phasing-type ssb generator

Complete construction information on a simple, all-passive phasing-type single-sideband generator

Worthie Doyle, W7CMJ, 1120 Bethel Avenue, Port Orchard, Washington 98366

Phasing-type single-sideband generators described in the literature use active devices, either to isolate the phase-shift networks from the modulators or as the modulators themselves. A few years ago it occurred to me that it should be possible to build a phasing-type sideband generator using only resistors, capacitors, inductors and diodes and using no dc power. This article describes a recent version of such a unit.

Its input requirements are about 3 volts peak rf across 50 ohms (0.1 watt) and a few tenths of a volt of audio across about 15 ohms. Output is from an rf transformer whose tuned winding can drive a vacuum tube or fet directly, while a transistor can be driven from an added low-impedance winding or a capacitive tap on the tuned winding. An attractive aspect of the circuit is that it could be fabricated as a compact, general purpose, sideband generator three-port, since only the two rf phase-shift reactors and the output transformer depend upon carrier frequency.

Usually, both phase-shift networks are designed for infinite impedance loads, automatically requiring that tubes or fets follow. On one memorable occasion, however, a design appeared for a relatively low-impedance network where the input impedances of the transistor loads were included in the resistive output branches of the audio phase shift network.[1] My unit carries this idea to the logical conclusion of dispensing with the drivers and simply including the impedances of the diode modulators in the design and adjustment of the output branch of the audio phase-shift network. The rf phase-shift network design also allows for the modulator impedance. Finally, since the diode modulator impedances vary somewhat with rf drive level, some swamping is used to simplify design and adjustment.

The result appears in **fig. 1.** The version shown operates at 10.5 MHz. Other versions have run at 12 and 7.25 MHz. The values shown for the audio phase-shift network components are those suggested by van Heddegem. The values actually used were scaled up a few percent in impedance to accomodate a couple of odd precision resistors in my own junk box. The test equipment used to build and adjust this circuit consisted of a diode rf probe connected to an ordinary vom, a low-frequency R-C bridge[2] and a receiver with a mechanical filter to verify sideband suppression.

The method of sideband switching is one I have not seen mentioned in print. It has the advantage that one side of every modulator input may remain permanently grounded. The only audio transformer required is the one driving the phase-shift network.

circuit description

The circuit consists of three sections, the audio and rf phase-shift networks and the two balanced modulators. The rf phase-shift network values are those I used, but other builders should be guided by what identical precision resistors are available. The diode balanced modulators are so arranged that both rf and audio inputs are single-ended with one side grounded. The audio and rf inputs are effectively in series, as usual.

The rf phase-shift network is an ordinary arrangement of plus and minus 45-degree sections, except that an estimate of the resistance looking into each modulator is made part of the resistive branches. To estimate this resistance, note that each diode conducts half the time. With one diode conducting, the rf input resistance for each modulator is half the balancing pot, 500 ohms, plus a few hundred more ohms for the diode (varying somewhat with rf drive level) plus another 500 to 1000 ohms for the load seen at the output winding feeding the rf transformer. This load will depend on the Q of the rf transformer and on the load presented by the other balanced modulator. You can only guess at these values, but a reasonable guess is that they will nearly match the roughly 700 ohms of diode plus balancing pot, giving an estimate of about 1400 ohms.

The 150-pF bypass capacitors were made small to avoid affecting the performance of the audio phase shift network. They have about 100 ohms reactance at 10.5 Mhz but do not significantly affect the rf phase shift, since they are in series with a few thousand ohms as well as combining in quadrature. Furthermore, any effects they have are identical for the two modulators, shifting phase slightly without changing the 90-degree relationship.

If 51 ohm resistors are used in the phase-shift networks, the modulator resistance is swamped by a factor of about 28, so a 28% error in the estimate of the modulator resistance is equivalent to a 1% error in the rf phase shift resistor. For this combination the effective resistances of the rf phase shifter output branches are about 49.2 ohms; the rf phase shifter L and C should have this reactance at the operating frequency.

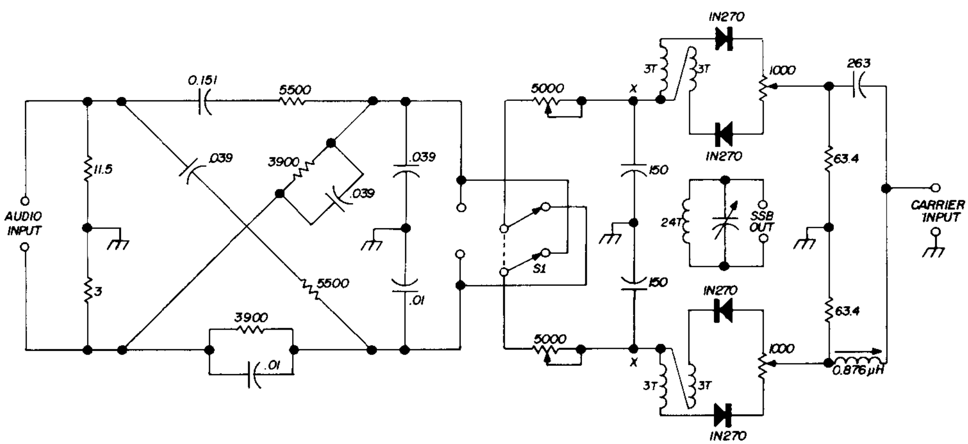

fig. 1. Circuit of a passive phasing-type ssb generator which uses no active devices.

My network was built by making the C from a precision unit a little above the calculated value in series with a larger low-precision unit. The L, a slug-tuned coil, was then adjusted so the rf voltages across the two phase shifter outputs were equal. As a check, note also that each of these outputs is about 70.7 percent of the whole rf input voltage. There is no reason why both L and C should not be variable. In that case you can forget about the exact modulator impedances as long as the two are built identically, but the rf phase-shift adjustment becomes more complicated.

audio phase-shift network

The audio phase-shift network was made of junk-box items. Resistors were precision types or a precision type shunted by a much larger ordinary resistor. Capacitors were paralleled from whatever was on hand. All R and C values were checked on the bridge before being wired in. I've built three audio phase-shift networks by this *dead-reckoning* method (no adjustments) and they all seemed to work fine as judged by listening to speech while switching sidebands.

The resistances at the input of the audio phase shift network should have a ratio of 3.83 with 1% accuracy, but actual values don't matter. I used 5.24 and 20 ohms because my junk box supplied them. Note that the sum of these two resistances should be matched to the audio driver. A junk output transformer from a midget broadcast set is ideal, since it has about the right turns ratio to match a medium-mu triode to 15 or 30 ohms and operating it at this higher impedance level will reduce low-frequency response below 300 or 400 Hz. Be sure neither old vc lead is grounded when using such a transformer.

The important adjustment in this unit is to make each output resistive branch look like the desired 3900 ohms. Each of these resistances is the sum of the trimpot resistance and the modulator audio input resistance. The modulator resistances will be about 700 ohms since the modulator rf transformer windings have negligible audio impedance. This shows that there is a swamping factor of about 5 for variations in the audio impedance of a modulator.

To insure that the resistance of this branch is correct under operating conditions, disconnect the input end (end at the dpdt switch) of each trimpot from the audio phase-shift network and connect this end of the trimpot and ground to the R-C measuring bridge. Set the bridge dial to 3900 ohms (or whatever the design resistance is for your own audio phase-shift network). Turn on the rf carrier oscillator to be used with this unit. It should be operating at the intended voltage, preferably regulated (I'm using a 6C4 fed from a VR150). Now adjust the trimpot for a bridge null. Repeat for the other trimpot and both output branches will have the desired effective resistance.

To insure proper combination of the two modulator outputs, all coils of the output transformer should be closely coupled and both sets of modulator windings should be identical bifilar windings. The easy way to do this, used in the unit described, is to wind the output rf transformer on a high-permeability toroid. The bifilar modulator windings are made from a slightly twisted pair of a few inches of thin magnet wire (cotton or silk covering increases your confidence in the absence of shorts) closely wound around the core.

The two modulator windings and the tuned output winding are all slightly spaced from one another so coupling will be mainly from flux through the core. The numbers of turns indicated in **fig. 1** worked at 10.5 MHz for a nice mystery core from the junk box. For your own core an easy solution is to use a grid-dip meter and the expected tuning capacitance (add 10 pF or so for strays) to discover how many turns are needed on the tuned winding. The modulator windings are then chosen for the indicated turns ratio.

Another arrangement I have used successfully is a solenoidal tuned winding with the two modulators connected to a quadrifilar winding made from four wires slightly twisted together and wound over the solenoid near the middle. A slug-tuned form is convenient in this case. The turns ratios are not critical. Cup cores are nice if you have small, steady fingers.

Balance pot adjustment also deserves some comment. Originally the usual 1000-ohm pots shown in the diagram were used. Later these were replaced by 100-ohm pots at the centers of pairs of 470-ohm resistors to ease carrier nulling.

This required some diode selection, unnecessary with the 1000-ohm pots. The diodes are 1N270s removed from computer boards, but any rf germanium diode is suitable.

In this diode balanced-modulator circuit an rf bypass is often shown across each 1000-ohm balance pot. Such bypasses will cause balance to occur far from pot center unless the diode back resistances are matched or swamped by about 50k across each diode. The reason is that this rf bypass assumes a steady voltage that applies reverse bias to the diodes. Since the diodes are in series for this bias, they divide it in proportion to their back resistances. Unless they are well balanced or swamped to equality the result is to require an eccentric setting of the carrier balance pots. The rf portions of the unit should be shielded so that balance is unaffected by hand capacitance.

sideband selection

The usual method of switching sidebands in a phasing-type sideband generator is to reverse the phase of one of the audio signals or one of the rf carrier inputs. This is not practical when all modulator inputs are to be single-ended with one side at ground. A dpdt switch could be used to reverse the connections of one pair of diodes to the corresponding modulator output winding, but this destroys the symmetry of the circuit and might degrade sideband suppression. At this point in thought I noticed that interchanging either the two audio signals or the two rf signals would also switch sidebands. Obviously, the audio signals are the ones to switch. I have never seen this method of sideband switching in print but assume the experts are aware of it.

results and afterthoughts

When I built the present unit, the rf phase shift C was computed and a fixed capacitor wired in; the coil was then adjusted to make the two modulator rf input voltages equal. The audio phase-shift network trimpots were then adjusted as described earlier and a voice-modulated signal tuned in on a receiver with a 3-kHz wide mechanical filter. The signal sounded normal. When the sideband switch was flipped only a few faint glitches were audible, indicating satisfactory sideband suppression. As noted, the test equipment used on this project is too rudimentary to permit any fancier assessment of unwanted sideband suppression. Suppression was audibly the same on either sideband position.

Having finished the unit and gotten it working, I noticed that I'd forgotten to include an audio balance adjustment to equalize the contributions from the two balanced modulators. In general such an adjustment should be included. Don't try to do it by twiddling the trim pots in the audio phase shift network. A suggested method is about 10k from one of the points X to ground and 5k pot plus 7.5k resistor from the other point X to ground. These resistors should be in the circuit with the variable branch set at 10k when the trim pots are adjusted.

The very small adjustment that is made to reach exact audio balance will not significantly affect the operation of the audio phase-shift network. If audio balance can't be reached (poor unwanted sideband suppression) look elsewhere for the trouble. A test of the audio phase-shift network can be made by checking that the output voltage at each trimpot (end away from modulator) is exactly half the voltage across the 3-ohm input resistor.

This unit has been on the air with conversion to the 75-meter band, where it was reported as sounding like a good, normal ssb signal. Of course, it also sounded normal, as monitored on my own receiver, before it was put on the air.

references

1. Wilfried van Heddegem, ON4HW, "Audio Phase-Shift Network for Transistorized SSB Transmitters and Receivers," *QST*, December, 1964, page 27.

2. Beverly Dudley, "An Impedance Bridge for Less Than Ten Dollars," *QST*, June, 1950, page 19.

ham radio