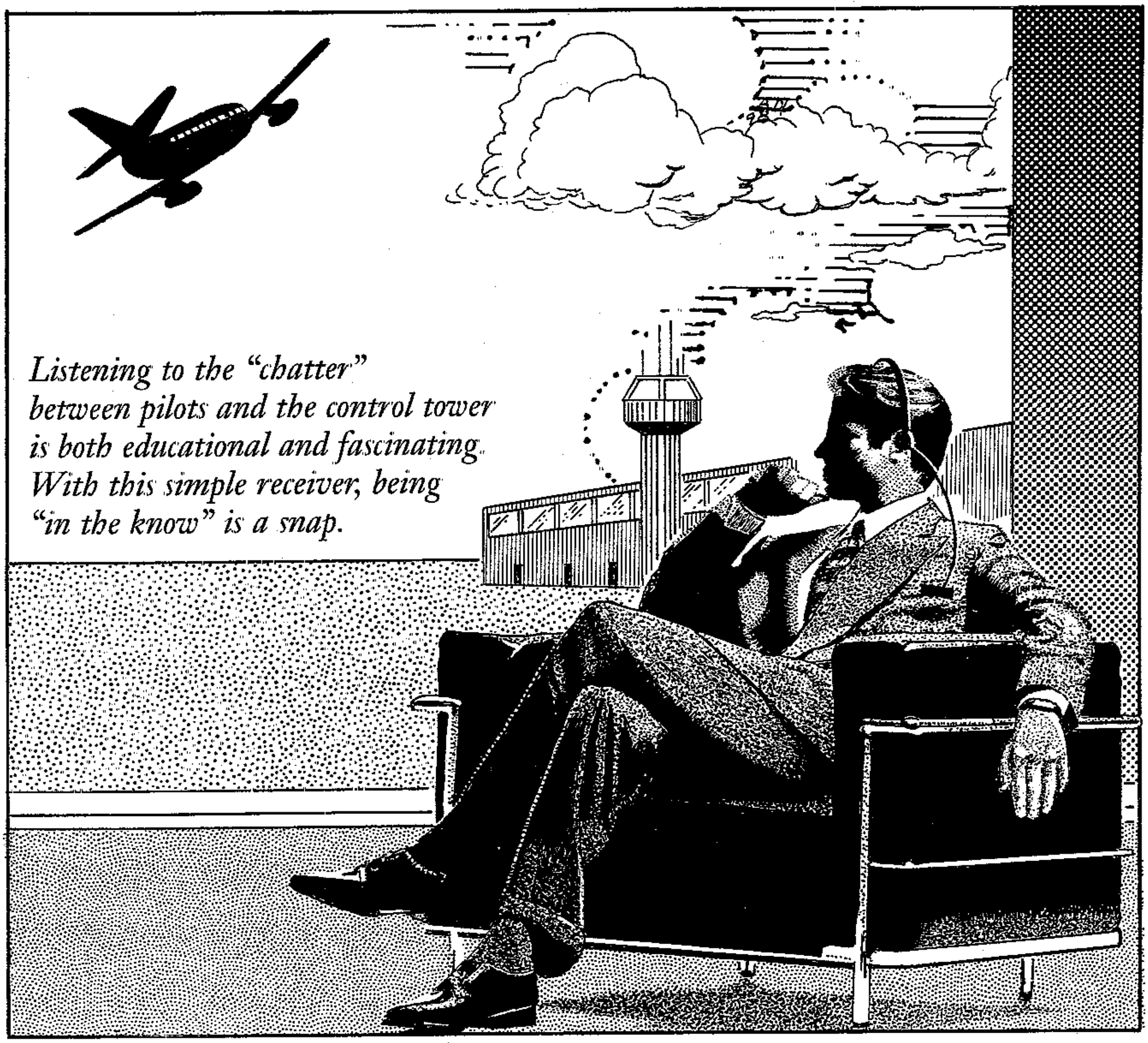
THE AIRPORT BUDDY



Listening to the "chatter" between pilots and the control tower is both educational and fascinating. With this simple receiver, being "in the know" is a snap.

ANTHONY J. CARISTI

If you find yourself spending a lot of time at airports waiting for an outgoing or incoming flight, or if you have an interest in aviation in general, you've probably wondered about the type of communication that occurs between the pilots and the tower Being "on the inside" has always fascinated people. If you want to be "in the know" in terms of aviation operations, then the Airport Buddy is a must-build project. This low-cost receiver will let you eavesdrop on communications between the control tower and aircraft flying above, and you will be able to keep up with what's going on Even if you don't have that type of interest in aviation radio, the Airport Buddy will make a unique gift for a friend or relative who does fly frequently.

The Airport Buddy is a one-chip VHF superheterodyne receiver that is easy to build, compact, and small enough to fit into a pocket It is designed to receive audio communications in the 108- to 135-MHz frequency band, which is used for ground-to-air communications.

The project consists of a small PC board that is powered by a common 9-volt battery and fits in a small case A pair of headphones is used to hear the received audio signals A knob-adjustable frequency control (either a single- or a multi-turn type) is used to tune in whatever conversations are taking place at the time. An optional volume control is easily added to the circuit

Since all of the difficult design requirements of the circuit have been taken care of by a suitable PC board layout a receiver that works well is easily built simply by following the construction details given here.

How It Works. The schematic diagram for the Airport Buddy is shown in Fig. 1 The heart of the receiver is IC1, a sophisticated IF (intermediate frequency) amplifier chip that contains a mixer, a local-oscillator transistor, and a pair of high-gain IF amplifiers Also included is a received-signal-strength indicator (RSSI) circuit that is used as an AM detector. The chip also has a built-in FM-quadrature detector; since air-traffic communications use AM instead of FM, it is not used here.

A short piece of wire or a telescoping radio antenna is used to pick up the RF signals The RF is coupled to the mixer input of IC1 through coupling capacitor C1

The emitter and base of the built-in local-oscillator transistor appear at pins 3 and 4 of IC1, respectively. The circuit is a Colpitts oscillator, with C3 and C4 forming the voltage-divider capacitor pair that is connected between the ground and the internal transistor's base and emitter. Coil L1 and varactor diode D2 form a parallel-tuned circuit that sets the local-oscillator frequency. Potentiometer R6 is a front-panel tuning control that adjusts the DC bias on D2 That sets the local-oscillator frequency for tuning the radio; it can be varied over the range of about 108 to 135 MHz.

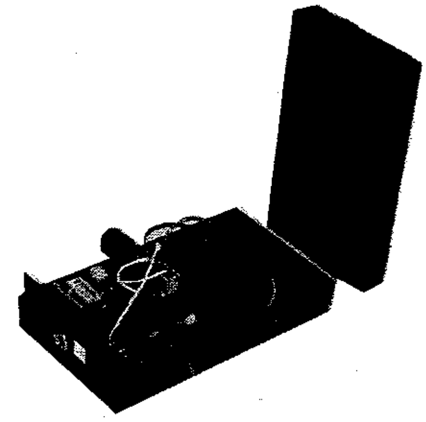
The intermediate frequency of the circuit, 455 kHz, is set by RES1 and RES2. An interesting feature of the Airport Buddy is the lack of RF preselection. That feature lets a received signal appear in two places on the dial The advantage to that approach is that it becomes easier to find an active communication channel

Within IC1 is a pair of high-gain IF amplifiers that are designed to provide limiting of the received RF signal. Limiting is needed for FM communications—the original use for the chip The RSSI circuit mentioned before normally monitors the current drawn by the IF amplifiers The RSSI outputs a voltage on pin 7 that is proportional to the amplitude of the received signal.

In order to demodulate the AM signal, the local oscillator is tuned either to 455 kHz above or below one of the sidebands of the received signal frequency. Because of that, the RSSI circuit makes a good demodulator for the received AM signals

The demodulated audio on pin 7 of IC1 is coupled to the gate of Q1 through C8. The amplified signal is then coupled to an external headset through T1.

Power to operate the circuit is provided by a common 9-volt transistor-radio battery. Current draw is about 10 milliamps, giving over 35 hours of use from a new alkaline battery.



The small size of the Airport Buddy's PC board lets the entire unit fit into a small case that can be easily carried in a shirt pocket. Here is the author's prototype. Note that ANT1 is simply a length of insulated wire

Construction. Because of the high frequencies involved, the Airport Buddy should be built on a PC board. When RF frequencies are involved with any circuit, a double-sided board with a large solid-copper ground plane helps to contain any stray RF radiation from the circuit Any circuit trace that is carrying a signal in the RF-frequency band

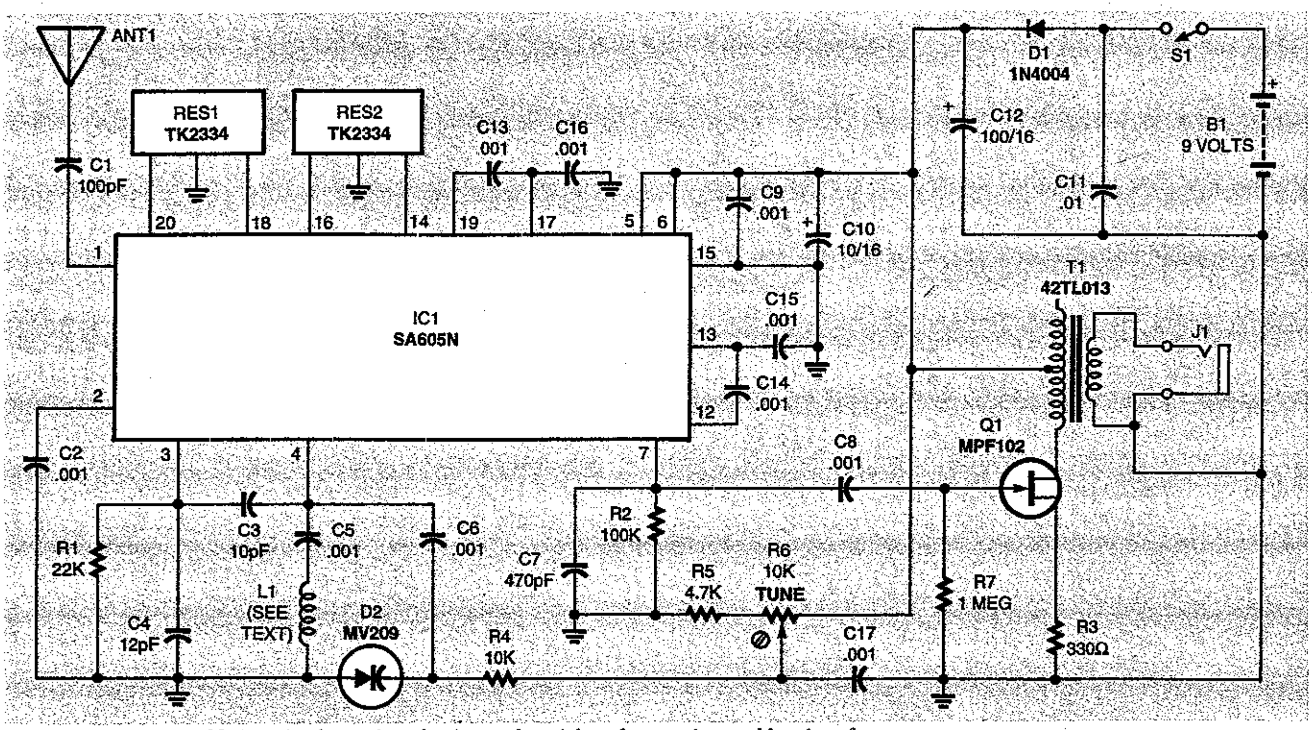


Fig. 1 The Airport Buddy is a simple receiver that is tuned to pick up frequencies used by aircraft Although IC1 was originally designed to be used in an FM radio, it does a superb job with the AM-style method used by aircraft and airports

TABLE 1 COMPONENTS GROUNDED TO GROUND PLANE

R1	C11
R2	C15
R3	C16
R5	C17
C2	IC1 pin 15
C4	D2
C7	L1

can act like a miniature broadcast antenna, resulting in the disruption of any other receivers that happen to be close enough to the source of the RF leakage.

Foil patterns for the Airport Buddy have been included. If you do not wish to fabricate your own board, one may be obtained from the source given in the Parts List. If you are going to etch your own board, note that only one foil pattern is needed. That pattern is for the solder side of the board—the component side is left as a single ground plane. An easy way to etch the board is to coat the ground-plane side with resist; common shellac can be used. The other "foil pattern" only shows the locations of the holes that should be cleared of copper ground plane before building the circuit. Use a sharp knife to clear a small amount of copper from around the indicated holes. The component leads that will be inserted into those holes should not touch the ground plane. The other holes that will not be cleared will be used as ground connections on the top side of the board.

The parts-placement diagram shown in Fig. 2 is to be used for locating the various components if you are using a purchased board or one made from the foil pattern. Be sure to double-check the orientation of the polarized components before soldering them in—especially the semiconductors. For example, D2 has an unusual package—it looks like a two-leaded transistor. Note, however, that RES1 and RES2 are *not* polarized. Do not install IC1 or C9 at this time.

Because of the high frequencies involved, keep the lead lengths as short as possible. Before installing T1, use an ohmmeter to measure the resistance of each of the windings. One winding, the primary, will measure about 50 ohms; the secondary will measure about 1 ohm. Mark the windings with a "P" and an "S" to be sure that the transformer is inserted properly into the circuit. The primary of the transformer is driven by Q1; the secondary feeds the earphone jack.

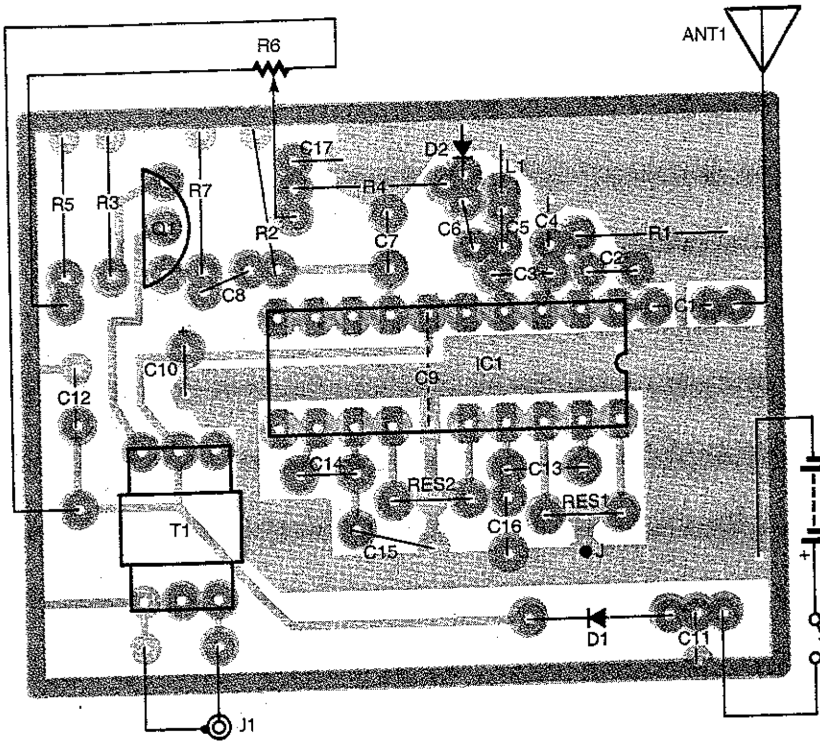


Fig. 2. Here's the parts-placement diagram for the Airport Buddy. Note that C9 is tack-soldered to the solder side of the board between the pins of IC1. Keep the body of C9 flat to the board.

Coil L1 will be made from a piece of solid wire wrapped around a form. Following the dimensions shown in Fig. 3, wrap 3½ closely-spaced turns of insulated 22- or 24-gauge wire around an $^1/_8$-inch-diameter form such as a drill bit. Following the height dimension shown in Fig. 3, insert the coil into the board and solder it in place. The coil can also be made from bare wire; however, the turns should not short out to each other or to the ground plane.

Table 1 lists the components that must have ground connections to the ground plane on the topside of the board as well as the bottom. Additionally, one through-hole wire is used to connect the ground plane to circuit ground; it is located next to RES1.

Once those components have been installed, use an ohmmeter to check the connections of all of the ungrounded components to be sure that there are no short circuits to ground. Carefully examine all of the solder joints—they should be shiny and smooth. Correct any problems now before proceeding.

Check that all of the holes for IC1 on the topside of the board are clear of copper except for pin 15. When IC1 is inserted, none of those

TABLE 2 NORMAL VOLTAGES ON IC1

Pin No.	Voltage
1	1.4
2	1.4
3	5.4
4	6.2
5	6.3
6	6.3
7	0.25*
8	2.1
9	2.1
10	3.7
11	1.7
12	1.7
13	1.7
14	1.7
15	0 (gnd)
16	1.7
17	1.7
18	1.7
19	1.7
20	5.1

* The voltage on pin 7 depends upon signal strength.

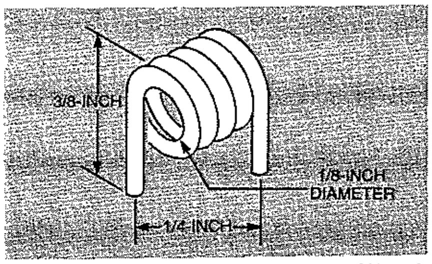


Fig. 3. It is easy to wind L1. Take a 3½-inch length of 22- or 24-gauge insulated wire and wind 3½ turns around a 1/8-inch-diameter drill.

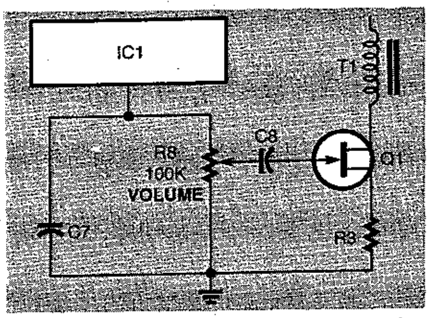


Fig 4. If you want to add a volume control to the Airport Buddy, simply replace R2 with R8 as shown here. Lift the lead of C8 that would normally be connected to R2 and C7 and connect it instead to the wiper of R8.

pins should be touching the ground plane. Integrated circuits usually have pins designed to sit on top of the hole. If everything looks good, install and solder IC1 into the circuit. Be sure to solder pin 15 on both sides of the board

Once IC1 has been soldered in place, turn the board over to the solder side. Capacitor C9 is tack-soldered underneath IC1 between pins 6 and 15 The leads of C9 must be cut as short as possible, and the body of the capacitor should lay as flat as possible against the board

Any small case that can hold the PC board, a 9-volt battery, and the controls will work well. For example, a small case with a built-in battery compartment that fits easily into a shirt pocket can be used Drill appropriate holes for J1, S1, and R6. You can use a single-turn potentiometer for R6 and draw a dial on the case, but it will be a bit more difficult to tune the Airport Buddy to a particular frequency than if you were to use a multi-turn potentiometer.

An option to consider is that of a volume control. If you want to use that option, which is detailed in Fig 4, R8 must also be mounted in the case

An additional hole will be needed for the antenna. The Airport Buddy will work fine with a simple whip antenna made from a length of insulated wire The hole should be as close to the point on the PC board where the antenna is connected as possible.

As an alternative, a telescoping antenna can be used instead of the length of wire. In either case, the length of the antenna is not critical. Although the ¼-wavelength at the frequencies is about two feet, the receiver will work with 16 inches of wire

Once the cabinet has been properly prepared and assembled, wire the battery clip and S1 to the circuit Be sure to observe the correct polarity of the battery clip If in doubt, use a DC voltmeter and a battery to verify the polarity of the leads Make the final connections to R6 and J1 as shown in Figs. 1 and 2 Be sure to wire R6 so that clockwise rotation causes the voltage at its wiper to increase That will give higher received frequencies with clockwise rotation of the knob If you are going to use a stereo jack for J1, you should connect both left and right together on the jack

Checkout Procedure. Before connecting B1 to the clip, check all of the wiring thoroughly once more to be sure that it is 100% correct. It is far easier to correct any problems or mistakes now rather than later if you find that the Airport Buddy does not work. Using an ohmmeter, measure the resistance across C12 to verify that there is no short circuit to ground on the main power line. Turn S1 off and clip a fresh alkaline 9-volt battery to the battery connector. Insert a headphone set into the jack The Airport Buddy will work with any stereo or monaural headphones. However, the volume of the audio is directly proportional to the quality of the headset. Very low-cost headphones are relatively inefficient and will not produce as much volume as higher-quality units. Good headsets are readily available for less than $20.00

Turn S1 on You should be able to hear a very soft "white noise" or static as the tuning knob is rotated over its range. If there are any aircraft nearby, you might hear voice communications

If the receiver is working correctly, you can take your Airport Buddy to an airport and verify that you are able to listen in on aircraft communications Otherwise, refer to the

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PARTS LIST FOR THE AIRPORT BUDDY

SEMICONDUCTORS

IC1—SA605N intermediate-frequency decoder/demodulator, integrated circuit
D1—1N4004 silicon diode
D2—MV209 varactor diode
Q1—MPF102 field-effect transistor

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—22,000-ohm
R2—100,000-ohm
R3—330-ohm
R4—10,000-ohm
R5—4700-ohm
R6—10,000-ohm, linear-taper potentiometer, panel mount
R7—1-megohm
R8—100,000-ohm linear- or audio-taper potentiometer, panel mount (optional volume control, see text)

CAPACITORS

C1—100-pF, ceramic-disc
C2, C5, C6, C8, C9, C13–C17—0.001-µF, ceramic-disc
C3—10-pF, NPO ceramic-disc
C4—12-pF, NPO ceramic-disc
C7—470-pF, ceramic-disc
C10—10-µF, 16-WVDC, electrolytic
C11—0.01-µF, ceramic-disc
C12—100-µF, 16-WVDC, electrolytic, low-leakage

ADDITIONAL PARTS AND MATERIALS

ANT1—Whip antenna, 16–24 inches (see text)
B1—9-volt transistor radio alkaline battery
J1—Earphone jack (stereo or monaural as needed)
RES1, RES2—455-kHz ceramic filter, Digi-Key TK2334
S1—Single-pole, single-throw, toggle or slide switch
T1—1000-ohm to 8-ohm audio transformer (Mouser 42TL013 or similar)
Enclosure (PacTek K-HM-9VB or similar), panel-mount adapter for R6, 9-volt battery clip, tuning knob, headset, hardware, etc.

Note: The following items are available from: A. Caristi, 69 White Pond Road, Waldwick, NJ 07463: Etched and drilled PC board, $15.75; IC1, $12.50; D2, $3.00. Please add $5.00 for postage and handling. NJ residents add 6% sales tax.

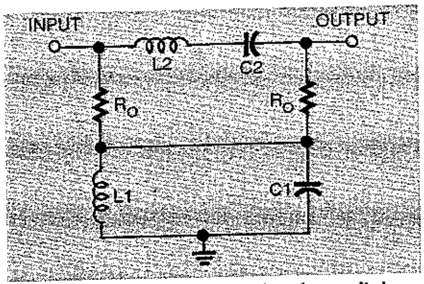

Fig. 10. Here's a practical bandpass diplexer design intended for use with mixers. Values are calculated using the equations in the text

any given frequency can be calculated from the equations below:

$$Q = \frac{f_o}{BW_{3dB}}$$

and

$$\omega = 2\pi f_o$$

The component values are:

$$L2 = \frac{R_oQ}{\omega}$$

$$L1 = \frac{R_o}{\omega Q}$$

$$C1 = \frac{1}{L1\omega^2}$$

$$C2 = \frac{1}{L1\omega^2}$$

Mixer Selection. Several different specifications may be applied to a mixer when making a selection First you want to select the frequency range. Don't select a mixer that barely covers the frequency you are interested in. For example, if you want to handle an RF input signal of 1.2 MHz, don't select a 1- to 400-MHz device. Select a device with a 0.5- or 0.1-MHz lower end. Keep in mind the RF, LO, and IF frequencies when selecting the mixer for an application. Here are some other specification to keep in mind:

Isolation. The LO-RF, LO-IF and RF-IF isolation tells you something about how much signal will feed through the pathway specified. For example, the LO-RF isolation tells you the amount the LO signal is attenuated when it reaches the RF port. Numbers such as 30 to 60 dB are common.

Dynamic Range This specification tells you the power range in which the mixer works properly. It is a good idea to obtain the highest dynamic range possible.

-1 dB Compression Point The input signal level that causes a 1 dB drop in output level, *i.e.* a 1 dB increase in conversion loss

Intercept Point The intercept point is the theoretical point on a graph of the output-*vs*-input signal levels that shows where the desired input signal and the n^{th} products become equal in amplitude. The third-order products are normally considered the most important, so the third-order intercept point (TOIP) is usually specified. The higher the number the better the device. Ω

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troubleshooting hints below to locate and correct the fault in the circuit

If you notice a large group of stations transmitting voice or music near the maximum CCW setting of the tuning control, those stations are commercial stations that are transmitting at the top of the FM-broadcast band. If you want to eliminate those stations, you can tweak the adjustment range of the receiver by slightly spreading the turns of L1; that will increase the local-oscillator frequency

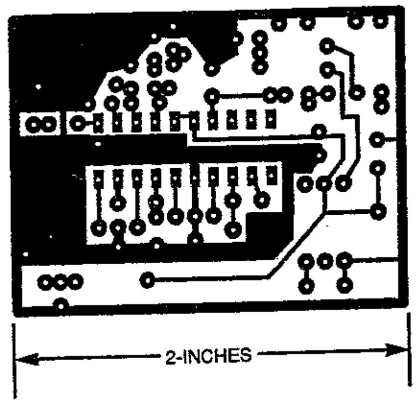
Troubleshooting. If the headphones are silent, check the voltage across the battery when the receiver is turned on with a voltmeter. The battery voltage should be at least 8 volts—weak batteries will not drive the Airport Buddy. Also measure the current; the normal value is about 10 milliamps. The polarized components (D1, IC1, Q1, and the electrolytic capacitors) should be checked for proper orientation. The voltage at pins 5 and 6 of IC1 should be at least 7 volts. If it isn't, D1 might be installed backwards

If power to the circuit is normal, check the voltage at pin 7 of IC1. It will normally be about 0.25 volts or less when no signals are being received and increase when an RF carrier is detected.

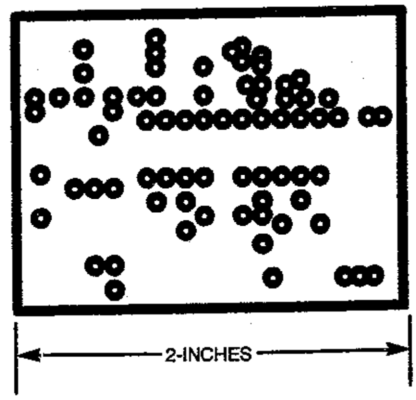
Check the voltage at the source of Q1. If it is about 1 volt, the transistor is drawing current. If not, check its orientation or try a new transistor.

If it is suspected that IC1 is not operating, carefully check the components that form the local oscillator: R1, C3–C6, L1, and D2. Check the bias on D2 to be sure that it changes when R6 is turned. Measure the voltage at each pin on IC1 and compare the reading with Table 2. The voltages listed assume that the battery voltage is at least 7 volts. If any pin on IC1 does not seem right, carefully check the wiring for short circuits. If a fault cannot be found, replace IC1

Using the Airport Buddy. When receiving signals at the airport, adjust the tuning control over its range very slowly to search out any possible transmissions. Once you have found the active frequency of the control tower, you can then keep the tuning control in that general vicinity to hear the audio communications as each aircraft arrives and takes off. Ω



Here's the foil pattern for the Airport Buddy. The circuit is simple enough for a single-sided layout; the other side is a simple solid-copper ground plane.



Although this is not a foil pattern for the Airport Buddy's ground plane, it shows the locations of the holes where copper should be cleared away so that the component leads do not short to ground. If you wish, a negative image of this layout could be used as a "foil pattern" that will only etch away a ring around the holes that need to be clear.