Simple Direct-Conversion Receiver

For QRPers and receiver aficionados in general.

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An essential ingredient for the newcomer in amateur radio is a good receiver, one that is sensitive enough to pick up signals that are down near the noise level, and selective enough to separate adjacent signals and provide clear copy. Without such a receiver, you can only look forward to "unanswered" CQs and lots of frustration. However, a good communications receiver can cost anywhere from $250 to $500, and most beginners don't have that kind of money. Even a good *used* receiver can cost $150.

As an alternative, a direct-conversion receiver should be tried. It performs well over a range of 3.5 to 4.3 MHz on AM, SSB, and CW, and is easily constructed at a cost near $30. Direct conversion is a much neglected type of design that can best be described by comparison with the more common system, superheterodyning.

In the superhet system (see **Fig. 1**), the first stage is an RF amplifier. This is followed by a mixer, where the signal is combined with the output of a local oscillator. The frequency of the latter is a certain amount above or below that of the RF, and the difference is called the intermediate frequency. The output of the mixer contains a high-frequency component and a low-frequency component. These two signals are produced by superheterodyning—that is, combining two signals to produce one at a frequency equal to the sum of the frequencies of the original signals, and one at a frequency equal to their difference.

At this point, we filter out the high-frequency component and amplify the lower in a stage that has high gain and a narrow passband, which affords selectivity. The output of the IF amplifier is sent to a detector, which may be of two types: For AM reception, it is an envelope detector (a diode followed by a low-pass filter). For SSB and CW, a product detector that is really a second mixer, fed by a beat frequency oscillator (BFO), is used. The difference component of this heterodyning process is an audio signal that is then amplified through one or more stages and passed on to phones or a speaker.

As you can see, there are usually four or more stages that must be properly tuned in conjunction with each other for proper signal recovery in a superhet receiver. Most quality communications receivers have two or three IF stages, with separate mixers, local oscillators, and tuned amplifiers for each stage. These complications drive the cost of receivers out of the reach of a large portion of newcomers to the radio hobby.

The direct conversion technique is a much simpler process. The block diagram of this system is shown in **Fig. 1**. The RF amp supplies the mixer with an amplified version of the signal received from the antenna. The mixer is also fed an RF signal of the same frequency as the incoming carrier from a local oscillator whose frequency is adjusted by the main tuning dial C26. The output of the mixer contains one audio frequency signal and one RF signal at twice the frequency of the original. The RF signal is then filtered out by a low-pass filter and we are left with an audio signal. This is then amplified by one or more stages of high gain, and the output is connected to a speaker or a pair of phones.

That's all there is to it. We have none of the complexities of dual- or triple-conversion superhet receivers, but do

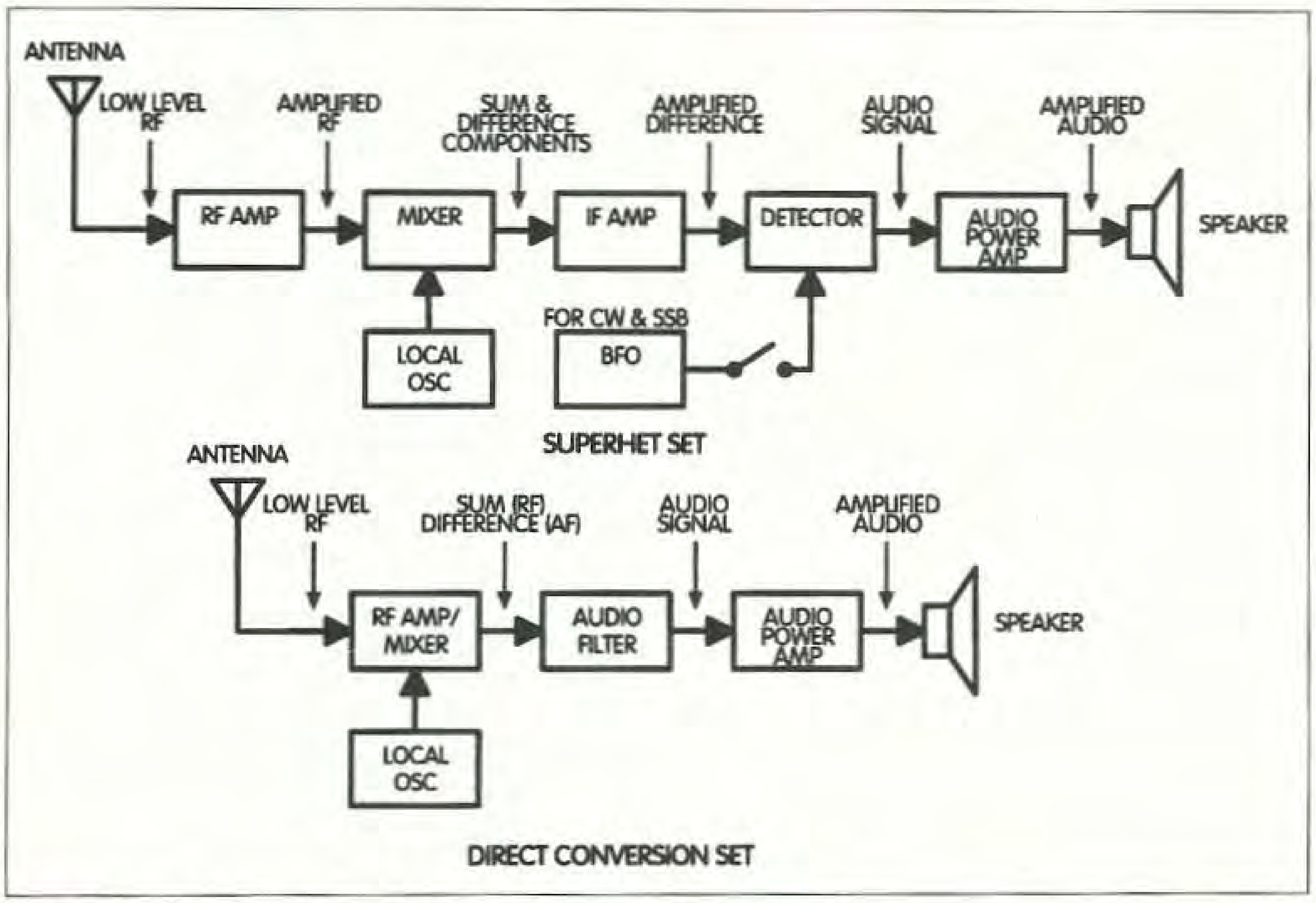

Fig. 1. Superhet (top) and direct-conversion sets compared.

have good sensitivity, and if we use a high-quality, narrowband audio filter, we have selectivity that will rival that of a superhet unit costing ten to twenty times more. The simplicity of operation is reflected in the ease of construction.

Circuit operation

A comparison of the block diagram (**Fig. 1**) and the schematic diagram (**Fig. 2**) will point out a few differences. For economy's sake, an RF amplifier has been omitted from this receiver. However, the receiver is still sensitive enough to pick up many signals that would be missed with a cheap "communications-type" superhet model. Signals from the antenna are coupled to the MOSFET mixer, Q1, over the tuned LC circuit composed of L1, C1, and C2. Transistor Q2 is the local oscillator and its output is coupled through a small silver mica capacitor, C28, to the second gate of Q1. The antenna coil L1, and the oscillator coil L2, are wound on small toroidal cores, which is an effective way of attaining high Q circuits—the basis of the selectivity of the receiver's front end.

The other contributor of selectivity in a direct-conversion receiver is the audio filter. This filter performs two functions: It rejects the high frequency component of the mixer output, passing the audio signal, and it provides a large part of the receiver's selectivity by virtue of its audio bandpass characteristics. In this circuit, L3, C5, C7, and C8 comprise the low pass filter. Coil L3 is a variable TV-width coil, and the capacitors are of the mylar type. Capacitors C1, C25, C27, and C28 are NPO or silver mica types. Op amp IC1 is a conventional audio amplifier, and almost any op amp will work well in this circuit. Variable resistor R10 serves as a volume control in the standard voltage divider mode, and IC2 serves as an audio output amplifier. Any one of the common audio modules furnishing 0.5 to 1 watt output can be utilized for this purpose. If desired, a headphone jack can be installed.

A power supply was not incorporated into the receiver. A suitable source supplying 500 mA at 12 V should be used. If you intend to use the receiver for portable operation, or don't wish to construct a supply, six to eight D cells in series will work fine. An inexpensive battery holder can be obtained for holding them. It is important to take care in observing polarities while connecting

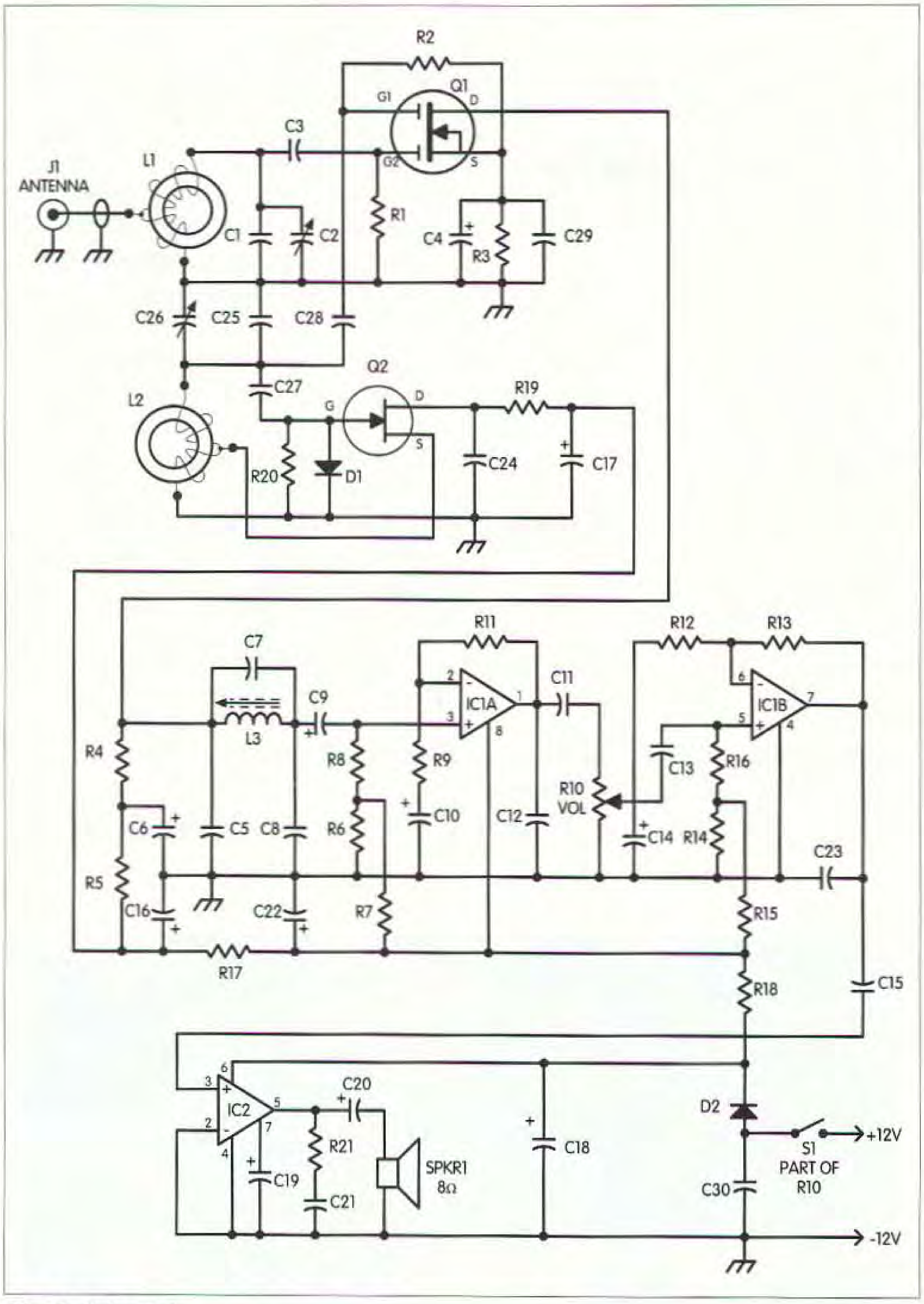

Fig. 2. Schematic.

the supply. To protect the sensitive semiconductors, diode D2 has been incorporated. If the wrong polarity is applied to the receiver, D2 is reverse-biased and will not conduct. If this diode is not installed, the FETs and ICs would be destroyed in the event of accidental reversal of power supply polarity. However, when incorrect polarity is applied, the receiver simply will not work, thanks to the protective action of D2.

Using other frequencies

The receiver can also be used on other frequency bands. Only the LC combination at the input of the mixer and the tuned circuit of the local oscillator need modification. For 40-meter operation, remove C1. Remove L2 and replace it with 15 turns of #22 enameled wire, wound uniformly spaced on a T50-2 toroid core and tapped 7 turns from ground end. Also, connect a 225-pF silver mica capacitor in parallel with C25.

For 20 meters remove C1 and wind a new oscillator coil L2 on a T50-2 toroid core. It should be 7-1/2 turns of

Parts List

Part	Description
R1-2, R8, R16	100k ohms
R3	560 ohms
R4	2.2k ohms
R5, R17-19	100 ohms
R6-7, R14-15	10k ohms
R9, R12	4.7k ohms
R10	10k pot w/ S1 SPST switch (fr. panel)
R11, R13	47k ohms
R20	27k ohms
R21	10 ohms
All resistors 1/4 W unless otherwise noted.	
C1	200 pF NPO disc or silver mica
C2, C26	100 pF var. tuning cap (fr. panel)
C3	22 pF disc
C4	22 µF electro 16 WVDC
C5, C8	0.02 µF mylar
C6	50 µF electro 16 WVDC
C7	0.01 µF mylar
C9, C10, C14	4.7 µF electro 16 WVDC
C11, C13, C15, C30	0.1 µF disc
C12	0.01 µF disc
C16-18, C20, C22	100 µF 16 WVDC
C19	10 µF 16 WVDC
C21	0.05 µF disc
C23-24	0.005 µF disc
C25	180 pF NPO disc or silver mica
C27	47 pF NPO disc or silver mica
C28	4.7 to 5 pF NPO disc or silver mica
C29	0.01 µF disc
All capacitors 50 V unless otherwise noted.	
Q1	dual-gate MOSFET RCA 40673, 3N140, or 3N141
Q2	2N3819 or MPF102
IC1	LF353 dual op amp
IC2	LM386 power amp
D1	1N914 signal diode
D2	1N4001 diode
L1	34T #22 enam. wire tapped at 11T from grnd
L2	34T #22 enam. wire tapped at 5T from grnd
L3	10 to 50 mH var. coil (Miller #6319) or color TV convergence coil from junk TV
L1 and L2 are wound on a T50-2 toroid core available from Palomar Engineers or Circuit Specialists. Q1, Q2, IC1, and IC2 are available from DC Electronics, P.O. Box 3203, Scottsdale AZ 85257.	

Table 1. Parts list.

#22 enameled wire, evenly spaced and tapped 2-1/2 turns from ground end. Remove the 225 pF capacitor across C25 if it was installed for 40-meter operation.

For 10 and 15 meters, L1, the antenna coil, must be replaced with 8 turns of #22 enameled wire wound on a T50-2 toroid. The L2 coil must be replaced with 5 turns of #22 wire, tapped at 2 turns from ground end. In winding both coils, spread the turns to space them evenly around the forms. If you wish, some sort of band-switching or plug-in coils could be used.

Alignment

Making sure that you observe correct polarities, connect a 12 V battery to the receiver. Connect a speaker and antenna to their respective jacks. Turn the audio volume control until you hear the "rushing" sound of the atmospheric noise. Rotate the preselector capacitor C2 slowly. At one point there will be a noticeable increase in sound in the speaker. Carefully adjust C2 for this peak. There is only one adjustment for receiver alignment, setting the value of inductance of L3. This prevents any RF components from local oscillator feedthrough or the heterodyne process from entering the audio stages of the receiver. The procedure is very simple. Adjust L3 until the tuning slug is positioned about halfway into the coil. This completes the receiver alignment.

Using the receiver

As you tune across a band, keep the front end of the receiver resonant by adjusting the preselector capacitor C2. You will notice one basic difference in receiver operation between the direct-conversion receiver and a superhet. On the conventional receiver, there is a mode switch that must be adjusted for the type of signal you want to receive. When this switch is in the SSB/CW position, it activates the BFO and product detector. It is not possible to properly demodulate such signals when the switch is in the AM position, which directs the signal to a simple envelope detector.

With the direct-conversion receiver, no such switch is necessary and any signal (CW, AM, SSB, or FM) is properly detected just by adjusting the frequency of the local oscillator, which is accomplished by turning C26, the main tuning dial. Thus the direct-conversion receiver provides many advantages over the superheterodyne model. It is less expensive, easier to build, and simpler to operate. Try it, you'll like it!

Reference

For interesting information by Joseph J. Carr on the theory of direct-conversion receivers, see *Popular Electronics*, August 1997, pages 39ff. 73