SINGLE SIDEBAND RECEPTION

AN ADAPTER TO CONVERT A SUPERHET INTO A TRUE SINGLE SIDEBAND RECEIVER

Materially Reduces QRM When Receiving AM, PM, CW or SSB Signals

The single-sideband adapter, shown in Fig. 1 from a rear view, when attached to a superhet receiver will permit reception of single-sideband signals. Further, this combination will receive amplitude modulated phone signals, phase modulated signals, and c-w signals in a fashion which will enable the user to reduce the qrm on any frequency by at least fifty per cent.

In the case of reception of true single sideband signals with attenuated or suppressed carrier, the adapter furnishes a carrier against which the sidebands may be demodulated. By selecting the proper sideband with a switch, the modulation may be read. For reception of AM phone signals, this SSB receiver (adapter plus superhet) exalts the carrier component of the phone signal, making it effectively stronger than it would otherwise have been, and thus allows reception of both sidebands, or either sideband singly. If qrm exists on one sideband, it can be avoided by receiving only the sideband on which the qrm does not exist. Where qrm exists on both sidebands, one is selected which is qrm'ed the least.

Phase modulated or NBFM signals may be received in the same manner as AM signals. No special detection equipment need be added to the SSB receiver. For the reception of c-w signals, the SSB receiver furnishes the heterodyning signal so that the BFO in the superhet is not needed. True single-signal reception of c-w signals is achieved.

GENERAL PERFORMANCE

A single sideband receiver is not necessarily a "sharp" receiver, although the results obtained are usually superior to those obtainable with a receiver with steep-sloped IF curves. This means that if a signal has modulation with good audio fidelity, the SSB receiver will receive the full audio band, limited principally by the bandwidth of the IF transformers in the superhet itself. Of course it is desirable to limit the audio range, both in transmission and reception,
to as narrow a range as possible, consistent with intelligibility. However, signals characterized by frequency modulation, carrier frequency drift, or combinations of these may be immediately apparent. The amateur using a SSB receiver is thus able to spot the situations of these sorts on any signal.

The SSB receiver does not cut out one sideband completely, but it attenuates it by approximately 40 dB. This is the same as about 7 dB on the average receiver. Attenuation is such that signals which are no closer than 75 cycles and as far away as 540 cycles from the carrier are attenuated at least 40 dB. However, sufficient attenuation takes place between zero and 70 cycles so that unless an interfering signal is practically zero beats it can be eliminated in most cases sufficiently well to allow the desired signal to be copied.

The SSB receiver thus allows reception of all of the usual types of signals found on the band, including single-sideband signals. The principal advantage is that it allows the user to receive only one sideband at a time so that qrm is reduced by at least 50%.

**ELECTRICAL DETAILS**

The SSB adapter described here may be switched to any one of four types of reception by switch S2 (see Fig. 2). Position 1 allows reception of one sideband of any type of signal described above. This will be either the upper or lower sideband, depending on which side of the received frequency the superhet oscillator operates. Position 2 permits reception of the other sideband. Position 3 is a locked-oscillator position. This means that the adapter is functioning as an artificial carrier (as it does also on positions 1 and 3) which augments (cautis) the carrier being received. This has the advantage of providing a strong non-fading carrier. The result is to reduce distortion on fading signals.

Position 4 of switch S2 allows the receiver to function normally. The SSB adapter is not completely out of the circuit, since audio connections with the receiver require that audio be fed through the adapter. Experience has shown that position 4 is seldom used since the operator is familiar with the operation of a SSB receiver.

The circuit diagram (Fig. 2) follows the principles set forth by D. B. Neagard in his article "Practical Single-sideband Reception in the July QST." With reference to Fig. 2, the second stage is the oscillator which generates the artificial carrier. Its frequency is the same as that of the receiver IF, Coil L1 and condenser C6, along with the first grid (reactance) tube, are the frequency determining elements. Transformer L3 is in a 90 degree phase shift circuit. The 6NE6 tube acts as demodulators. The IF signal from the receiver is coupled through the 6AK6 tube (which functions as an impedance matching device) to both 6HS6 tubes. The output of the 6SS7 oscillator is coupled to one of these 6HS6 tubes. A portion of the output of the upper 6HS6 is fed back through a bout RC filter (Rs, Rp, Rs, Co, Cs) and acts on the 6SS7 reactance tube so that automatic carrier synchronization is achieved.

The outputs from the two 6HS6 demodulators are fed independently to two audio-frequency phase-shift networks. The upper two 6SN7-GT tubes with their associated components act as one network and the lower pair of 6SN7-GT tubes with their circuit components act as the other phase-shift network.

The audio outputs of these two networks are mixed by resistors Rs and Re so that response from sideband 1, sideband 2 or both sidebands can be selected. The 6CA is an audio amplifier tube. The power supply circuit and the voltage regulator tube circuit are conventional. A large amount of capacitance is required because the audio phase-shift networks must be supplied from a low impedance source of voltage.

**CONSTRUCTIONAL DETAILS**

Before starting the constructional work, it is wise to have all the necessary components on hand. Some of their needs explanation at this point. Resistors RP through RP6 are specified for 1/2 watt precision resistors, with a resistance tolerance of ±1%. These are an important part of the SSB adapter. Quantities
of this type are available at low prices. Naturally, one watt resistors may be used if 1-3 watt ones are not available. It is possible to measure regular tolerance resistors until suitable values are found. This is not advisable unless the resistors chosen are certain to hold their measured values. A better alternative is to use stable resistors and pair them. For example, RP and RP; need not be exactly 4000 ohms so long as they are the same value (within 40 or 50 ohms). Similarly, other pairs are RP; RP; RP; RP; RP; and RP;.

Resistors RB through RS; are listed separately because it is desirable for them to be very stable although their exact value is not important as long as they hold that value. Precision resistors are usually stable types, and for this reason they are recommended although not required. Ordinary resistors are suitable, although the performance of the unit may suffer if these resistors change value with time.

Condensers CA; through CA; are shown as single condensers, but except for CA; they are all multiple units. For example, CA; is listed as a 2200 mfd adjustable condenser. This made up by paralleling a 0.100 mf mica and a 130 to 300 mfd mica. Each of these specified condensers consists of a 130-200 mw series condenser. CA; is simply a 100-500 mfn trimmer. The objective of the chapter is to permit adjustment of the RC products (RS; times CA; RS times CA; etc.) to the proper values. This will be covered more thoroughly under "Tune-Up Adjustments."

A Millen IF transformer is specified for L4. Other types will undoubtedly work, although difficulty may be encountered in obtaining the correct coupling between the primary and the secondary windings. Grossly speaking, high stability air tuned IF transformers of the proper frequency are suitable. Switch S2 is specified as a shorting type switch in order to provide smooth switching action.

Inductance L2 should be approximately 0.15 millihenrys, for use with receivers having 450-470 kc IF amplifiers. The value of inductance is obtained from a 4-pc 2.5 mch choke, by removing 3 of the pcs, then making the 4th turn off the remaining pcs. The particular choke used was a Millen No. 3410.

The SBB adapter is a simple device for supporting the chassis in a 2 1/16 inch diameter by 4 inch long shield can (Millen No. 80006). The chassis is placed on a piece of aluminum to the 2 1/2 inch long shield can (Millen No. 80006). In Fig. 7 it is shown as an assembly, with the board placed in position. The chassis is then drilled with four holes, two on the 6SJ7 tube side, and two on the 6AK5 tube side. These holes are drilled with a 26-32 hole, and the headphone jack is then soldered to the tube side.

The chassis, referring to Fig. 1, is drilled for the two mounting lugs for the Millen IF transformer, the right of center, and the fuse and a-c cord on the right. Fig. 1 is a plan view of the chassis, with the on-off switch, oscillator tuning control, control switch (S), and the pilot light. All holes are in a

Fig. 3. Detail View of Probe with Cover Removed

center line 1 1/4 inches up from the bottom of the panel, and the side dimensions are three inches and 5 inches, respectively, in from either side of the panel.

The under-chassis view (Fig. 4) clearly shows the layout of parts. Note the shield which encloses the wiring for the two 6SJ7 and two 6HJ tubes. In order to better balance the layout in this shield compartment, the IF transformer could be moved toward the 6HJ oscillator tube.

It is necessary to make a small change in the IF transformer, assuming that the Millen No. 6456 is used. The blue lead should be unsoldered from the terminal point on the end of the coil form (which is a tap on the coil) and soldered instead to the center of the primary tuning condenser. Also, the 24 mw padding condenser across the primary coil should be removed.

The tune-up process will be simplified if a small piece of wire is soldered to the right cathode connections of the four 6827-7 Q tubes. This wire should be about one inch long and arranged so that a clip lead may be attached to it.

The chassis of all the 6.3 volt tubes except the 6AK5 are wired to the 0.3 volt power transformer.

The 6AK5 tube is mounted in the probe chassis. The mounting piece is made of aluminum to fit the shield can. See Figs. 4 and 5. The coax lead which comes out the rear of this can connects to the receiver by means of a coaxial connector. The two diameters, and the coaxial lead to the receiver are brought out the side of the can.

TUNE-UP ADJUSTMENTS

When the SBB adapter has been completed it is necessary to check the alignment carefully. In particular, the amount of attenuation obtainable on either sideband depends upon how well these adjustments are made.

Connect the adapter to the receiver in the following order. The small can with the 6AK5 tube should be placed as close as possible to the last IF transformer in the receiver. The lead marked "receiver IF" should be soldered to the "hot" end of the secondary winding of this IF transformer. The lead from this point going to the second detector. The shielding braid on the coaxial cable should be stripped back only as far as necessary and then soldered to grounds (receiver chassis). The 6.3 volt filament leads should be wired into a 0.3 volt a-c socket.

If the IF alignment of the receiver is questionable, it is possible to make further adjustments by means of a simple switch in the secondary of the last IF transformer to compensate for the addition of the 6AK5 stage.
The other two connections are those marked "audio in" and "audio out." The audio connection to the input of the first audio amplifier must be opened. If the receiver has a phone input jack which accomplishes this, the two leads may be connected at this point. The "audio in" lead should be connected to the receiver connection which receives the voltage from the second detector tube, and the "audio out" lead should be connected so that the audio signal on this lead is fed to the remainder of the audio system of the receiver. It is advisable to do this because the adapter may be connected to a wide variety of receivers.

Turn on the receiver and the adapter. Allow both units to reach operating temperature. Turn off the avc on the receiver and set the adapter switch S1 to position 4 (normal). Turn in a stable signal, such as a broadcast station. Adjust R20 and the receiver volume control until an adequate volume level is obtained. Change S1 to position 3. Adjust condenser C3, which tunes the oscillator, until a beat note is heard. Adjust for zero beat. If no beat is heard, the oscillator is either not oscillating or is not able to reach the correct frequency. With the constants shown, the oscillator will operate in the 350 kc to 450 kc IF range. For higher or lower frequencies it may be necessary to change L1 and C1.

Next, detune the receiver slightly so that a beat note is audible. Set the rf gain on the receiver to ensure that no overloading is taking place. Adjust condenser C6 until this beat note is as loud as possible.

If the receiver does not use a 430-455 kc IF, it may be necessary to change L2, C3, C5, and C7 in order to achieve resonance.

Turn the receiver to a low frequency beat note. Inability to hold a low-frequency beat note indicates that the rf gain control should be reduced. Insert a very small amount of bypass condenser R1 and ground. The positive connection on the meter should connect to ground. A 0.4- or 0.02-µf meter may also be used if a 0.1-mil meter is not available. The 0.1-milliammeter becomes, in effect, a 0.2-volt voltmeter (approximately).

Adjust the tuning condenser in the primary of L2, for a maximum reading of this meter. This adjustment probably will cause the oscillator to change to another component and the beat note to change in frequency. If so, adjust C10 to get the original low-frequency beat note. Note: regard for main alignment when reading and repeat if necessary. Remove the meter and readjust L2 and C4 again to be sure this change was not made between R1 and ground in the same way. Adjust the tuning of the secondary of L4 for maximum meter reading. If the beat note changes, adjust C3 as before.

If the 0.1-mil meter is not now tuned, connect the condenser to the receiver IF. It is next necessary to adjust the coupling between this amplifier and the preamplifiers. Leads are fed to the two 0.01-mf tubes. This condition is satisfied when the voltages from "x" to ground and "y" to ground are equal. (These voltages are those that were measured with the 0.1-milimeter.) It may be desirable to connect a closed circuit jack between R4 and ground and R17 and ground. Inserting a 0.4- or 0.45-µf meter in the jack between R4 and ground reads voltage "x" and between R17 and ground reads voltage "y". It is desirable to have equal coupling between the primary and the secondary of L4. Carefully heat the coil form of the Millen IF transformer with a soldering iron, through the large hole in the coil, and then insert the high coil and the bottom coil can be pushed slightly toward the top coil. After this adjustment, return C6 to obtain the low-frequency beat note if this note changes frequency. Now measure voltages "x" and "y" by plugging the 0.1-mil meter into the two temporary jacks. Voltage "y" should increase as the coupling is increased. Several adjustments should be required as this process should be taken in easy steps to avoid too much coupling. Each time the coupling is adjusted the oscillator frequency should be adjusted to the low frequency beat with the signal in the receiver. Also the primary and secondary tuning condensers should be checked for proper tuning as indicated by a peak reading of the 0.1-mil meter. (Peak the primary and read current in R17 and peak the secondary by reading current in R20.)

When voltages "x" and "y" are within per cent of each other another adjustment may be considered complete. These voltages should normally be about 100 volts—half-scale on the 0.1-milliammeter.

The next step is to determine that transformer, L1 is acting as a 90-degree phase-shift device. An oscil- lometer is required for this and the following adjustments. The horizontal and vertical amplifiers in the scope may be used to check wave form phase shift, so it is first necessary to check for this condition.

Connect the "high input" leads of the horizontal and vertical amplifiers of the scope to pins 3 and 5 of the 8SN7-GT tube (point j). The ground connections of the scope should be tied to the chassis of the 885-GT chassis. The horizontal and vertical amplifiers in the scope are operated at approximately 6000 cycles as obtained as observed in the scope, as this receiver has a rather low sensitivity. If a 45-deg angle is obtained in the scope until a straight line at 45 degree angle is obtained at 45 degree angle is obtained with the correct condition. If this line will be a thin straight line. If phase shift is not obtained, it may be due to poor coupling, or split, so that it is in the form of a flat ellipse.

In order to correct this phase shift insert a 50,000 ohm potentiometer in the "head" of either the horizontal or vertical input at the scope. Adjust this potentiometer until the line becomes a solid line. If this is not possible, a transformer to the other "head" lead, it should now be possible to adjust the resistance to give a straight line on the scope.

Next, remove one scope lead from point j and connect it on point c of the cathode of the first 6SN7-GT tube in the lower network. Do not remove the potentiometer and do not change the gain controls on the scope.

Change the receiver tuning to get a beat note of approximately 250 cycles. A circle should now appear on the scope. If it may be inspected, but it should resemble a circle. Adjust the condenser in the second- ary of L4 until the circle is a small circle. The best adjustment does not give a perfect circle but a horizontal or vertical line through the small circle. The control should be adjusted to give equal horizontal and vertical deflections. This is the final step in the compensation adjustment so check as before and readjust the 50,000 ohm potentiometer if necessary. Now repeat

Fig. 5. Front View of SSB Adapter
the check for the circle by adjustment of the secondary tuning of L2. Detune the receiver to provide a 6000 cycle beat note. If not, the fault will probably be in condensers C1, C2, C3, C14, C15, C16 or resistors R8, R9, R10, R11. Ideally C1 and C2 should be the same value, that is, equal in capacitance. Also, C3 and C4 should be equal, and C5 and C6 should be equal. Further, R8 and R10 should be equal, R9 and R11 should be equal. It may be necessary to measure them in order to pair them in the way which makes them as close to equal values as possible.

The final tune-up adjustment concerns the two audio frequency phase shift networks. In addition to the scope, an audio oscillator is required. This oscillator should be as good an instrument as can be obtained, since accurate calibration and good waveforms are required in order to permit adjustment of the audio-frequency phase shift networks for optimum performance. This audio oscillator is required to generate the six audio frequencies shown in the circuit diagram (Fig. 2).

If the available oscillator is not accurately calibrated, it is not too difficult to calibrate it for the six frequencies involved. This can be done by means of a piano, if the piano is in tune. Using the proper key on the piano it is possible to produce a frequency which may be used as a calibration point, or in some cases as a sub-multiple of a required calibration. Of course, any other calibration means which is accurate may also be used.

When the oscillator is ready for use, turn on the adapter and remove both 6H6 tubes and set S2 to position 4. The receiver need not be turned on. Connect the audio oscillator output to pin 8 of the upper 6H6 tube with the ground lead on the audio oscillator output going to the adapter chassis. Connect the ground connections of the horizontal and vertical amplifier inputs of the scope to adapter chassis. Connect both "high" connections of both amplifiers to point J. Set the audio oscillator at 10,840 cycles and adjust its output to approximately one volt. The scope tube should now show a line at a 45 degree angle, or the gain controls should be adjusted.
so that it does. If the line is thin and not split the phase compensation is correct. If not, adjust the 50,000 ohm potentiometer which should still be in series with one scope lead, as explained before. Next, move one lead from position 1 to position 2. A figure which resembles a circle should now appear on the scope. Adjust the variable condenser CA until a perfect circle is obtained. If this is not possible, then either the correct RC product (CA times RC) is outside the range of adjustment or the gain controls on the scope are set in the wrong position. As before, adjust the gain controls so that equal horizontal and vertical deflection is obtained. Then check phase compensation again. This must always be done whenever the gain controls are changed. If the RC product is wrong change CA, RC, or both in order to obtain the required values.

The next five steps are repetitions of the above as follows. Remove the scope lead from 1 and place it on 2. Adjust the oscilloscope to 140 cycles. The phasing adjustment to get a single line, if it is required, may call for a condenser in series with one of the scope leads. For T. Check for phase compensation by getting a single line as before. Move one of the leads on to point Q. Adjust CA until a perfect circle is obtained. This completes the upper network adjustment.

Change the oscilloscope output so that it connects to pin 8 of the lower 6SN7 in the circuit diagram. Connect both scope leads to point S and set the audio oscillator to 2710 cycles. Check for phase compensation as before, using either capacitor or resistance as required. Move one lead from S and place on point T. Adjust CA until a perfect circle is obtained.

Change oscilloscope to 35 cycles and move the lead from S to T. Check for phase compensation. Move one lead from T to point U. Adjust Ru and Cu until a perfect circle is obtained. Unbalance adjustment of Ru, alone is all that is required, if a perfect circle cannot be obtained. If CA is unbalanced, adjust CA until perfect circle again with Ru. Repeat until you get a perfect circle.

Change oscilloscope to the 50,000 ohm condenser. Set the lead from T to point U. Check for phase compensation. Move a lead from U to point V. Adjust Ru and Cu until a perfect circle is obtained.

Now adjust the network, and the balancing adjustments of Ru and Cu are now complete. The receiver, replace the 680 ohm in the adapter and allow the receiver to reach operating temperature. Set Ru and Cu to approximate mid-position. Connect the vertical input to the scope or output lead. Sweep frequency so that several cycles can be observed. Set the horizontal plates to swing frequency so that several cycles can be observed. Set the horizontal plates to swing the wave so that several cycles can be observed. If the receiver is to be connected to a broadcast station, while the adapter is in position 3. Set the QI gain for a low signal level and make sure that the advantage is turned off.

Tune the receiver slightly until the 1000 cycle beat note is heard. If the note is not heard, move the QI gain until this heterodyne is just barely audible with the beat note not visible on the scope. Then move the QI gain until the beat note disappears. Now move the QI gain until the beat note is heard. This heterodyne will be weaker. This heterodyne will now be selected by the scope. Adjust vertical calibration until the sine wave covers about one-third of the scale. If the scope is in position 1, adjust Ru or, if in position 2, adjust Ru until the heterodyne sounds as weak as possible on the ear. At this point, the scope trace will decrease in amplitude. Next, return the receiver through zero beat, to the opposite side of the signal until a 1000 cycle heterodyne note is obtained. Change switch J to the other of the two sideband positions. Then adjust the other potentiometer (which was not touched before) for a minimum, checking both by the scope and ear.

Finally, very carefully adjust the secondary tuning condenser of La in conjunction with the potentiometer for a further reduction in volume of the heterodyne. Now return the receiver for a 1000 cycle note on the other side of the signal to that sideband. Then readjust the potentiometer which controls this sideband for minimum heterodyne strength. If this is not as little as before, it will be necessary to go to the other sideband again and adjust La again for equal rejection. It may be necessary to go back and forth several times to accomplish this. This rejection should be in the order of 60 db, which means a voltage ratio of about 1831:1 as seen on the scope screen by switching J back and forth between positions 1 and 2 while everything else is fixed.

Two more adjustments must now be made before the SSB receiver is really ready for use. Disconnect the scope lead from position 3, tune in a station. Be sure the input signal is small. Return to position 4. If the audio level is adjusted, adjust RA until no change in audio level is noted when going from position 3 to 4 or vice versa. (When in position 1 or 2 receiving AM the audio level will be lower by 6 db than the level observed in positions 3 and 4. This is normal.)

Lastly, tune in a signal zero beat in position 3 of b. Make sure the unit is at operating temperature. Reduce QI gain as far as practical. Switch to position 4, wait five seconds and switch to position 3. If a sliding frequency change is heard as the oscillator is pulled in, RA needs adjustment. Make a slight adjustment, return to position 4, wait five seconds, then switch to 3. If the frequency change is less continuous the adjustment process in that direction until no change of frequency is heard. If the frequency change was worse, adjust RA in the opposite direction and follow the above steps until no frequency change is heard.

The SSB adapter is now completely aligned and will render the receiver of a proper level, if at some future date some of the previous steps in the alignment process had to be made, it will be for the receiver and transmitter the same or almost the same. It will have to be set for the new 3F of the receiver and transmitter to accomplish the alignment of RA and Ru, and Ru will probably need re-adjustment. It may be desirable further to change the settings of Ru and Cu in the manner previously described. The two audio phase shift networks should not be used at any re-adjustment at any time unless the components change. It may be a good practice to make sure that the adjustments which have been described may be saved on some means of record so that the receiver can be made easier to perform than to describe in writing.

Fig. 7. Layout Guide for SSB Adapter
USE OF THE SSB RECEIVER

A person using a SSB receiver for the first time will be in a position very similar to that of a young child taking his first steps. That is to say, the child does not know where to turn, how to walk. A SSB receiver will not be able to use the SSB receiver to full advantage until he has had some experience with it. (And he is due for as big a thrill as the child gets—Editor’s note.) However, there are some basic rules to keep in mind. The smaller the r-f input, that is, the more the r-f gain can be turned down and still have a readable signal, the more certain one will be of obtaining maximum unwanted-sideband rejection. Always use the receiver with the ave off.

When the SSB receiver is used for the reception of c-w signals, it is not necessary to use the receiver SFO, as the necessary beat note is supplied by the oscillator in the adapter. Of course, when switch S is in position 4 the BFO is used as usual with the receiver. Tuning is usually done in the locked oscillator position when the receiver is in first in use, although with experience a c-w man will develop his own tuning patterns. For example, if the receiver is set to reject the high frequency sideband, and tuning is done from a low to a high frequency, then signals are not heard (unless they are very strong) until you have passed them frequency-wise.

For AM reception, the oscillator in the adapter will produce a heterodyne when tuning across phone signals, when in position 1, 2, or 3. This beat note disappears when the received signal is tuned to zero beat. It thus acts as a signal locator and is a real tuning aid.

For phasemodulated signals and narrow-band FM signals reception is carried out in positions 1 or 2, assuming that the frequency swing is not excessive. It is not necessary to tune to one side of the signal to receive it. It might be well to emphasize that reception of PM and NBFM signals requires only the SSB adapter and a regular superhet—no special limiting device or FM adapter is necessary, or desirable, on the receiver. Merely tune in the signal to zero beat in position 3, and switch to either sideband (position 1 or 2) for reception.

Reception of single-sideband signals is obviously possible, whether the signal is transmitting a carrier or not. If a carrier is transmitted the SSB receiver will lock on it and provided the carrier is of sufficient amplitude. If this is not true, it is only necessary to ensure that the receiver is kept properly tuned. After tuning in the signal, make certain that you listen on the sideband being transmitted.

The user of an SSB receiver will find that he switches back and forth between positions 1 and 2 rather often, during a QSO. Tuning is done by the adapter. (Unless he is listening to a single-sideband signal.) In addition, he will find that whatever interference is heard may also be further reduced by means of the crystal filter, assuming that the superhet has such a device.

For best results, the receiver to which this adapter is connected and the signals which are tuned, should have reasonably good frequency stability. The more perfect the receiver, the better the results will be.