An S.S.S.C. Transmitter Adapter

An Exciter Using the "Phasing" Principle

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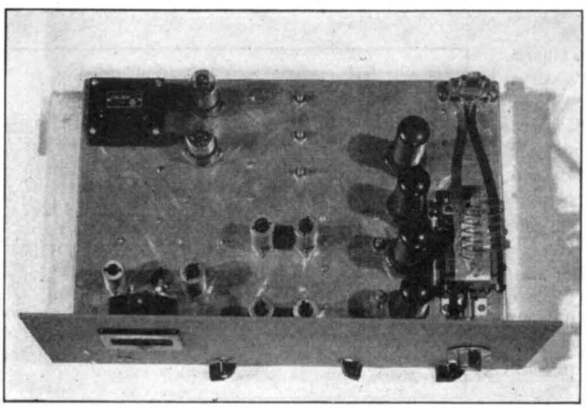
• S.s.s.c. operation can be added to an existing c.w. or 'phone transmitter by inserting an adapter unit between the present exciter portion and the final amplifier stage. The adapter described in this article has output power to spare when driving a beam-tetrode final amplifier to one-kilowatt input. No expensive or unduly critical components are required; circuit-adjustment procedure is within the capabilities of the average amateur who "builds his own." The circuit details were derived and the adapter unit was constructed in the *Radio Handbook* laboratory.

The use of single-sideband suppressed-carrier transmission for amateur radiophone operation offers many advantages,[1] both to the station using this method of transmission and to the amateur fraternity as a whole. The fact that an s.s.s.c. station requires slightly less than one-half the spectrum in kilocycles as compared to a conventional a.m. station transmitting the same audio-frequency range is of basic importance. Further, the absence of a carrier in an s.s.s.c. signal means that the bedlam of heterodynes between carriers on the amateur 'phone bands can be eliminated. True, the carrier heterodynes would be replaced on a band loaded with s.s.s.c. signals by heterodynes between sidebands. It is difficult to visualize how such a band might sound. But certainly the duty cycle of interference under such conditions with the same number of stations operating would be greatly reduced. Each station would be transmitting a signal only at the particular instant when the operator was talking. The amplitude of signal transmitted could be, particularly when duplex operation was in use, only that amount necessary to sustain communication. Since the power output of an s.s.s.c. transmitter is proportional to the signal level, it is only necessary to reduce the gain setting on a kilowatt station to cut the peak power output down to perhaps 20 to 50 watts, if this amount is all that is required to sustain good communication. There would be neither need nor justification for an "S9-plus-40-db." signal when the level of interference was far below this value.

From the point of view of the station operator, the s.s.s.c. system offers many additional advantages. In the first place, the additional investment required to convert a c.w. station to s.s.s.c. is modest. An adapter unit such as described later on may in many cases be constructed almost in entirety from components found around the average ham shack. Second, the use of s.s.s.c. gives a very marked increase in the maximum effectiveness of a particular transmitter, even when that transmitter is already running a kilowatt with high-level plate modulation. And third, s.s.s.c. is very easy on the power bill. The average power taken by the final plate supply even of a kilowatt (peak) transmitter during a period of transmission will probably be found to be less than that required by filaments and low-voltage power supplies. Of course, the use of speech clipping in connection with s.s.s.c. transmission would alter this picture somewhat, but the total power requirement would still be materially less than that

*Editor, *Radio Handbook*, Santa Barbara, Calif.

[1] Donald E. Norgaard, "What About Single Sideband?" *QST*, May, 1948.



The s.s.s.c. exciter unit used at W6DHG will drive a pair of beam tetrodes to 1-kw. peak input at 14 Mc. The exciter shown is complete except for the frequency-control unit and a power supply for the four 6L6s.

required for high-level plate modulation of the same transmitter.

An additional advantage of s.s.s.c. transmission, and this must be chalked up as tentative until proven, is that BCI *seems* to be reduced when changing from conventional a.m. to s.s.s.c. with a comparable peak power level. If this is found to be fact, it will be because the effective modulation percentage of the signal emitted by an s.s.s.c. transmitter is somewhat lower than that of a 100%-modulated conventional a.m. transmitter. Also, the BCL will be unable to understand what is being said!

There are at least two basic methods of generating an s.s.s.c. signal. The first might be called the "brute-force" method or the "classic" method. This consists of generating a double-sideband suppressed-carrier signal at a frequency low enough so that one sideband may be removed by filters. This method has been in use by the telephone company for many years, and was first reported in use by amateur station W6DEI in 1933.[2] A modernized and improved system has recently been described by WØTQK.[3]

The second system might be called the "phasing" method (or the system with finesse). It consists essentially of two balanced modulators whose outputs are combined, operating 90 degrees out of phase both with respect to r.f. and a.f. It has long been known as a mathematical exercise but has not been completely practicable as a method for the transmission of a speech or music signal because a simple method was not known for the introduction of a constant phase shift of 90° into a band of audio frequencies. This situation was rectified by Dome in 1946 [4] with his disclosure of a method for obtaining such a phase shift over an audio-frequency band. A detailed discussion of this system has been given in *QST*.[5]

Obtaining the R.F. Phase Shift

The phase-shift method of obtaining an s.s.s.c. signal requires in essence that quadrature audio and quadrature r.f. be fed to two balanced modulators whose outputs are combined. The r.f. signal fed to the balanced modulators can be at the actual frequency upon which it is desired to operate the transmitter. Theory teaches us that a quadrature relationship may be obtained by the use of two coupled circuits, both resonant at the operating frequency. Such a system is adequate, and has been used in several s.s.s.c. transmitters, but it has the disadvantage that both circuits must be carefully tuned to obtain the proper 90° phase shift. Then, with VFO operation, if an appreciable change in the frequency of operation is desired the two circuits must be retuned to obtain the proper phase shift again.

The circuit arrangement diagramed in Fig. 1 uses a low-Q arrangement to obtain the phase shift, and once properly adjusted for either the 4- or 14-Mc. 'phone band it will stay sufficiently close over the entire band. As can be seen from Fig. 1, two *RC* networks and two *RL* networks are used to obtain the "four-phase" r.f. signal needed to excite the grids of the two balanced modulators. The center-tapped coil, L_3, provides two signals with a 180° phase difference. The two *RC* networks are then used to obtain a 45° voltage phase lag from the 180° signals, and the *RL* networks are used to obtain a 45° voltage phase lead. The 45° phase shift in each case is obtained by making the resistance equal in value to the reactance with which it is in series. Or rather, as a practical matter, the four series resistors are made all the same value and then the net reactances in each of the four branches are made equal to the resistance value. Other broadband methods of obtaining the polyphase r.f. signal may suggest themselves, but the method described has proven to be the most satisfactory of those tried.

Since the *RC* combinations introduce a voltage phase lag of 45° from each end of the coupling coil L_3, the two grids being fed by the *RC* networks (R_1C_2 and R_2C_3) are being fed 180 degrees apart with respect to each other. Then, the *RL* networks (R_3L_4 and R_4L_5) introduce a phase lead of 45°, but again the two grids being fed by these networks have a 180° phase relation with respect to each other. Hence, the net phase difference between the pair of grids being fed by *RC* networks and the pair being fed by the *RL* networks is 90°. In this way we meet the requirement of having two balanced modulators operating with an r.f. phase difference of 90 degrees.

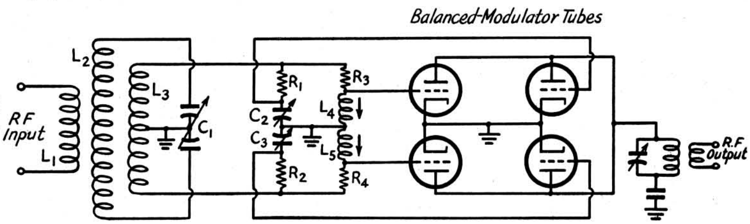


Fig. 1 — Schematic of the r.f. phase-shifting system.

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[2] Robert M. Moore, "Single-Sideband Transmission," *R/9*, Sept.-Oct., Dec., 1933, Jan.-Feb., 1934.

[3] Arthur H. Nichols, "A Single-Sideband Transmitter for Amateur Operation," *QST*, Jan., 1948.

[4] R. B. Dome, "Wideband Phase-Shift Networks," *Electronics*, Dec., 1946.

[5] Donald E. Norgaard, "A New Approach to Single Sideband," *QST*, June, 1948.

Obtaining the Proper Reactance for the Networks

Fig. 2 shows the actual manner in which the proper value of shunt reactance is obtained from grid to ground on each of the four grids of the balanced modulators. The 6L6 tubes used have an effective value of input capacitance of approximately 11 μμfd. This value of capacitance is ndicated by C_i in Fig. 2. The reactance of this

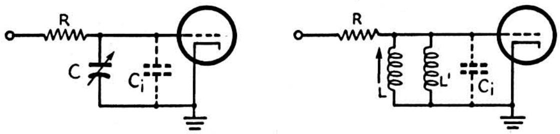


Fig. 2 — **Detail of the resistance-reactance networks used to feed the grids of the balanced-modulator tubes. C_i represents the input capacitance of the tube plus distributed capacitance. C adds to this capacitance in the case of the RC networks. In the case of the RL networks C_i must be neutralized by equivalent inductance L^1, which is a portion of the inductance, L, from grid to ground.**

amount of capacitance is low enough at amateur-band frequencies so that it must be taken into account in the calculation of the values of reactance that will be included in the circuit from each grid to ground. In the case of the *RC* networks, additional capacitance is simply added to the existing input capacitance of the tubes until the proper total value is obtained. However, in the case of the *RL* networks the input capacitance, C_i, of the tubes must first be neutralized by placing the proper amount of inductance from grid to ground, and then an additional amount of inductance is included in parallel with the resulting combination so that the net input reactance of the tubes is inductive and has a value of reactance equal in magnitude to the resistance from which the combination is being fed. In practice the two values of inductance L and L' from grid to ground are lumped into a single inductor which uses a tuning slug to allow adjustment of the net value of inductance.

Obtaining the Proper Audio Phase Shift

As was mentioned before, it is necessary that one balanced modulator be fed with an audio signal having a phase difference of 90 degrees with respect to the audio signal fed to the other balanced modulator. In the case of a system for the transmission of speech, such as is the transmitter unit to be described, this means that the audio signals fed to the two balanced modulators must have a constant phase difference of 90 degrees over the entire speech range to be transmitted.

In the equipment to be described this requirement is met through the use of the audio phase-shift method of Dome,[4] which has been mentioned. Fig. 3 is a schematic drawing of the audio phase-shifting stage in the s.s.s.c. adapter unit. Single-phase audio from the speech preamplifier is fed to the grid of the "hot-cathode" phase inverter. The plate and cathode of the phase inverter are coupled to the two audio phase-shifting networks. The signals obtained from the output terminals of the phase-shift networks have a constant phase difference quite close to 90 degrees over the speech frequency range of approximately 125 to 3000 cycles.

Block Layout of the S.S.S.C. Adapter Unit

Fig. 4 is a block diagram of the complete s.s.s.c. adapter unit. The r.f. circuit of the unit is quite simple, but a total of 11 tube elements in 6 tube envelopes is required to generate the proper audio signal and to impress this signal on the control grids of the r.f. balanced-modulator stage. Included in Fig. 4 is a group of numbers that represent the approximate peak audio-signal level at each stage when the volume control is at maximum and an input peak voltage of 10 millivolts is fed to the microphone jack. In practice the crystal microphone used with such a unit will have an output voltage several times this value with normal talking; hence it will be possible to reduce the setting of the volume control and still have adequate signal gain.

The input stage of the speech amplifier is quite conventional and uses a 6AU6 tube. All the other stages of the speech amplifier use sections of the Type 12AU7 tube. This tube type actually is a pair of 6C4s in a single miniature envelope having the new 9-pin base. Three leads are brought out so that the heater may be run from either a 6.3- or 12.6-volt source. Type 6SN7GT tubes could just as well have been used in each of the circuit positions where a 12AU7 is shown, but a 6SN7GT requires twice the heater power of a 12AU7.

The second stage of the audio system is a voltage amplifier that feeds through a simple low-pass audio filter having a cut-off of about 2800 cycles. The output of this filter is connected directly to the grid of the phase inverter that

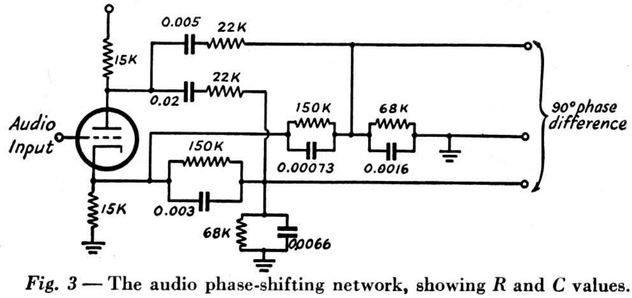


Fig. 3 — **The audio phase-shifting network, showing *R* and *C* values.**

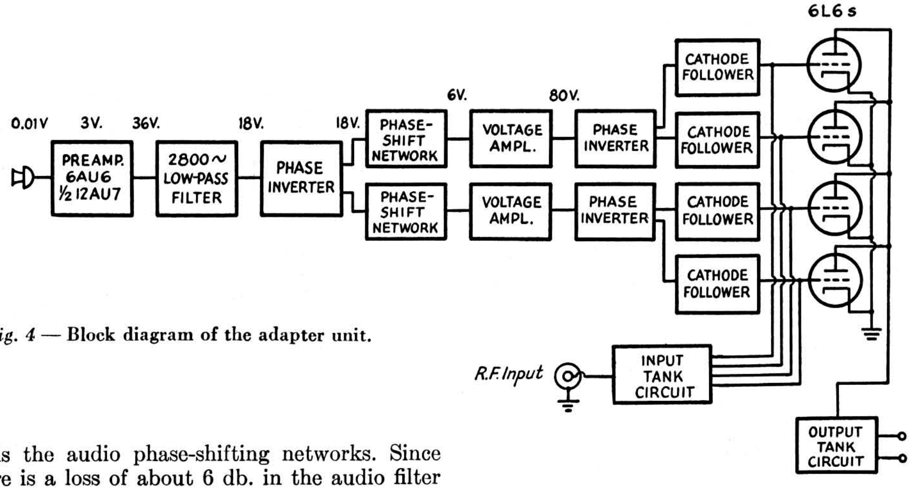


Fig. 4 — **Block diagram of the adapter unit.**

feeds the audio phase-shifting networks. Since there is a loss of about 6 db. in the audio filter and 10 db. more in the audio phase-shifting networks, it is necessary to add a voltage-amplifier stage in each of the audio channels. These two stages again are directly coupled to the preceding stage so that a minimum of components will be required. Since the grids run positive with respect to ground, a high value of bias resistor is used in each of these voltage-amplifier stages, so that the proper value of operating grid-to-cathode voltage will be obtained on the tubes.

The two balanced modulators require that push-pull audio voltage be fed to their grids, and it is necessary to add a phase-inverter stage in each audio channel. Since the "hot-cathode" type of phase inverter requires that a positive voltage with respect to ground be applied to the grid, this voltage is obtained through a high value of isolating resistance from the most convenient spot having an average potential of positive 60 volts — the output of the low-pass audio filter.

The Grid-Bias Modulation System

The four elements of the last two 12AU7s act as grid-bias modulators for the four 6L6s in the r.f. stage. Each of the four tube elements feeds the grid of one of the four 6L6s in the r.f. stage. The tube sections serve as bias regulators and in addition act as cathode followers, to supply audio voltage with relatively good regulation superimposed upon the average value of d.c. bias voltage. With appropriate tubes used as cathode followers, this system of grid-bias modulation is, incidentally, quite effective for use with any type of r.f. amplifier stage up to quite sizable power levels.

It is necessary to have some means for balancing each of the balanced modulators and, in addition, to have some means for balancing the output of one balanced modulator with respect to the other. In the unit shown these functions are accomplished through the use of potentiometers R_2, R_3 and R_4 in Fig. 5. R_2 and R_3 act as balancing potentiometers for each of the balanced modulators and R_4 provides the adjustment between the relative outputs of the two balanced modulators. Each of these potentiometers acts by varying the average bias on the grids of the elements of the 12AU7 modulators. Variation in the grid bias on these tubes results in a proportional change in the cathode voltage on the tube and hence in the grid bias on the 6L6 tube to which the cathode is connected.

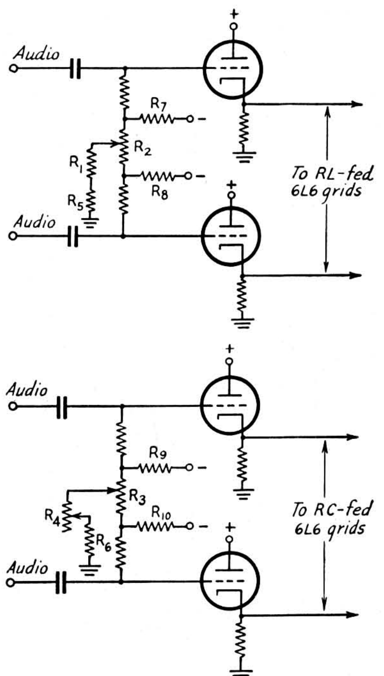


Fig. 5 — **Showing the balancing system for the r.f. portion of the adapter.**

Operating Conditions for the Balanced-Modulator Stage

Fig. 6 shows two basic circuit arrangements for the double balanced-modulator stage that generates the s.s.s.c. signal. Fig. 6-A shows the push-pull input and single-ended output system used in the adapter unit to be described. Fig. 6-B shows an analogous circuit arrangement with single-ended input and push-pull output circuits that might give improved circuit balance in the higher frequency range.

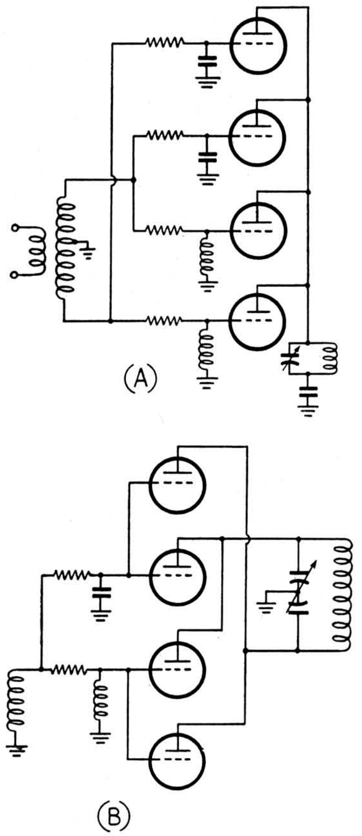


Fig. 6 **— Alternative circuits for double balanced modulators.**

Both circuit arrangements are suitable for use at low level or for the generation of moderate amounts of power. Since the individual tubes in the stage operate into a load circuit whose voltage swing is not at all times in phase with the grid-exciting voltage, the plate-circuit efficiency is not as high as would be attained if the same tubes were operating as a conventional Class C amplifier. Approximate measurements of the unit to be described have shown that the plate efficiency is of the order of 40%. Such a stage may be used as the output stage in a high-power transmitter, but higher over-all transmitter efficiency can be obtained by operating the s.s.s.c. stage at a moderate power level and following it with a Class B linear amplifier. Plate-circuit efficiency of the order of 65 to 70% may be obtained from the Class B final amplifier.

Operating Conditions for the Adapter Unit

Fig. 7 shows the complete schematic diagram of the s.s.s.c. adapter unit shown in the photographs. Since the r.f. stage operates at relatively high plate current at low plate voltage under peak modulation conditions, a high-*C* plate tank circuit has been used. Actually a plate tank coil of standard manufacture for the 28-Mc. band has been used with approximately 140 μμfd. of tuning capacitance, in order to give high-*C* operation on the 14-Mc. band.

The approximate unmodulated operating conditions for the four 6L6 tubes are as follows: plate voltage, 500; screen voltage, 300; d.c. grid bias at the tubes, 60 volts; peak value of r.f. exciting voltage per grid, 40. Under these conditions the static plate current on the four 6L6 tubes is approximately 125 ma. and the r.f. output is substantially zero, with proper adjustment of the elements. With 600-cycle audio input to the speech system and with the gain control adjusted such that about 25 volts peak is being applied to each of the 6L6 grids, the plate current will rise to approximately 225 ma. Under these conditions, a power output in the vicinity of 40 watts will be obtained. With a voice signal fed to the speech system, the plate current on the 6L6 tubes will rise on peaks to about 175 ma. A greater audio input will cause the plate current of the 6L6 tubes to rise to higher values, but distortion will result through overloading in the audio system.

Approximately 8 watts of r.f. driving power is required for the adapter unit to attain the operating conditions specified (40 volts peak to each of the four 6L6 grids). Substantially all of this driving power is dissipated in the four 470-ohm 2-watt composition resistors used in the r.f. phase-shifting network.

Tuning & Adjustment

The tuning procedure for an s.s.s.c. generator unit of this type is not something to be taken lightly. However, the procedure is not difficult if it is done in an orderly manner and with proper test equipment. Three pieces of test equipment are required, in addition to the obvious accessories of an adequate exciter unit of good stability and a plate- and screen-power supply for the four 6L6s. These items of test equipment are: (1) either a vacuum-tube r.f. voltmeter or a high-sensitivity d.c. voltmeter. The sensitive d.c. voltmeter is actually to be preferred, since its use will introduce the least change into the operating conditions of the stage. (2) An audio oscillator capable of covering the range, or selected frequencies within the range, from 125 to 3000 cycles. (3) A simple cathode-ray oscilloscope. Only the simplest type of oscilloscope is required since the requirements placed upon the time base are not stringent. Simple sine-wave a.c. sweep may be used, although an oscilloscope using a recently-described [6] simple modification of the a.c. sweep that gives a single-stroke time base 60 times per second has proven to be very satisfactory.

Checking the Audio System

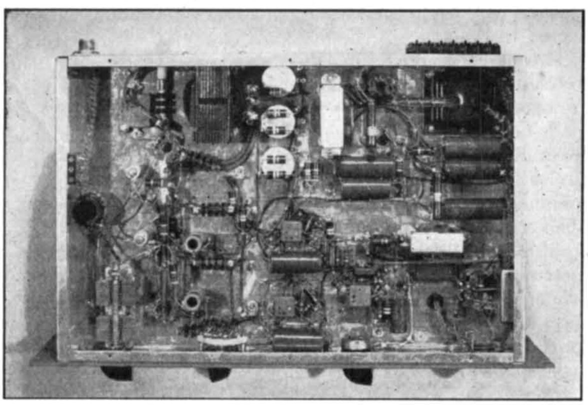
The d.c. voltages present within the speech portion should first be checked with a high-resistance voltmeter, to insure that the unit has been wired properly and that the tubes are operating at normal potentials. The 6L6 tubes should not be in their sockets for these audio checks. Then, with low-level sine-wave audio input at a frequency between 300 and 800 cycles, the amplifier should be checked in the normal manner to make sure that overloading does not take place in the audio system until a peak potential of at least 50 volts is available at the 6L6 grids. When these conditions have been attained, the operation of the audio phase-shifting networks may be checked.

The first procedure in checking the operation of the audio phase-shifting networks is to pad the cathode-ray oscilloscope so that equal deflection sensitivity will be obtained on both the horizontal and vertical sets of deflection plates. This procedure is quite simple and is as follows: (1) Turn down the "Intensity" control on the oscilloscope so that the screen will not be burned by allowing the spot to remain in one place for a period of time. (2) With no horizontal time base, apply the voltage from the secondary of a 6.3- or 10-volt filament transformer directly to the vertical deflection plates of the oscilloscope; measure the length of the line in inches or centimeters. (3) Apply exactly the same voltage directly to the horizontal deflection plates with no vertical signal; again measure the length of the line obtained in the same units as used before. In all normal cases it will be found that the vertical deflection will be somewhat greater than the horizontal deflection.

The problem now is simply to use a very-high-impedance voltage divider of proper value in the circuit leads to the more sensitive set of deflection plates so that the net sensitivity to both sets of plates will be the same. As an example, suppose that the vertical plates give 1.3 times as much deflection for the same voltage as the horizontal plates. We then need 1/1.3 or 0.77 times as much sensitivity on the vertical plates. Since nearly all oscilloscopes already have a resistor from each deflection plate to ground, it is merely necessary to connect an external resistor of correct value in series with the lead to the most sensitive plate to obtain the sensitivity reduction. The value of this series resistor should be: [(ratio of deflection sensitivity) − 1] times the value of resistor from deflection plate to ground. In the case cited above, and assuming that there is a 5-megohm resistor from deflection plate to ground, $1.3 - 1 = 0.3$, $0.3 \times 5{,}000{,}000 = 1.5$ megohms. Hence a 1.5-megohm resistor should be connected in series with the external lead to the more sensitive deflection plate. The sensitivity-padding arrangement should now be checked again with the a.c. voltage source used before to insure that equal sensitivity is obtained on both the horizontal and vertical sets of plates.

The ground terminal of the oscilloscope should now be connected to the chassis ground of the adapter unit. Then, with all 6L6 tubes still removed from their sockets, and with no r.f. excitation to the unit, one deflecting plate should be connected to the grid terminal of the first 6L6 tube. Audio signal in the vicinity of 600 cycles should be applied to the microphone terminal of such amplitude that about one-inch deflection is obtained on the oscilloscope. Then the other deflection plate of the oscilloscope should be connected to the grid terminal of the next 6L6 tube in the line. A straight line should now be obtained on the oscilloscope. It will be 1.4 times as long

[6] *Radio Handbook*, 11th edition, p. 427.



A view under the chassis of the s.s.s.c. exciter. The input tuning condenser for the r.f. excitation can be seen at the lower left, with its companion coil just above. The other panel controls are upper sideband/lower sideband/f.m. switch and audio gain control. The three balancing potentiometers can be seen at the top center, and the small ceramic phasing condensers can be found near the r.f. input coil.

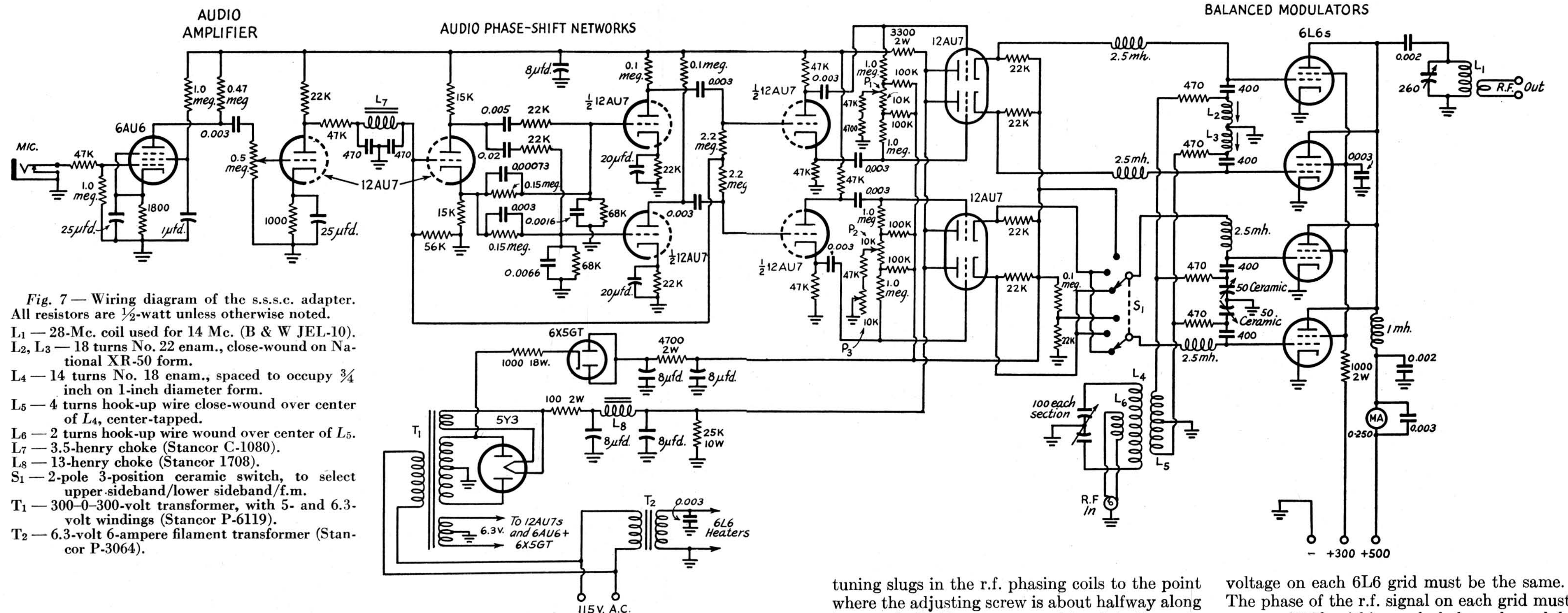


Fig. 7 — Wiring diagram of the s.s.s.c. adapter. All resistors are ½-watt unless otherwise noted.

L_1 — 28-Mc. coil used for 14 Mc. (B & W JEL-10).
L_2, L_3 — 18 turns No. 22 enam., close-wound on National XR-50 form.
L_4 — 14 turns No. 18 enam., spaced to occupy ¾ inch on 1-inch diameter form.
L_5 — 4 turns hook-up wire close-wound over center of L_4, center-tapped.
L_6 — 2 turns hook-up wire wound over center of L_5.
L_7 — 3.5-henry choke (Stancor C-1080).
L_8 — 13-henry choke (Stancor 1708).
S_1 — 2-pole 3-position ceramic switch, to select upper-sideband/lower sideband/f.m.
T_1 — 300-0-300-volt transformer, with 5- and 6.3-volt windings (Stancor P-6119).
T_2 — 6.3-volt 6-ampere filament transformer (Stancor P-3064).

as the original line and will be displaced 45° in direction from the first line. The second of the deflection plates should now be connected to the grid terminal of the third 6L6 tube. A circle should now be obtained on the face of the oscilloscope tube. The lead from the second deflection plate should now be moved to the grid of the fourth 6L6 tube. A circle again should be obtained. Now if the lead from the first deflection plate is moved to the grid of the third 6L6 a straight line again should be obtained, the same as is the case where the two 'scope leads were connected to the grids of the first pair of 6L6s.

Through the above procedure we have checked to make sure that the grids of both pairs of 6L6s are operating 180° out of phase as they should be for a balanced modulator (straight line at 45°). In addition we have checked by means of the circles to make sure that the two pairs of 6L6s (balanced modulators) are operating 90° out of phase. If the values of the components in the audio phase-shifting networks have been checked carefully, and if all the other circuits are operating properly, the circles should be quite clean throughout the range from 125 to 3000 cycles. As the audio oscillator feeding the unit is tuned over the frequency range the circle should appear quite satisfactory, with only a moderate tendency toward looking like an ellipse near the extremes of the frequency range.

If the circles obtained are not quite good, the condition may be caused by overload, or the values of the components in the audio phase-shift networks may not be those values which have been quoted. Overload in the audio system is quite easily detected by the appearance of one or more flat sides on the "circle." However, the use of improper values in the phase-shifting networks will cause the "circle" to be elliptical and to "lean" either to the right or to the left. If overloading is being obtained, merely turn down the gain of the audio system until the overload condition disappears. However, if a leaning ellipse is obtained on the face of the 'scope it probably will be best to check the values of all the components in the phase-shift networks to make sure that their values are as listed in Figs. 3 and 7.

Alignment of the R.F. System

Probably the most satisfactory method for initially aligning the excitation to the grids of the 6L6s is first to remove the "audio" ends of the four r.f. chokes (which attach to the 6L6 grids) from any circuit connection. Then adjust the tuning slugs in the r.f. phasing coils to the point where the adjusting screw is about halfway along its travel. (6–32 nuts were soldered to the ends of the tuning-slug screws in the unit shown so that the slugs could be adjusted by means of a standard neutralizing wrench.) The variable ceramic capacitors on the other pair of 6L6 grids are now adjusted to the point where the rotors are about 20° from the position of minimum capacitance.

Now about 6 to 8 watts of excitation power should be applied, the split-stator capacitor that tunes the grid coil should be resonated, and the peak r.f. voltage appearing on each 6L6 grid should be determined by measuring with a high-sensitivity voltmeter (1000 to 20,000 ohms per volt) the d.c. voltage from the "open" end of each of the four r.f. chokes to ground. This voltage should be from 35 to 40 volts and should be within one-half volt of the same value on all four grids. A moderate touching-up of the slugs in the phase-shifting coils, and trimming of the rotor of the phase-shifting capacitors, should bring all four voltages to the same value.

In addition to the obvious requirements that proper d.c. potentials must exist on the electrodes and the fact that the audio-signal phase must be as mentioned previously, five conditions must exist in the 6L6 stage before completely satisfactory operation may be obtained. These conditions are: (1) The amplitude of the r.f. excitation voltage on each 6L6 grid must be the same. (2) The phase of the r.f. signal on each grid must be proper (180° within each balanced modulator and 90° between the two balanced modulators). (3) The relative output from each balanced modulator circuit must be the same. (4) Loading on the plate circuit of the stage must be proper. (5) The balancing adjustments must have been made with sufficient accuracy so that carrier output is negligible. The procedure for making each of these adjustments will be described in turn.

The previous series of adjustments will insure that condition (1) has been met, but condition (2) has not necessarily been met by the adjustment. The procedure for meeting condition (2) is the most difficult but it will hold indefinitely over a complete amateur 'phone band when it has once been attained. The set-up is as follows: Excitation, plate and screen voltages, and audio signal at about 600 cycles are applied to the adapter unit. The audio gain control initially is turned down to zero gain. One set of deflecting plates of the oscilloscope is connected to the "R.F. Out" terminals of the unit while sawtooth or other sweep is applied to the horizontal deflection plates. A 5000-ohm 10-watt noninductive resistor is connected across the output tank circuit as a load. A small carrier deflection probably will now appear on the oscilloscope as the output tank circuit is tuned to resonance, through lack of balance in the balanced modulators. This small carrier can be eliminated by adjustment of the balancing potentiometers P_1 and P_2 of Fig. 7. Now slowly turn up the audio gain of the unit. If you are very lucky and all the five conditions have been met accidentally, a pure carrier wave will appear on the oscilloscope, as shown in Fig. 8-A. The frequency of this wave will be equal to the excitation frequency for the unit plus or minus the frequency of the audio signal. In most cases, however, the signal appearing on the oscilloscope will appear something like Fig. 8-B. In this sketch conditions (2) and (3) are not being met. The adjustment for condition (3) is potentiometer P_3 of Fig. 7, so P_3 should be varied to make the picture appear more like Fig. 8-C, in which only condition (2) is not satisfied.

The adjustments to meet condition (2) are time-consuming at best, since the procedure is almost entirely a cut-and-try process. The procedure involves making small adjustments in L_2 and L_3 of Fig. 7, then making small adjustments in the two variable ceramic capacitors, following up with adjustments to the three balancing potentiometers P_1, P_2 and P_3, always in an effort to make the picture with modulation look like Fig. 8-A rather than any of the other examples. After a little experiment it will be found that any condition of adjustment of the r.f. phase-shift components which does not give balance with all three potentiometers near the midposition is predestined to failure. When P_1 is at midscale for balance it means that the voltages across the two variable inductors are the same. In the same way the adjustment of P_2 gives a good idea of balance between the voltages across the two variable capacitors, and P_3 shows by its adjustment for balance whether or not the r.f. voltage exciting the two balanced modulators is approximately the same.

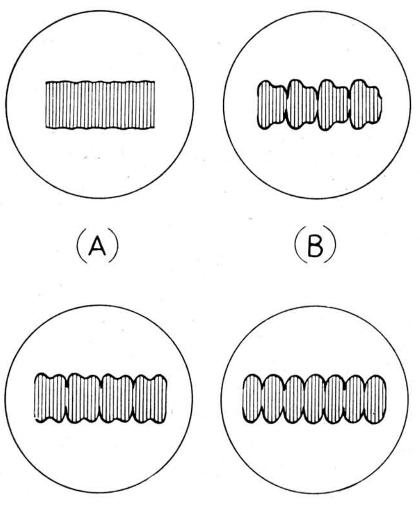


Fig. 8 — **Sketches of the oscilloscope face showing different conditions of adjustment of the adapter unit. (A) shows the substantially clean carrier obtained when all adjustments are at optimum and a sine-wave signal is fed to the audio input. (B) shows improper r.f. phase and unbalance between the outputs of the two balanced modulators. (C) shows improper r.f. phasing but outputs of the two balanced modulators equal. (D) shows proper r.f. phasing but unbalance between outputs of two balanced modulators.**

After a series of adjustments has resulted in a reasonably satisfactory picture on the oscilloscope, the signal should be checked on a well-shielded receiver. With the audio gain at zero, a weak carrier wave only should be heard at the excitation frequency. Then as the audio gain is brought up with an audio signal being fed to the microphone jack, a strong carrier should be audible on one side of the carrier. When the gain is turned up to the point where distortion begins to take place in the audio channel, additional sidebands will be heard in the receiver on both sides of the carrier frequency. However, up to the point of audio distortion no spurious sidebands should be apparent. The "rejected" sideband on the other side of the carrier from the desired signal probably will become audible at relatively-high gain settings. But up to the overload point the other sideband should be at least 20 db. down from the desired sideband.

The Final Amplifier

The 6L6 stage is capable of delivering 20 to 25 watts of power output with a minimum of distortion. However, when the adapter unit is used to feed a Class B r.f. power amplifier approximately one-half of this available power should be dissipated in a swamping resistor. This procedure is necessary to maintain good r.f. voltage regulation from the adapter unit when feeding the variable load impedance imposed by the grids of the r.f. power amplifier. The placing of a bank of 2-watt carbon resistors (total resistance about 5000 ohms and total dissipation about 12 watts) directly across the output tank of the 6L6s has given adequate swamping.

The adapter unit may be used to feed a triode power amplifier, within the excitation capabilities of the 10 to 15 watts available after swamping, but most satisfactory results probably will be obtained when feeding a beam-tetrode power stage. The adapter unit has been used to excite a push-pull power amplifier in which both 4-125A and 4-250A tubes have been used. In either case it was easy to excite the final-amplifier stage to one-kilowatt input. The pair of 4-125As took the kilowatt of s.s.s.c. with slight coloring on sustained modulation, while the 4-250As operate even more conservatively. A pair of 813s would make a satisfactory alternative power amplifier for one kilowatt, while smaller beam tetrodes could be used for less peak power input.

It probably is wise at this point to insert a note of warning regarding the stability of the power amplifier. The normal operating conditions for a Class B r.f. power amplifier are frequently given in the tube handbooks. In any event, the best operating conditions for the tubes will be approximately as follows: normal rated plate voltage, screen voltage at the maximum rating for c.w. operation or slightly above (to improve the power sensitivity of the stage), and grid bias at such a value that with no excitation the static input is approximately one-half normal plate dissipation. This last condition is the one which frequently will give trouble. The final-amplifier stage must operate with a reasonable value of plate current in the absence of signal if severe transient distortion (resembling the splatter of an overmodulated a.m. transmitter) is to be eliminated. This requirement for standing plate current in the absence of excitation imposes a stringent requirement upon the stability of a stage used to amplify an s.s.s.c. signal. There must be *no* tendency toward parasitic oscillation in the stage. If even the slightest tendency toward parasitics exists in the stage following the adapter, that tendency must be eliminated through the normal parasitic-suppression procedures.

Adjustment of Final-Amplifier Loading

The adjustment of the antenna coupling to a stage amplifying an s.s.s.c. signal is important. The loading adjustment is not as critical as would be the case if a conventional a.m.-signal-with-carrier were being amplified, but the loading must be approximately correct. The following procedure has been found to be satisfactory. Apply a sine-wave signal to the adapter unit and adjust the gain until approximately the rated value of grid current is being obtained on the final amplifier. Vary the coupling between the adapter and the grid circuit of the final amplifier until this amount of grid current is obtained with not more than about 180 ma. of plate current on the 6L6s. Then adjust the antenna coupling to the final amplifier until a point is reached where the plate current to the final stage is about 25% greater than the normal value which will be used. Then with speech input to the adapter the plate current to the final stage will kick up to about the normal value.

If less antenna coupling than that determined by the method given in the previous paragraph is used, limiting action will take place in the final amplifier before its full power-handling capabilities are reached. If greater antenna coupling is used, the final-amplifier stage will not operate at good plate-circuit efficiency with the normal power input.

Suggested Alternatives

The adapter unit may be operated on the 3.9-Mc. or the 21-Mc. band by substituting appropriate coils for those shown in the grid and plate circuits. It will be necessary also to change the values of capacitance-to-ground and inductance-to-ground from the grids of the 6L6s when going to another frequency range. The net capacitance-to-ground and inductance-to-ground, respectively, from each of these grids should present 470 ohms reactance at the frequency of operation.

Experience in operating and testing the adapter unit has shown that its power output is limited by the four 12AU7 sections used as grid-bias modulators. If somewhat larger tubes, such as triode-connected 6AQ5s, were substituted it would be possible to drive the 6L6s to greater plate current and power output before audio-channel distortion became important.

Tubes such as the 807 or the 2E22 could be substituted for the 6L6s in the adapter unit if greater power output were desired. If either of these tube types were substituted, the unit could be operated as an effective medium-power s.s.s.c. transmitter in its own right. Or, if desired, the scheme of operation of the adapter unit could be applied to four of any type beam-tetrode tubes, provided appropriate r.f. and audio phase and r.f. and audio signal levels were applied to the grids. It is quite practicable to generate the s.s.s.c. signal by this method at any power between the milliwatt and the kilowatt level.

Calling Technique

As any person using s.s.s.c. without a schedule will soon discover, it is difficult to raise a station under QRM conditions when calling with s.s.s.c. If a separate band or portion of a band were set aside for s.s.s.c. operation, this difficulty would be eliminated. But for the present it would appear desirable that a calling station who desires later to use s.s.s.c. make the initial call using either f.m. or p.m. of a c.w. carrier. Then as soon as contact is made it will be possible for the receiving station to change over to receive s.s.s.c., on instruction from the calling station — probably with much improved results.

An alternative to the above is for the calling station to call with conventional a.m., using the final amplifier as a linear amplifier. This facility may be obtained, if desired, in the adapter unit described by biasing off and removing the audio from one pair of 6L6 balanced modulators. The remaining balanced modulator is then unbalanced so that a carrier of proper level is transmitted. The third position of the sideband switch in the adapter unit provides as shown for straight transmission of an incoming carrier through the unit, so that f.m. in the exciter will pass unaltered through the adapter unit to the final amplifier. A fourth position of this switch might be added to provide for medium-power a.m. transmission, as discussed above, for a calling system. Such dodges appear to be necessary until more operators learn to recognize s.s.s.c. signals.