# An FM Wireless Microphone

***A battery-powered microphone eliminates the trailing cable while it transmits on a frequency in the FM broadcast band***

**By Anthony J. Caristi**

Microphones for recording and public-address applications are cumbersome to handle due to the long umbilical cord that connects them to an amplifier. Many professionals eliminate the cable problem by using miniature *wireless* microphones that have their own built-in amplifier/transmitter, doing away with cables. As a result, they have more freedom to move around without worrying about snarling cable and a trip hazard. The FM wireless microphone to be described here can give you the same advantages. It is low in cost, yet high in audio quality.

Our wireless microphone is designed to work with an FM receiver, tuner or radio. Since its r-f output is very low in power, and has a usable transmitting range of 50 feet or less, it should not interfere with your neighbors' FM reception. Its extremely high sensitivity allows it to pick up voices and sounds several feet away; so there is nothing critical about locating it in a pick-up area. If this inherent sensitivity is too "hot" for your application, such as in PA announcing where the user usually speaks directly into the microphone element, an option allows you to reduce the sensitivity so that background noises will be largely excluded.

Some of the applications for this project include using it as a miniature PA system or as an electronic babysitter while you monitor sounds from another room. You can even build two wireless microphones to use as a simple wireless system in your home. For the kids, this can be a fascinating toy that lets them sing and talk through an FM radio.

## About the Circuit

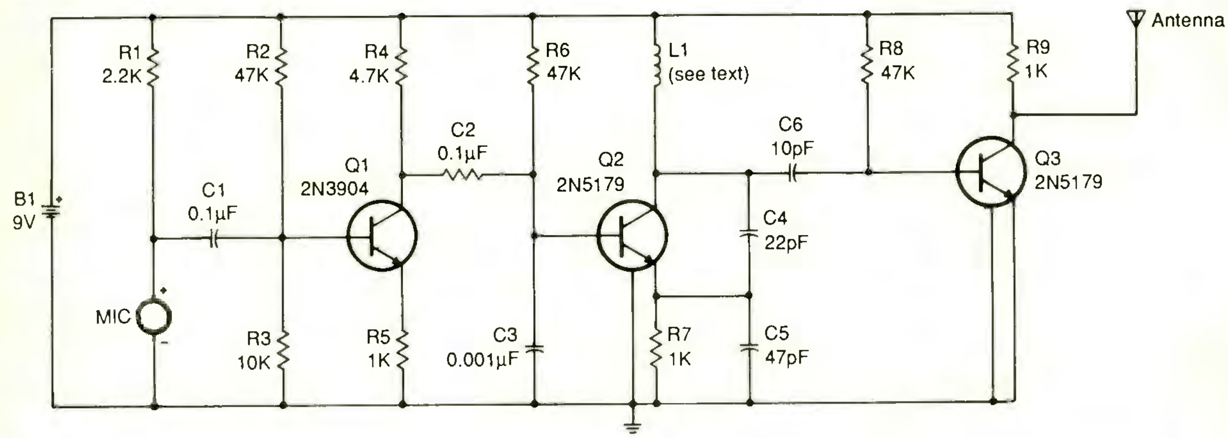
Shown in Fig. 1 is the complete schematic diagram of the FM wireless microphone. Microphone element *MIC* is an electret type that is powered from battery *B1* through resistor *R1*. When sound reaches the microphone element, the current through *R1* is varied in accordance with the intensity of the sound intercepted. This produces an ac voltage through *R1* that is coupled through *C1* into the base of audio amplifier stage *Q1* as a small ac voltage.

Gain of the *Q1* stage is held at about 4.7 by the ratio of the collector and emitter resistance values. The output of the audio amplifier stage, at the collector of *Q1*, is then coupled to the base of r-f oscillator *Q2*.

Transistor *Q2* and its components make up a classic Colpitts oscillator. To produce oscillation, the transistor's base and collector are connected to opposite ends of an LC "tank" circuit, with the emitter connected somewhere between these two points. When the gain of this arrangement exceeds unity (1), the circuit oscillates at a frequency determined by the parallel resonant frequency of the tank circuit.

In the oscillator stage, the LC tank is composed of coil *L1* and the series combination of *C4* and *C5*. The base of *Q2* is held at r-f ground potential by *C3*, and the "cold" side of *L1* is held at ground potential by *C7*. This effectively places the base of *Q2* at the same r-f point as the cold end of the tank circuit.

The voltage-divider action of *C4*




**PARTS LIST**

**Semiconductors**
Q1—2N3904 or similar silicon npn transistor
Q2,Q3—2N5179 or similar silicon r-f npn transistor
**Capacitors** (50 WV)
C1,C2,C7—0.01-µF ceramic
C3—0.001-µF ceramic
C4—22-pF ceramic (NPO temperature stable)
C5—47-pF ceramic (NPO temperature stable)
C6—10pF ceramic (NPO temperature stable)
**Resistors** (¼-watt, 10% tolerance)
R1—2,200 ohms
R2,R6,R8—47,000 ohms
R3—10,000 ohms
R4—4,700 ohms
R5,R7,R9—1,000 ohms
**Miscellaneous**
B1—9-volt transistor battery
L1—Inductor (see text)
MIC—Electret microphone (Radio Shack Cat. No. 270-090 or similar)
Printed-circuit board; shield (see text); snap connector for B1; wire for antenna; solder; etc.

**Note:** The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Pc board, $5.00; 2N5179 transistor, $3.75 each; set of 22-, 47- and 10-pF NPO temperature-stable capacitors, $1.75. Ass $1.00 P&H. New Jersey residents, please add state sales tax.

*Fig. 1. Complete schematic diagram of wireless FM microphone.*

and *C5* provides a simple means of placing the emitter of *Q2* at the optimum r-f point. This is one-third (33 percent) above ground potential and ensures that the circuit oscillates.

Resistor *R6* forward biases *Q2* so that the transistor draws collector current and is forced into oscillation. Since the bias voltage at the base of *Q2* is modulated by the ac signal voltage variations from *Q1*, the frequency of oscillation in the *Q2* circuit varies in accordance with the frequency of the sound reaching the microphone element. Thus, the oscillating signal from *Q2* is frequency modulated to conform with the needs of the FM receiver, tuner or radio with which the project is used.

To enhance the frequency stability of the oscillator, an additional stage has been included in the circuit to buffer the oscillator from the antenna. With this stage, *Q3*, small changes in capacitance due to physical positioning of the antenna will have an attenuated effect on the oscillator circuit. The result is much less frequency drift.

Taken at its collector, the output of *Q2* is capacitively coupled into the base of r-f amplifier/buffer *Q3*. Resistor *R8* forward biases transistor *Q3*. The resulting current flow in this stage causes *Q3*'s collector to output an r-f signal composed of the frequency-modulated output from *Q2*. Resistor *R9* in *Q3*'s collector circuit limits current flow. The antenna for the microphone connects directly to the collector of *Q3*.

## *Construction*

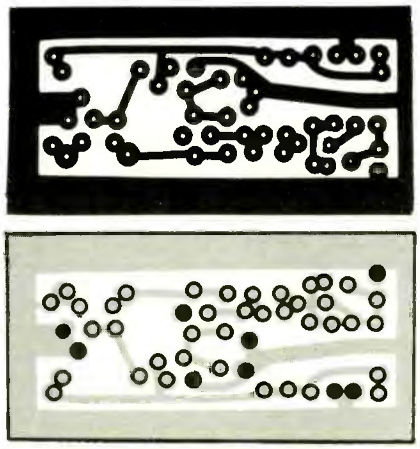
Due to the r-f nature of the wireless microphone's circuit, printed-circuit construction is mandatory. For this board, you need a pc blank that is clad on both sides with copper. One side will be etched in the usual manner to produce the wiring pattern to which component leads are soldered. The other side will serve as a ground plane to which only selected leads (those that are grounded, of course) are soldered as well. It serves a second function as a shield for the circuit. You can make your own pc board or purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

You can home fabricate your own pc board with the aid of the actual-size etching-and-drilling guide shown in Fig. 2. Note in Fig. 2 that the ground-plane side of the board is not shown in the usual etch-and-drill format. Because this side of the board is not to be etched at all, only the hole-drilling/clearing information is graphically presented. In this illustration, all holes to be drilled are identified by either circles or solid black dots.

When fabricating the board, make sure to mask off the top side with etch resist to prevent the copper from being removed by the etchant. After the board has been etched, trim it to size. Then carefully drill all holes through the board as indicated, using the pattern of pads on the *wiring* side to accurately locate where each hole is to be drilled.

After using a No. 60 bit to drill the component lead holes, turn over the board and orient it as shown in the ground-plane illustration in Fig. 2. Carefully mark all holes indicated by open circles. Then *very* carefully isolate these holes from the copper-clad ground plane by drilling with a 3/16-inch diameter bit only enough to clear copper from around the holes. Do *not* drill all the way through the board! When you are finished, there should be eight holes from whose edges you have not removed the copper cladding, all indicated by the solid black dots in the illustration.

Now wire the board exactly as shown in Fig. 3. Start with the transistors, making sure that they are properly based as you plug their leads into the holes. Note that *Q2* and *Q3* have four leads, one each for the emitter, base and collector and a final one that is internally connected to the case. Make sure all leads are soldered to the pc board after installing each transistor. Solder the grounded leads of *Q2* (case only) and *Q3* (emitter and case) to the copper trace on the bottom *and* the ground plane on the top of the board. When the transistors are soldered into place, there should be no more than ¼ inch of space between the bottoms of their cases and the board.



o—Clear these holes of copper.
●—Do *not* clear these holes.

*Fig. 2. Actual-size etching-and-drilling guide (upper) and drilling/hole-clearing details (lower) for double-sided printed-circuit board.*

Use an ohmmeter to check that any lead that is not supposed to be grounded does not short to the copper cladding on the top of the board. Refer back to Fig. 1 to make sure. If you find any lead that does short to the ground plane but should not, gently bend it until it no longer does.

Once the transistors have been mounted, install and solder into place *C3*, *C5*, *R3*, *R5* and *R7*, all of which have one lead that goes to circuit ground. Solder this lead to the copper cladding on both sides of the board as you did for the transistors. When installing these components, leave about 1/16 inch of lead length on the top of the board to make it easy to solder the appropriate leads to the ground plane.

It is easiest to solder the connection first on the bottom of the board, clip off excess lead lengths and then solder the ground-plane side connection with only enough solder to make a secure electrical connection. Then use the ohmmeter to make sure that the other leads do not short against the ground plane. Install and solder into place the remaining capacitors and resistors.

At this point, you might wish to consider the circuit option that lets you reduce the sensitivity of the microphone pickup. If your wireless microphone is to be used to pick up sounds at some distance from the microphone element, you need do nothing. On the other hand, if you wish to use the project as a hand-held microphone for direct close-up pickup, this option should be incorporated to prevent overmodulating the r-f carrier and, thus, audio distortion.

For reduced microphone sensitivity, you can eliminate the *Q1* amplifier stage in its entirety. That is, omit *C2*, *Q1* and *R2* through *R5*. Then simply connect *C1* from the junction of the microphone's + terminal and *R1* to the *R6/C3/Q2* base junction.

No changes need be made to the pc board if you exercise this option. In fact, if you wish, you can build in a switching arrangement between the output side of *C1* and the base inputs of *Q1* and *Q2* in alternate positions of a miniature two-position slide switch. Doing this gives you a choice between full-sensitivity and reduced-sensitivity modes of operation.

You can mount the microphone element directly at the edge of the board, using short lengths of cut-off component lead between the element's terminals and the appropriate holes in the board. Be sure to properly polarize the microphone element. Solder the negative (−) lead of the microphone element to the copper cladding on both sides of the board.

Instead of mounting the microphone element directly on the board, you can locate it elsewhere and make interconnections with an appropriate length of shielded cable. Use the center conductor for the "hot" (+) and the shield for the ground (−) sides of the element.

Now hand-wind inductor *L1*, using either 20-gauge enameled copper wire (preferred) or 20-gauge bare solid hookup wire. First cut the wire to *exactly* 4½ inches long so that it "tunes" to the center of the FM broadcast band. Carefully scrape away ¼ inch of the enamel insulation.

Wrap this wire around an ordinary pencil, making 3½ turns and winding as tight as possible. Slide the coil off the pencil and note that it should have two equal-length "tail" ends that are parallel with each other. (They may not be exactly parallel with each other, due to the springiness of the wire, but will become so once the tails are plugged into the holes in the circuit board.)

Press the coil end-to-end between your thumb and forefinger until the spacing between the turns is about one wire diameter. This spacing is not critical, but if done correctly will make it easier to plug the tails into the holes in the circuit board.

If you used ordinary bare solid hookup wire to wind the coil, place a strip of electrical tape on the ground plane in the *L1* area to provide insulation in case the coil sags or is pushed against the copper cladding. Plug the coil into the holes in the board so that the tails protrude about 1/16 to 1/8 inch on the bottom of the board and there is air space between the bottom of the coil and the circuit board's ground plane. Solder into place.

Tightly twist together the fine wires in both battery snap connector leads and sparingly tin with solder. Place the circuit-board assembly solder side up and plug the red snap connector wire into the hole labeled B1+ and the black wire into the hole labeled B1− (see Fig. 3). Solder both connections to the pads on the bottom of the board. Flip over the board and clip the excess length of the red-insulated wire as close as possible to the board's surface. Then solder the black-insulated wire to the ground plane and clip off its excess lead length. Check with your ohmmeter to make sure that the red wire is not shorted to the ground plane.

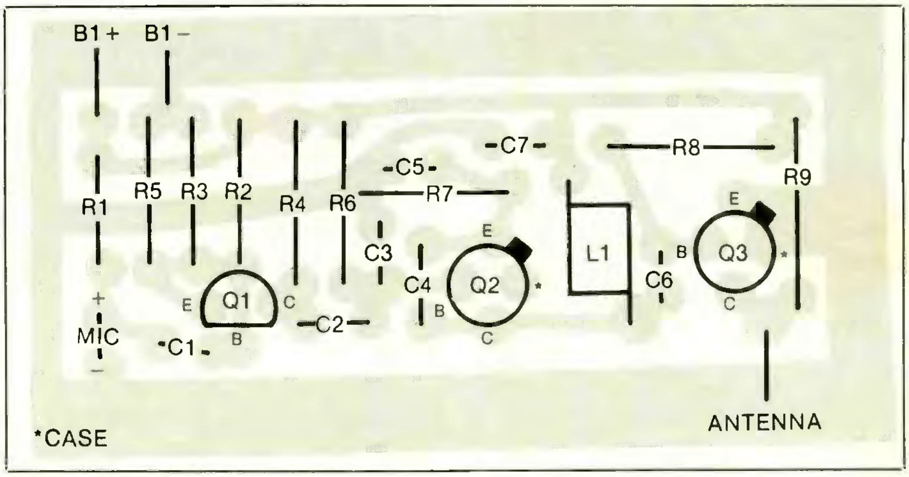



*Fig. 3. wiring diagram for pc board.*

The antenna for your wireless microphone should be as short as possible but not so short that it provides less than satisfactory operation. Start with a 6-inch length of insulated solid hookup wire. Strip ¼ inch of insulation from one end and plug this end into the hole labeled ANTENNA and solder into place.

With the circuit board fully wired, refer back to Fig. 1 and use your ohmmeter to make certain that no component leads not shown connected to circuit ground touch the ground plane on the top of the board. Readjust the position of any component that registers a short circuit to the ground plane to eliminate the short circuit.

To preserve the frequency stability of the circuit, you must place an r-f shield on the top of the board after the circuit has undergone preliminary check. Fabrication of the shield is very simple, as shown in Fig. 4.

You can use any thin solderable sheet metal, such as copper or brass. Copper flashing, available from lumberyards and roofing supply houses, works well, as does thin brass sheet obtainable from most hobby shops.

Trim the copper or brass sheet to 2 1/16 by 2 inches. Then use a soft lead pencil or a scribing tool to strike the fold lines and mark the center of the ¼-inch diameter hole to be drilled. Place the marked sheet metal in the jaws of a vise, lining up one of the fold lines with the vise's jaws and bend first the inner-channel edges and then the outer tab edges. You will not be able to make complete 90-degree bends using the vise. The idea is to get clean, sharp bend lines. You can square up the bends by hand with the aid of slip-joint pliers.

Once the U-channel shield has been bent to shape, punch the location of the ¼-inch hole to be drilled. Then drill the hole, backing up the metal with a scrap wood block to get as clean a hole as possible. Use a 3/16-inch bit to drill the hole. Then carefully enlarge the hole to its final ¼-inch diameter with a tapered reamer.

## Checkout

Before plugging the battery into its snap connector, perform a visual check of the board to ascertain that there are no short circuits or cold-soldered joints on either side of the board. Reflow the solder on any joint that appears to be questionable. Double check all transistor basings. If you wish to be absolutely certain of your wiring, perform a final ohmmeter check, with the aid of Fig. 1, to ascertain that all component leads that are not supposed to be grounded are not shorted to the ground plane. When you are satisfied that all is well, plug a 9-volt battery into the project's battery snap connector.

Use an ordinary FM radio to check that the circuit is working. Start at the low end of the FM band and very slowly tune the radio upward in the band. At some point near the middle of the band, you should hear either silence as the radio responds to the microphone's r-f carrier or "howling" as acoustic feedback between the radio and microphone causes oscillations.

If you turn the volume control on the radio low enough, you will be able to eliminate the feedback so that when you talk into the microphone you hear your voice. Keep in mind that the sensitivity of the microphone is very high (unless you opted for reduced sensitivity); hence, you need only whisper into the microphone for this test.

After you have pinpointed the wireless microphone's signal on the FM dial, mark the frequency at which it appears. You will note that when the shield is mounted to the circuit-board assembly the received signal will be shifted some 3 MHz higher in frequency on the dial.

If you wish to tune your microphone for a specific approximate frequency on the FM dial, perhaps to avoid interfering with a station on a given frequency, you can increase the spacing between the turns of *L1* to raise its operating frequency or decrease the spacing to decrease the frequency. Be sure as you do this that the coil's leads do not short to the ground plane (and that no turns of the coil touch the ground plane if you used bare solid hookup wire to make the coil).

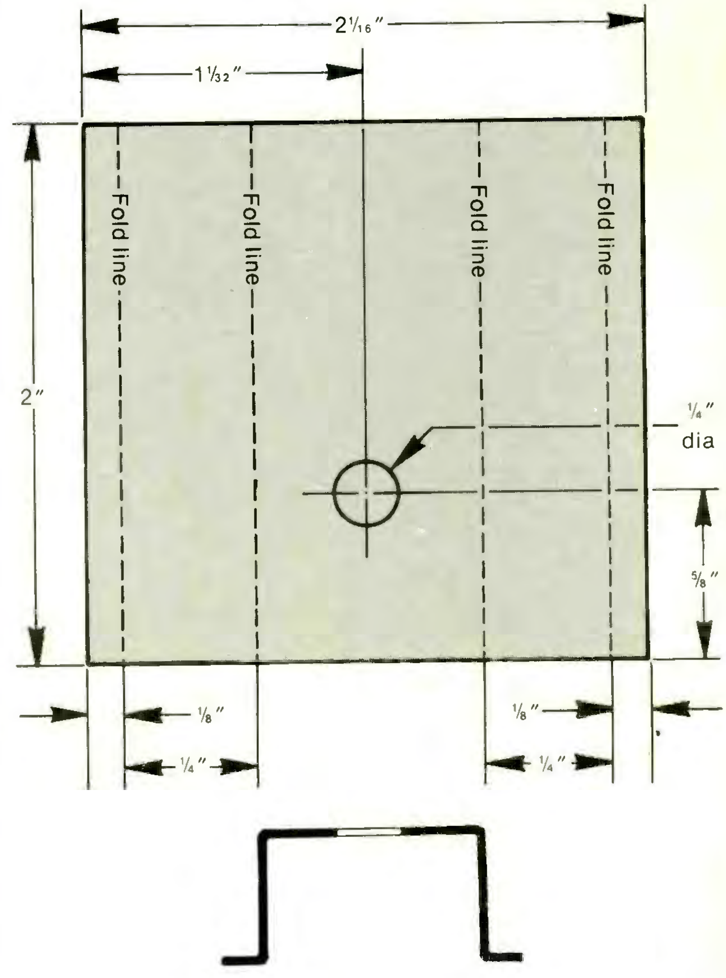



*Fig. 4. Fabrication details for project's r-f shield.*

When you are satisfied that your wireless microphone is operating as it should and is tuned to approximately where you want it to be on the FM dial, attach the shield by soldering it to the perimeter of the copper ground plane.

To simplify soldering, first flow a thin film of solder onto the ground plane at all four corners of the board and on the four corners of the underside of the shield's tabs. Make sure that no solder flows far enough to short a component lead that should not be connected to the ground plane. Place the shield over the circuit-board assembly with the ¼-inch hole centered over *L1* and use more solder at the four corners to make mechanically secure electrical and mechanical connections. You do not need continuous beads of solder; in fact, you do not want them should you ever have to service the circuit.

After the shield is in place, power up your microphone again and tune the FM radio to a dead spot on the dial, where no stations are broadcasting until you hear the micro-

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## Wireless Microphone

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phone's r-f carrier loud and clear. Then very carefully adjust the spacing between the turns of *L1*. Use an *insulated* tuning wand for this—*not* a metal object like a screwdriver or capacitive effects will give false results. Just a slight movement of the coil's turns is needed. A word of caution is in order here: Under no circumstances should you attempt to tune your wireless microphone to a frequency beyond 108 MHz. Such frequencies are reserved for aircraft services and must not be used for any other purpose or be interfered with for any reason.

You can house your wireless microphone in any enclosure that suits your tastes. For general-purpose use to pick up sounds at a distance, a small plastic box with a hole or slot cut in it directly in line with the microphone element will do fine. For up-close announcing applications, as in a PA system arrangement, use an enclosure that is small enough to be conveniently hand-held, such as an inexpensive microphone housing or a small project box. Another alternative is to mount the circuitry inside of a box that has a clip on it to permit hanging the electronics from your belt and locating the microphone element on a tie bar or pocket clip at the end of a shielded cable.

To obtain long operating life, use a high-energy alkaline battery to power the wireless microphone. A single fresh alkaline battery will power the microphone continuously for about 30 hours. If your anticipated applications call for intermittent use, such as in paging over a PA system, you might want to place a normally open pushbutton switch in series with the +9-volt line to power the circuit only on demand. This will considerably extend battery life. Yet another alternative is to use a common spst slide or toggle switch that will allow you to turn off power whenever the microphone is not being used.

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