single-sideband detectors

How the single-sideband signal is demodulated in your receiver

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The air is full of single-sideband signals these days. Up and down the ham phone bands, a-m holdouts can hear the donald-duck chatter of their modern-minded cohorts QSOing away—squeezing every last decibel of usefulness from every watt—on sideband.

It doesn't take much to turn that chatter into plain talk. Just a special detector will do it. At least those guys with a-m sets could **listen.**

The sideband operator already has that special demodulator, built right into his ssb receiver. It goes by many names, but the one used most is **single-sideband detector.** Other names come from the method of operation. Product detector, heterodyne detector, carrier-insertion detector, bfo detector—are among the terms that describe typical ssb demodulators.

The basics of a sideband detector are simple. The signal your sideband receiver picks up is nothing but one sideband of some operating frequency. To recover the voice modulation which created that sideband signal, you need a carrier for the sideband to heterodyne with. (That's how an a-m detector works; the sidebands heterodyne with their carrier in a nonlinear detector—usually a diode.)

A single-sideband signal has no carrier of its own; that was removed at the transmitter. So a carrier has to be added at the receiver. Then the carrier and sideband can be fed together through an ordinary diode detector, and the voice signal recovered.

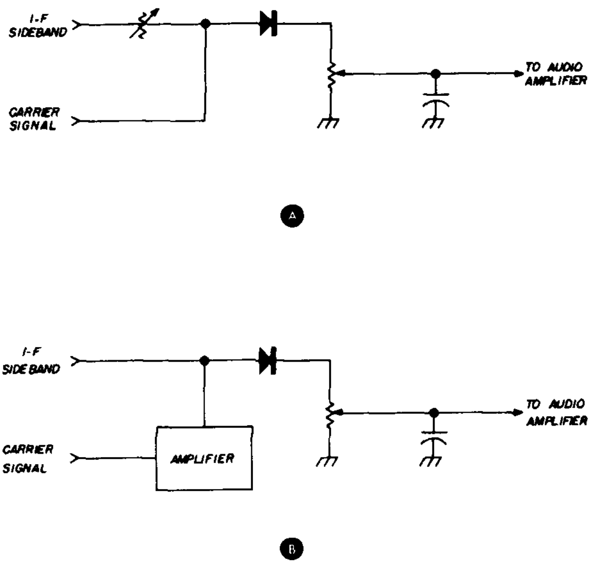
The i-f amplifier is the best place to mix the carrier and sideband signals. The frequency there is always the same, no matter what band is tuned in up front. A single-sideband detector mixes the i-f sideband signal with a signal at the frequency the i-f carrier would be if there was one. The steady signal is then called the carrier, since its purpose is to supply a signal against which the sideband can beat for demodulation—the purpose of a carrier.

The steady signal in receivers is most often supplied by the bfo that is used for code reception. Adjusting the **bfo pitch** control lets you control the timbre of the demodulated voice. In transceivers, the signal more often comes from the carrier oscillator; it's common practice to generate the initial carrier (before balanced modulation, sideband filtering, and up-translation) at the same frequency as the i-f. Whatever its source, the fixed frequency is fed to the demodulator system along with the sideband.

You can see one oversimple system in **fig. 1A.** (Don't bother copying it though; it's inefficient.) For distortion-free detection in any mixing-type ssb demodulator, the carrier signal must be much stronger than the sideband signal. One way is to attenuate the sideband signal; that's why the variable attenuator is included.

The arrangement in **fig. 1B** is a little more effective. The improvement comes from isolation provided by an amplifier between the carrier source and the mixer. The amplifier also gives that needed boost to the carrier signal.

fig. 1. The simplest principles of ssb demodulation. There is no isolation between signals in A; isolation plus carrier amplification are provided in B.



toward a better way

Extra care must be taken with single-sideband detectors. Distortion is always a possibility, unless each signal is handled so that the only nonlinearity is in the detection circuit itself. Applying the signals to a single detector diode is not the most desirable way to get this particular job done.

Better efficiency can be had from the improved version in **fig. 2,** using two diodes. The carrier signal is applied to them in a parallel mode (its coupling capacitor is connected between their cathodes). The i-f sideband signal, on the other hand, is in series with both diodes. This parallel-series hookup lets the two signals mix in the special way that produces an audio signal.

The special way mixing takes place in **fig. 2** as the result of how the signals are brought together. The carrier signal is fed to the stage in a mode different from that of the sideband. The mixing generates a **product** of the two signals instead of sums and differences. (That's where the name **product detector** comes from.)

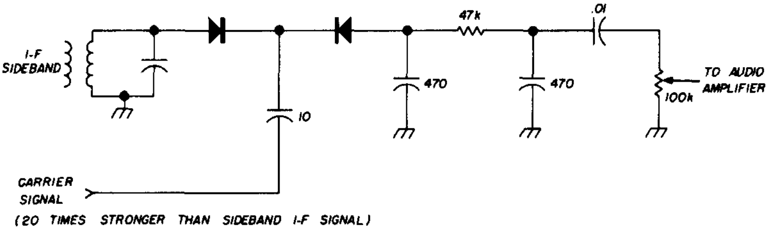


fig. 2. More elaborate diode circuit for ssb demodulation; circuit has fundamental resemblance to balanced demodulators.

Furthermore, the output signal is taken from the stage in series—a mode opposite to the carrier input mode. This encourages cancellation of the input carrier, keeping it from the output. The **product** of this mode of mixing, therefore, is a relatively pure audio signal—the recovered voice signals that originally formed the sidebands. Any slight remaining carrier or sideband signal is eliminated by the 470-pF capacitors and 47k resistor.

(The parallel/series method of feeding the two signals into the stage—and of taking the output—should sound familiar if you've read earlier articles in this series. Beginning on page 24 of the May issue, I described balanced modulators in ssb equipment. They also use this two-mode way of handling input and output signals.)

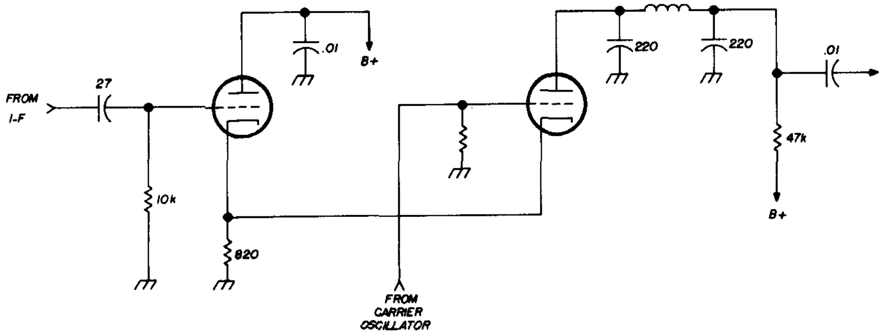
Tubes offer a better means of isolating and mixing (see **fig. 3**). Furthermore, the tubes can build up the carrier-signal strength. The sideband signal from the i-f amplifier is applied to a cathode follower; that isolates the signal source from the mixing circuit, without adding any gain. The sideband is then cathode-coupled to the mixing tube. Meanwhile, the carrier signal is also fed to the grid of the mixer, and is amplified.

These signals mix within the tube. The output is a **product** of both signals—a heterodyne product that includes the original modulation that has been carried by the sideband. All rf is filtered out by the pi-network, and clean audio is sent to the audio amplifiers.

balanced ssb detectors

You've already seen a simple single-sideband detector with characteristics ap-

fig. 3 Two-triode version exemplifies principles of sideband detection and is used commercially.



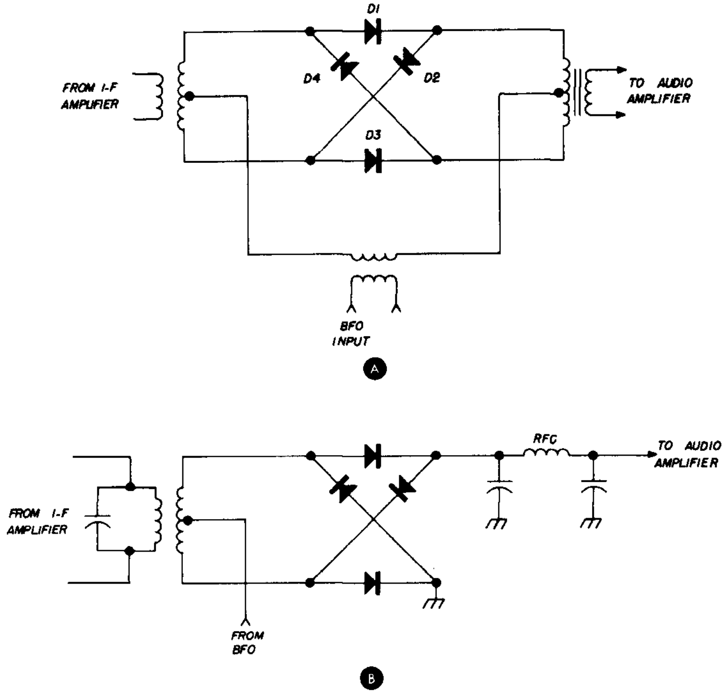
proaching those of a balanced modulator. The fact is, you can use a circuit very like a balanced modulator to demodulate sideband signals.

If you study the stage in **fig. 4A,** you will see that it differs only slightly from a balanced modulator. Both input transformers are rf types, whereas in a balanced modulator one of them would be an audio type. The output transformer in **fig. 4A** is an audio transformer; in a balanced modulator it would be an rf type. What you see in **fig. 4A**, therefore, is a balanced demodulator.

The diodes are in what's called a **ring** arrangement; if you trace through them, you'll see they are essentially in series—'round and 'round. The name of the stage is **ring demodulator.**

Its operation is exactly what is needed to recover audio from sideband signals. It accepts the sideband i-f signal and the carrier signal (from a bfo or a carrier oscillator), reinserts the carrier so the signal can be demodulated, and then couples out the resulting audio signal while eliminating the carrier. The action in a balanced detector is thus very like the action in a balanced modulator; whatever signal is fed into the stage in a mode opposite from the output mode is canceled. This helps considerably in a ssb detector, since the carrier must be applied at a level so much higher than the level of the sideband.

fig. 4. Ring type ssb demodulators. Primary version in A is balanced demodulator; eliminating the costly and bulky transformers doesn't alter stage operation (B).



The ring demodulator can be simplified. Transformers are costly and bulky, and any circuit alteration that eliminates them has an advantage. An altered version is shown in **fig. 4B.**

Major characteristics remain. The solid-state diodes are hooked in a ring, the i-f sideband signal is applied in push-pull, and carrier signal is applied in parallel. With the bottom of the sideband-input transformer grounded (instead of the center tap), ground is made one side of a push-pull arrangement; the output is therefore effectively in push-pull, even though it is single-ended for any circuit following. The effect is thorough demodulation of the

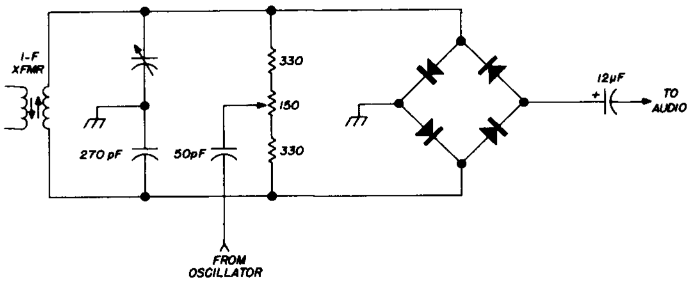


fig. 5. Commercial version of ring demodulator looks slightly different, but uses all principles of others.

sideband signal, with the carrier canceled in the output. The pi-network eliminates any slight rf that remains.

Does anyone use the balanced sideband detector? Yes. One version is part of the Sideband Engineers SB-34 transceiver. There's a schematic of the stage in **fig. 5.** I've redrawn the ring circuit to simplify the looks of the stage for you, but operation is the same as already described. The carrier signal, which in this case comes from the oscillator that generates the initial carrier for the transmit function, is fed to a resistive balancing network; the resistors also isolate it from the ring diodes.

The carrier is applied in the parallel mode, as you can see; the sideband input is push-pull, because of the "phantom" center-tap ground point offered by the ground connection between the two capacitors. In the ring circuit, input and output connections are the same as in **fig. 4B;** you'll see it if you trace them carefully, even though they may look different at first glance.

a one-transistor version

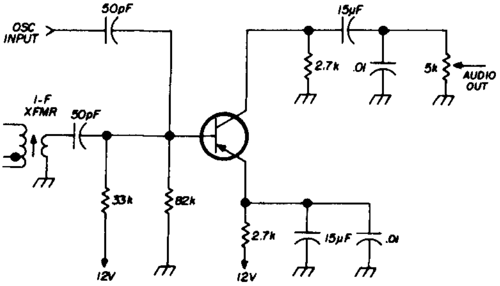
Diode sideband demodulators are all solid-state, since almost no manufacturer uses vacuum-tube diodes today. Semiconductor diodes are more efficient and less expensive. When you talk about solid state, though, you must include transistors. At least one manufacturer uses a transistor ssb detector.

You can see the circuit in **fig. 6.** This stage is from a Gonset Sidewinder transceiver. The pnp transistor is biased in a way normal for negative-ground power supplies—the emitter goes to the power-supply bus, and the collector goes to ground through its load. The two inputs are not isolated in this particular demodulator. The carrier signal is already amplified before it is applied to the transistor base (through the 50-pF capacitor). It and the sideband signal mix in the transistor.

What keeps this from being a simple amplifier for both signals is the bias level chosen for the transistor. The base-emitter junction is strongly backward-biased; the heavy carrier signal then is amplified class C, which is nonlinear.

Mixing in the base resistor as they do, these two signals generate considerable cross modulation. When the cross-modulation products are amplified by the Class-C transistor, the audio is easy to separate from the other products of this nonlinear mixer. The 0.01-µF capacitor across the volume control eliminates most of the rf signal that is left over. The original modulation, which has been masquerading as a sideband, is thus recovered.

fig. 6. Transistor product detector, with no isolation between input signals. Bias of the transistor is what makes it a demodulator rather than amplifier.



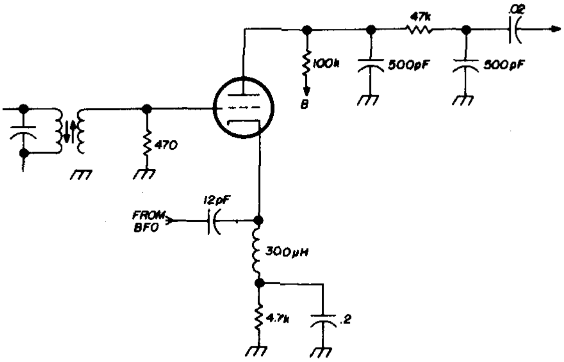
This transistor sideband detector hasn't become popular; no other set uses it that I know of. But transistors can be substituted in any triode-tube demodulator, provided you consider their dc supply requirements and their low impedance.

ssb detection with tubes

In any single-sideband detector system, isolation of the two input signals is desirable. One way to achieve this is in a simple triode product detector—**fig. 7.** The high-level signal from the bfo (or from the carrier oscillator) is fed to the cathode, using a 300-μH choke as high-impedance—and therefore efficient—input load. The i-f signal, which is the sideband to be demodulated, is applied to the grid, across a low-impedance load: the 470-ohm resistor. This disparity between the two input-load impedances goes part-way toward setting the 10-to-1 ratio you want between these two signal strengths.

This triode stage is another reminder of an important principle of product detectors. It isn't always the circuit arrangement that makes a stage detect sideband signals; it is the way the stage is operated. Without the high bias developed by the 4.7k cathode-bias resistor, the triode would be nothing more than an amplifier. It would transfer both signals to its output, amplified but otherwise unaltered. It is the nonlinear operating characteristic that permits product detection—and therefore *sideband demodulation.*

fig. 7. Triode product detector with some isolation for signals. Same idea could be used with a transistor.



The pi-network in the output of this triode single-sideband detector consisting of two 500-pF capacitors and a 47k resistor eliminates whatever rf products get through the detection process. Good rf filtering is more important in a detector stage like this than in a balanced type, simply because the balanced stage inherently keeps most rf from reaching the output.

The **fig. 7** circuit is popular because of its economy and simplicity. You'll find it in several Heathkit sets and in the Hallicrafters SR-2000 transceiver.

A tube version like the one I described in **fig. 3** is part of the Hammarlund HQ-180. The stage configuration is the same; the only differences are in parts values. A triode Colpitts bfo is used in the HQ-180 to furnish the carrier.

The other Hammarlund models revert to the single-tube product detector using a pentode: the HQ-110 and the HQ-145. There is no isolation between the two inputs; both signals are applied to the control grid. Some isolation is achieved by the weak coupling used for both signals. The strong carrier signal is applied through a 3-pF capacitor, small even in this service. The i-f sideband signal is coupled only by a twisted-wire "gimmick" capacitor offering less than 1 pF of coupling capacitance. The high gain of the pentode makes up for any expected weakness in the output—the demodulated voice signal.

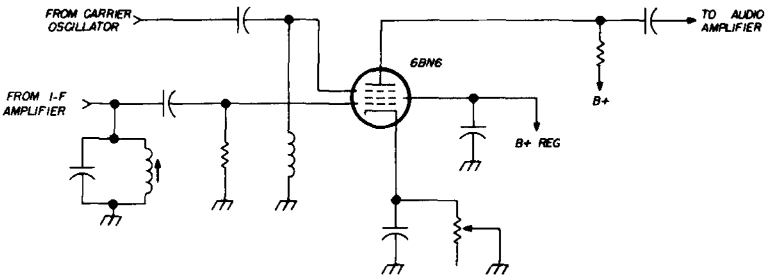
using special tubes

You read earlier that product detection is more how the tube is operated than what kind of circuit it's in. That being the case, imagination suggests that tubes with certain special operating characteristics could do an efficient job of demodulating single-sideband signals. That's right. One such tube is the gated-beam detector, a tube with pentode qualities and special construction that makes it particularly suitable for product detection. The beamed electron stream in a gated-beam tube is controlled by both the control grid and a special "gating" grid near the plate. Both grids have exceptionally linear control over the electron stream, and very little effect on each other.

Combine these characteristics into the stage in **fig. 8** and you have a better-than-passable product detector. The sideband signal is applied to the control grid, or G1. The carrier-oscillator (or bfo) signal is applied to the special grid, G3.

The gated-beam stage is a little tricky to adjust. Unless the bias is just right for each particular tube, considerable output distortion is common. Designers also must carefully work out the strength ratios of signals applied to the two grids. Properly designed and adjusted, though, the gated-beam ssb detector does a good job.

fig. 8. Gated-beam detector, used for years in tv and fm receivers, can also make a good ssb detector.



An offshoot of the gated-beam idea is used in the Galaxy V Mark 2 transceiver. The circuit is shown in **fig. 9.** The tube is a 6GX6, a pentode specially designed for broadcast-receiver use in fm detectors. Its non-interacting quality between grid 1 and grid 3 serve sideband detection admirably. As you can see from the diagram, a crystal-controlled oscillator is formed by the cathode/grid 1/screen portion of the tube. The 6GX6 thus provides its own insertion carrier. Sideband signals from the i-f stages are applied to grid 3.

This tube, like the gated-beam detector tube, is touchy. Signal levels must be guarded to avoid crossmodulation that might upset output clarity. The diode between the i-f transformer and the tube input acts as something of a safeguard, to prevent overdriving grid 3. (The diode can't act as a detector because there is no carrier with the i-f sideband signal.)

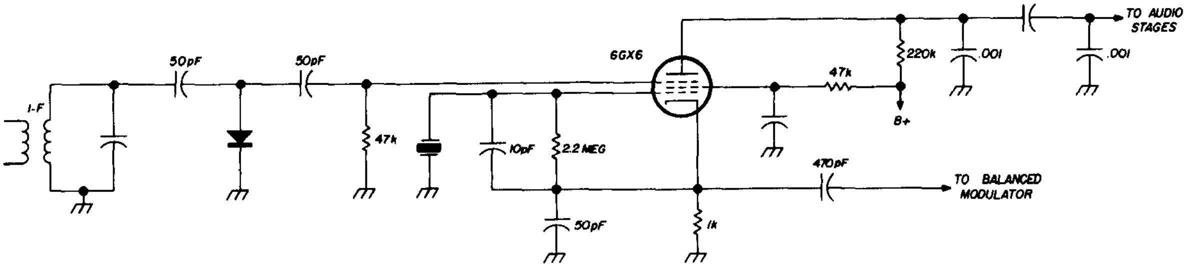
The connection going to the balanced modulator is shown because the oscillator portion of the 6GX6 circuit doubles—during transmission—as the carrier oscillator. That connection has no bearing on detector operation during recepiton.

beam-deflected ssb detection

If you did read the earlier article on balanced modulators, you may remember a rather unusual stage using a **beam-deflection** tube. The tube is an RCA 7360, and makes an efficient—though expensive—balanced modulator. This circuit can be altered slightly to become a balanced demodulator, as can other balanced modulators.

The sidebands are applied to the beam-deflecting plates in push-pull. (Supply circuits are not shown to keep the diagram

fig. 9. Another special tube, the 6GX6, makes an excellent ssb demodulator if care is taken with the levels of carrier and sideband signals fed to it.



simple.) The carrier signal is applied to the control grid, which puts that signal in parallel insofar as the rest of the stage is concerned. The demodulated audio output is taken off in push-pull by the simple device of grounding one output plate for audio through C4. (C5 is a different value because its purpose is to eliminate any stray rf signal that might be left over after demodulation.) Output is from the other plate, coupled to the audio amplifiers by C6.

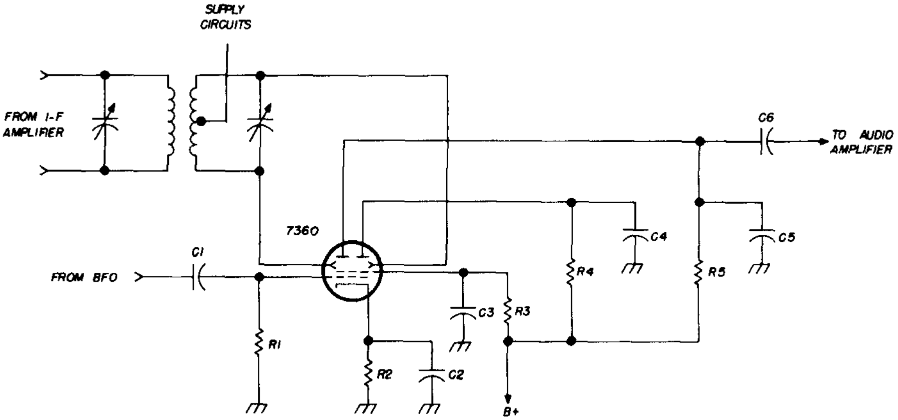


fig. 10. Tube developed especially for use in ssb communications; can be either a modulator or demodulator.

The beam-deflected method of ssb demodulation hasn't been used in any commercial ham equipment I know of. Its expense, though not great, is more than for diode balanced-demodulator systems; cost is always a deterrent to inclusion in factory-built equipment. The circuit is showing up occasionally, however, in home-brew designs. It is efficient, and you might want to try it in a receiver of your own. Operating characteristics for the 7360 can be found in The Radio Amateur's Handbook, in the Special Receiving Tubes table. From those, you can work out parts values.

sideband detectors in general

Summing up the characteristics of various single-sideband detectors, you can draw certain general conclusions. First of all, any ssb modulator can be altered to become a demodulator. You merely feed in carrier and sideband signals instead of carrier and voice signals. A balanced modulator becomes a balanced demodulator by that simple switch; of course, you have to change one input transformer from an audio type to an rf type and change the rf output transformer to an audio type.

In demodulators of the product-mixer kind, you have to be sure the carrier signal is 10 or 20 times as strong as the sideband signal. That's because the carrier is always much more powerful than the sidebands in an ordinary a-m signal, and that relationship must be maintained for proper demodulation. If you're working up your own demodulator circuit, you should adjust the ratio between the two signals until you get the best output signal-to-noise quality; at the same time, keep both signals low enough in strength that one doesn't overload the tube(s) you're using.

With the information here, you should find that sideband detectors have few secrets anymore. You've seen both tube and transistor types, as well as solid-state diode types.

And—speaking of transistors—that's what we'll go into in the next article: transistors in single-sideband equipment. More transistors are being used, so there should be a lot of dope that will help you in your future ssb activities.

ham radio