frequency dial calibration must now be multiplied by a factor of two in which cast the settings for the 40 meter phone band extermities reference to the dial would be 3.6 to 3.65 mc.

In closing, may I suggest some interesting experiments others may desire to try. For example, the shorting of the 50K resistor inserts carrier for tuning purposes and with the addition of a keying relay or a change in potential balance of the beam deflecting electrodes by a small dry battery and resistive network for this function the procedure may be used for c.w. operation.

Another experiment would be to use a 7 mc BC-459 Command transmitter chassis for the construction of a three band d.s.b. transmitter. The original frequency range of the BC-459 adequately covers the 40 meter band, the × 2 multiplication covering the 20 meter band, and the × 3 multiplication covering the 15 meter band. Two points will require further consideration than was necessary on the above experimental transmitter. First, the oscillator stability requirement is a little more severe because of the × 3 multiplication factor on the 15 meter band and a second frequency spread control for the oscillator would be required to provide adequate dial frequency change on the 20 and 15 meter bands.

Upon the examination of the Fourier Analysis made for a thin pulse, it was seen that harmonics appear infinite in number and of equal size. It would be interesting to drive a balanced modulator of the 6AR8 type and study the limitations of such a unit and examine the possibilities of continuous frequency coverage from a single variable frequency oscillator. ■