A Wireless Remote Telephone Ringer

This "poor man's cordless telephone" works with an FM radio to remotely signal when your wired telephone rings

By Anthony J. Caristi

A cordless telephone is a useful consumer-electronic de- device. Though it lets you originate calls, its major benefit is in alerting you to incoming calls when you are not near enough to a wired phone to hear it ring. If the alert feature is all you really need, the Wireless Remote Telephone Ringer presented will do the job inexpensively, though you will have to get to a wired telephone to answer the call.

This Wireless Ringer is easy to build because the "receiver" section already exists. It is an ordinary portable FM radio that can be picked up for $10 or less. Only one radio is needed in any given installation, but because this is an r-f transmitter project, any number of radios can be used if more than one person wants to listen for an incoming-call signal from different remote locations. Transmitter power from the Ringer is low enough so that the project will not interfere with your neighbors' FM reception.

Totally automatic in operation, this project does not even require a power switch, though you can include one to permit you to turn it off when it will not be used for weeks or months at a time.

About the Circuit

Referring to the schematic diagram in Fig. 1, the cordless telephone transmitter consists of telephone ring-signal detector *IC1*, which is followed by a two-stage transmitter consisting of *Q2* and *Q3* that operates on the 88-to-108-MHz FM broadcast band. The transmitter's carrier frequency is modulated by unijunction-transistor oscillator *Q1*, whose operating frequency is set at about 2 kHz.

Power for the transmitter and audio oscillator is provided by 9-volt transistor battery *B1*. This battery is automatically switched through to the project's circuits to deliver current only in the presence of the ring signal that announces an incoming call. Current demand from the battery is very modest. Because of the automatic power-up feature, useful battery life should therefore be extremely long.

Transistor *Q2* and its associated components make up a traditional grounded-base Colpitts oscillator whose frequency of oscillation is de-

PARTS LIST

Semiconductors

D1,D2—1N4148 or similar silicon switching diode
IC1—TCM1520AP ring-signal detector (Texas Instruments)
Q1—2N2646 unijunction transistor
Q2,Q3—2N5179 npn r-f silicon transistor
Q4—2N6659 n-channel enhancement-mode field-effect transistor
Q5—2N2907 pnp silicon switching transistor

Capacitors (50 WV or greater)

C1—6,800-pF ceramic or Mylar
C2,C10—0.1-μF ceramic disc
C3,C11—0.001-μF ceramic disc
C4—22-pF NPO ceramic disc
C5—47-pF NPO ceramic disc
C6—0.33-μF, 250-volt Mylar
C7—10-μF electrolytic
C8—0.47-μF ceramic disc
C9—10-pF NPO ceramic disc

Resistors (¼-watt, 10% tolerance)

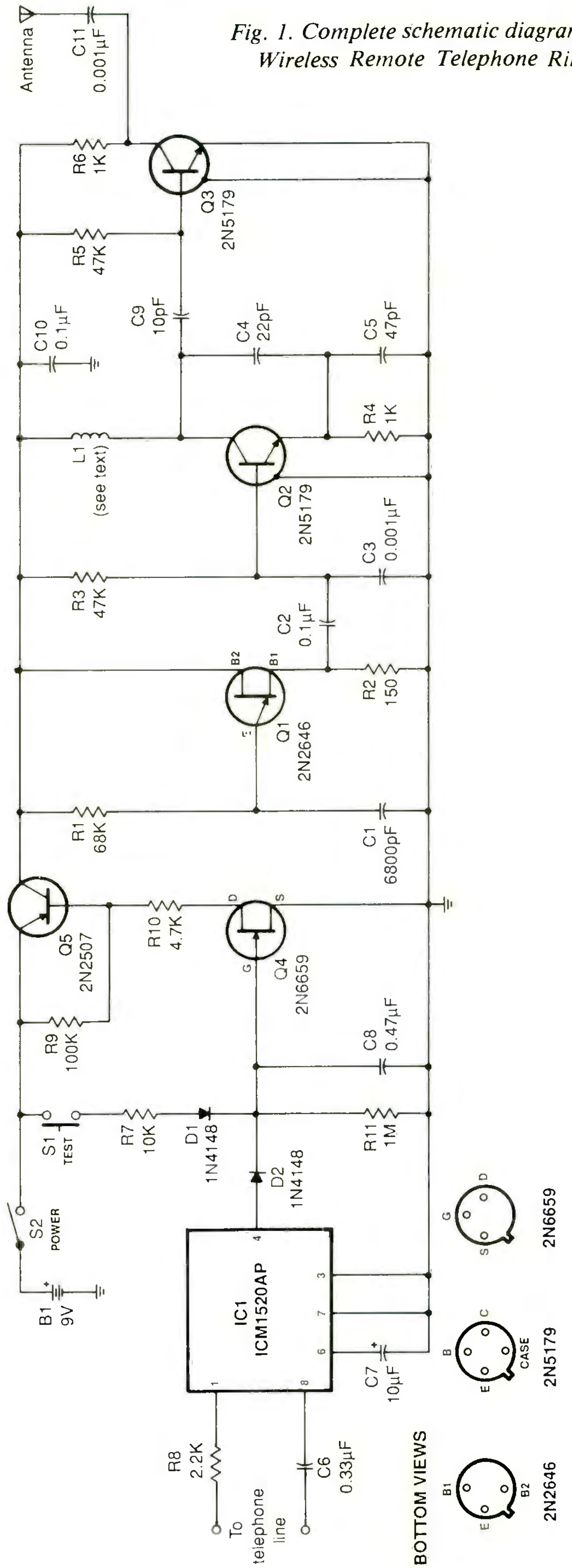
R1—68,000 ohms
R2—150 ohms
R3,R5—47,000 ohms
R4,R6—1,000 ohms
R7—10,000 ohms
R8—2,200 ohms
R9—100,000 ohms
R10—4,700 ohms
R11—1 megohm

Miscellaneous

B1—9-volt transistor battery
L1—Inductor (hand-wound—see text)
S1—Spst normally-open, momentary-action pushbutton switch
S2—Spst slide or toggle switch (optional—see text)
Printed-circuit board (see text); suitable metal enclosure (see text); 12" to 18" telescoping portable-radio antenna; socket for IC1; snap connector and holder clip for 9-volt battery; small rubber grommet; heavy-gauge magnet wire for L1; ¼" or ½" metal spacers; machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Ready-to-wire pc board, $9.95; 2N2646 UJT, $2.95; 2N5179 r-f transistor, $3.75 each; 2N6659 FET, $2.95; 2N2907 switching transistor, $1.50; TCM1520AP ring detector IC, $4.95; 0.33-μF Mylar capacitor, $1.00; and set of three NPO ceramic capacitors, $2.00. Add $1.50 P&H per order. New Jersey residents, please add state sales tax.

Fig. 1. Complete schematic diagram of the Wireless Remote Telephone Ringer.



termined by the values of *L1*, *C4* and *C5*. To meet the criteria to sustain oscillation, it is necessary that the base and collector of the transistor be connected to opposite ends of an LC tank circuit, with the transistor's emitter connected somewhere between these two points. In the Fig. 1 circuit, this is accomplished by placing the base of *Q2* at r-f ground potential by means of *C3* and the emitter about one-third the way up from ground, which is accomplished through the voltage-divider action of *C4* and *C5*.

A traditional Colpitts oscillator has two capacitors connected in series with each other to form the voltage divider needed in an oscillator circuit of this type. Contrast this to the Hartley oscillator, which is similar in design to the Colpitts oscillator except that a tapped inductor is used to provide voltage division. Transistor *Q2* is forward-biased by *R3* to sustain oscillation when power is applied to the circuit.

Unijunction transistor *Q1* is connected into the circuit to form a free-running relaxation oscillator. When 9-volt dc power is applied to the circuit, *C1* charges up at a rate determined by the RC time constant of *R1* and *C1*. When the potential across *C1* reaches about 50 percent of the supply voltage, *Q1* suddenly conducts and dumps most of the charge on *C1* into *R2*.

Now partially discharged, *C1* once again begins to charge, as it did initially, until *Q1* breaks into conduction and dumps the charge into *R2*. This charge/discharge action repeats at a rate of about 2,000 times per second for as long as power is applied to the circuit.

When *Q1* conducts, a voltage spike appears across *R2* as a result of the discharge action of *C1*. This voltage is capacitively coupled, via *C2*, to the base of *Q2* and causes a very slight variation in this transistor's operating current at the 2-kHz audio-frequency rate at which *Q1*

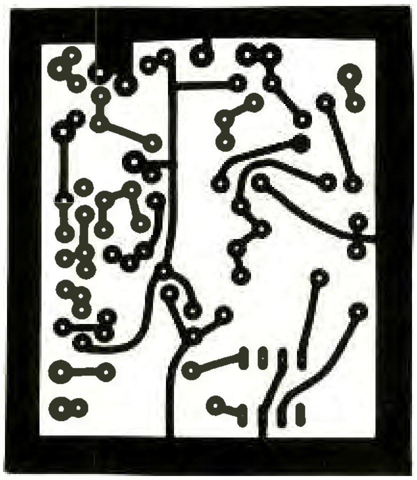


Fig. 2. Actual-size etching-and-drilling guide for bottom of printed-circuit board needed for this project.

is operating. As a result, the frequency of operation of *Q2* is modulated so that its output signal, amplified by *Q3* and radiated by the antenna, can be detected by the discriminator circuit in any FM radio or receiver that is within range and is tuned to the project's carrier frequency. When this signal is detected, the FM radio will produce a pulsed 2-kHz tone to

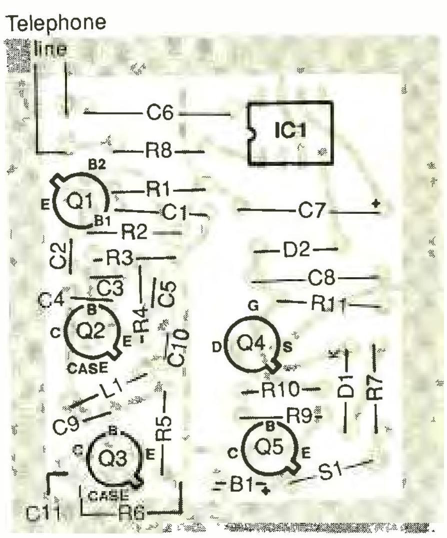


Fig. 3. Copper on top surface of board serves as r-f ground plane for circuit board. Holes indicated by solid black dots are to be cleared of copper as described in text.

inform you that your telephone is ringing.

Integrated circuit *IC1* is a special device that has been specifically designed as a telephone ring-signal detector to respond to the pulses on the telephone line to which it is connected. Contained inside this chip are a bridge rectifier, 5-volt regulator and transient suppression circuits that prevent damage to the IC and false operation in the event of a random voltage spike on the telephone line.

During standby, *IC1* presents a high impedance to the telephone line and does not affect either outgoing or incoming calls. However, when the 90-volt, 20-Hz ring signal appears across the line to announce an incoming call, the energy of the incoming signal is stored in *C7* and the on-chip voltage-regulator circuit produces + 5 volts dc at output pin 4. This regulated voltage is then fed to the gate of enhancement-mode n-channel field-effect transistor *Q4*.

Transistors *Q4* and *Q5* and their associated circuitry make up an automatic electronic switch that permits current from *B1* to flow to the rest of the project's circuitry only in the presence of the telephone ring signal. At all other times, the switch is "open" and disconnects the battery from the circuit.

Battery voltage is fed to the emitter of *Q5*, which cannot conduct current until its base if forward-biased. During standby, *Q4*'s gate-to-source voltage is zero because *IC1* is idle and, thus, is delivering no voltage to the circuit. The drain-to-source resistance of *Q4* is essentially infinite under this condition, so no base or collector current flows through *Q5*.

When *Q4* is switched on by the voltage that appears at its gate in response to the ring signal, this transistor's drain-to-source resistance becomes almost zero, allowing base current to flow out of *Q5* and causing this transistor to saturate. This places almost the full battery voltage on the collector of *Q5* and allows the transmitter to operate.

Since the time constant of *C8* and *R11* is relatively short, *Q4* operates only during each 2-second burst of ring-signal energy produced by telephone company equipment. This produces a sound in the portable FM radio that is similar in cadence to the normal telephone ring signal.

To verify that the circuit is operating, normally-open TEST pushbutton switch *S1* has been included in the transmitter. When closed, this switch applies forward-bias to *Q4* without the need for the ring signal to be present. Pressing *S1* verifies the operating condition of the transmitter by allowing you to listen for the 2-kHz tone (this time continuous as long as *S1* is closed) in the FM radio being used as the system's receiver.

Construction

Since this project operates in the vhf radio range, it is important that you adhere to certain construction techniques to obtain proper operation. Printed-circuit-board wiring, therefore, is mandatory. Furthermore, this pc board must be copper clad on *both* sides. One side has no copper removed from it during the etching process (except for small areas, which will be discussed presently), while the other is etched to remove all copper from it except as needed for interconnecting conductors. The solid-copper side of the board serves as both an r-f ground plane and circuit common to which all grounded component leads are to be soldered.

You can fabricate your own printed-circuit board using the actual-size etching-and-drilling guide given in Fig. 2. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

If you fabricate your own board, be sure to first coat one entire side with etch resist or mask it with tape to prevent the etchant from eating away any copper. After etching the board to bring out the required copper-trace pattern, remove the etch resist (or tape) from both sides of it. Then, referring to Fig. 2, drill *all* component-lead holes, as indicated by the solder pad centers.

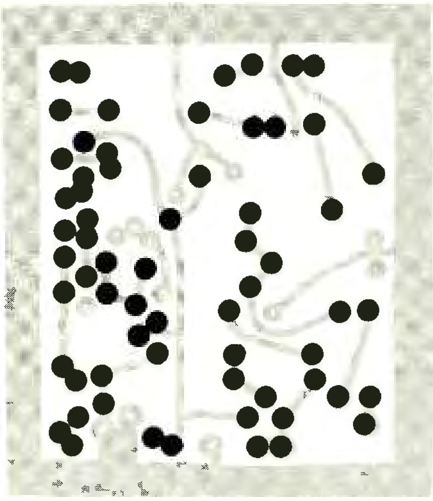


Fig. 4. Wiring diagram for pc board.

Though you do not etch the top (ground-plane) side of the board, you must still clear copper from around all holes through which component leads must pass and are *not* to connect to the ground plane. These holes are indicated by the heavy solid-black dots in Fig. 3.

Use about a $^3/_{16}$-inch drill bit to remove about a $^1/_8$-inch-diameter circle of copper around each indicated hole. After placing the bit in the hole, gently rotate it *by hand* to clear away the copper. Do *not* use a power or pin drill for this operation; the danger of accidentally drilling clear through and ruining the board is too great. Instead, use a very sharp, preferably new, bit. The sharper the bit, the faster and easier will be the manual drilling task.

Bear in mind that the holes into which component leads that are to be grounded must *not* be cleared of copper. Otherwise, it will be difficult, if not impossible, to solder these leads to the copper on the top of the board.

When the board is ready to be populated, refer to Fig. 4. Start populating it by plugging the leads of the resistors into the indicated holes and soldering them into place. (Note: All components mount on the ground-plane side of the board.) Next, install and solder into place the capacitors and diodes, taking care to properly orient the latter. Then install the transistors in their respective locations, referring to Fig. 1 for lead identifications. Remember that just one orientation-sensitive component incorrectly installed on the board will render the circuit inoperative and may even result in damage to itself or/and nearby components.

It is important that you use the specified components for *C4*, *C5*, *C6*, *Q2* and *Q3*. The transistors are rated for high-frequency amplifier applications, as in this project, and the capacitors are temperature-stable to maintain stable operating frequency.

Note that *Q2* and *Q3* have four leads: one each for emitter, base, collector and case. The case lead must be soldered to the ground plane on the board to provide an r-f shield for the transistor in both cases. All transistor grounded leads and grounded leads of the other components shown in Fig. 1, except for *IC1* as noted below, must be soldered to the copper on *both* sides of the board.

Use a socket for *IC1*. It will not be necessary to solder grounded pins 3 and 7 to the top-of-the-board ground plane. These two pins will automatically be grounded through the copper paths on the bottom of the board after soldering the socket into place. Be sure, however, that all holes for the socket, except those for pins 3 and 7, are cleared of copper on the top surface.

Though you must hand-wind inductor *L1*, the procedure for doing so is very simple. Start with a length of solid bare hookup wire or enamel-coated magnet wire. If the latter, use fairly heavy wire so that it readily holds its shape without having to use a coilform and scrape away the ena-

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mel coating a distance of ¼ inch at both ends of the wire. This wire must be exactly 4½ inches long to assure that the circuit will tune to the center of the FM broadcast band.

Wrap the wire around an ordinary lead pencil so that you end up with 3½ closely spaced turns with two "tails" that are parallel to each other and of equal length on opposite sides of the pencil. Slide the coil off the pencil and gently spread the turns evenly so that the inductor's two leads drop into the L1 holes in the board (see Fig. 4).

Adjust the height of the coil above the ground-plane surface of the board so that ¹⁄₁₆ inch of lead length protrudes from the center of each pad on the bottom of the board. Solder both leads into place. If you use bare hookup wire to wind the coil, inspect the installation to make sure that no turns short to each other, the ground plane on the board or any nearby components.

When you have completed wiring the board, examine the assembly very carefully for inadvertent short circuits between closely spaced pads and conductors. Pay particular attention to the top of the board to verify that all grounded leads are properly soldered to the ground plane and that all leads that are not supposed to be grounded are fully insulated from the ground plane. If in doubt about the latter, use an ohmmeter set to its lowest range or an audible continuity tester to verify that you have the required insulation between component lead and ground plane in each case.

Check all solder joints for good soldering. If any connection appears to be suspicious, reflow the solder on it. If you locate a solder bridge, reflow the solder and use solder wick or a solder sucker to remove it. Most problems in projects like this can be attributed to poor soldering.

Plug the IC into the socket, making sure you properly orient it. Also, make certain that no pins overhang the socket or fold under between socket and IC as you push it home.

For optimum circuit stability, it is best to house the circuit assembly inside an all-metal enclosure that has a removable top to permit internal access for fine tuning the the tank circuit. Use an enclosure that is at least 2 inches high so that you can mount the circuit-board assembly horizontally and spaced about ¼ or ½ inch above the bottom panel. Use metal spacers to mount the assembly so that the copper border around the solder side is electrically connected to the metal of the enclosure to ensure that the metal box is also at r-f ground potential.

A telescoping-type transistor-radio replacement antenna that extends to 12 to 18 inches is suitable for use with this project. Bear in mind, however, that you should use as short as antenna as needed for consistent operation at the desired range over which the project is to be used.

Use plastic hardware to mount the antenna to the enclosure so that it does not short to any part of the metal box. Also, locate the antenna close to the connecting pad on the printed-circuit board where the connection between the two is as short as possible. Capacitor *C11* will be used to make the actual connection between antenna and the collector of *Q3*.

POWER switch *S2* is optional and should be included if you anticipate long periods of time (weeks or more) during which the project will not be used. This switch and TEST pushbutton switch *S1* should be located on the top or side of the enclosure where it will not physically or electrically interfere with the circuit-board assembly and as far as possible from the antenna so that when operating either there will be minimum hand-capacitance effect coupled to the antenna circuit.

Use a snap-type battery connector to make connection to the 9-volt battery used for *B1*. Be sure to wire this connector so that the battery's negative terminal (connector's black-insulated lead) connects to the ground plane on the circuit board. Then plug the red-insulated connector wire into the B1- hole and solder into place. Secure the battery inside the enclosure with either a standard 9-volt battery clip or a length of double-sided foam tape.

Connection to the telephone line *must* be made via a telephone cord that has a modular connector at the end that attaches to the telephone line. Such cords are readily available from any outlet that stocks telephone accessories. Use of a modular connector is an FCC requirement, aside from the fact that it makes it easy to plug in and remove the project from any phone connector block.

If the only cord you can obtain has connectors at both ends, cut off one connector. Then remove about 1 inch of outer plastic jacket and strip ¼ inch of insulation from the ends of the exposed red- and green-insulated conductors. (If there are other conductors besides the red and green ones, clip them off flush with the plastic jacket.)

This project's circuit is ac coupled to the telephone line. Therefore, it is not necessary to observe any particular polarity when wiring the telephone cord into the circuit via the indicated holes in the circuit board. Route the cord into the enclosure through a rubber-grommet-lined hole and tie a knot in it about 3 inches from the prepared end inside the box, to serve as a strain relief, before plugging the wires into the board's holes and soldering them into place.

Checkout & Use

Use an ordinary FM broadcast-band radio (portable or otherwise) to check out circuit operation. For initial tests, do *not* connect the project to the telephone line. Also, *IC1* need not be installed in its socket at this time. During testing, the circuit-board assembly and antenna should be mounted in and on the project's enclosure to avoid any shift in frequency after circuit tuning.

With a 9-volt battery plugged into the snap connector, operate the transmitter either by having an assistant hold down the TEST button continuously or by temporarily connecting a wire jumper across the terminals of *S1*.

Place the FM radio 10 or 20 feet away from the transmitter to obviate overloading the radio with excessive signal strength. Now very slowly tune across the FM band until you hear the transmitted 2-kHz audio tone. If you are unable to detect any signal from the transmitter, its carrier may be tuned outside the FM radio's band. In this event, change the transmitter's operating frequency by spreading or compressing the turns of *L1* to raise or lower, respectively, the frequency until you are able to find the tone within the FM band. Be careful to avoid shorting the turns to each other or the circuit-board's ground plane!

When you do hear the 2-kHz tone, tune the FM radio to a dead spot on the dial and place it about 20 feet away from the transmitter. Now use a plastic tuning tool to adjust the spread of the turns of *L1* until you once again hear the 2-kHz tone. Work very carefully because only a very slight adjustment of the coil's turns should yield the proper results. Remember, to raise the frequency, spread the turns and to lower it, compress them.

Check that the signal is still present in the radio when you place the cover on the project's enclosure. If necessary, "tweak" the coil slightly to keep reception of the tone signal at the dead spot on the FM dial.

If you are unable to hear the 2-kHz audio tone in the FM radio at any setting of the dial and with any spreading or compression of the coil's turns, you will have to troubleshoot the circuit. Start by checking the electronic switch, using a dc voltmeter to check the reading at the collector of *Q5* to verify that the *Q4/Q5* switching circuit is operating. (Use a meter with at least a 20,000-ohms/volt input sensitivity for this test.) You should obtain a reading between 8 and 9 volts when the TEST button is closed, assuming the battery is reasonably fresh.

Carefully check the circuit-board assembly to make sure you installed all components in their respective locations, that the components are of the correct value or number in each case and that the diodes and transistors are properly oriented or based. Also make sure that none of the turns of *L1* are touching each other or anything else in the circuit. Review the winding instructions for the coil to ascertain that you have wound *L1* correctly.

Use the dc voltmeter to measure the voltage across *R4*, which should yield a reading of 4 volts when *Q2* is drawing current. To check the *Q1* circuit, you need an oscilloscope. Use the scope to observe the sawtooth waveform across *C1*; presence of this waveform indicates that the 2-kHz oscillator is operating as it should.

Once you are satisfied that the circuit is performing properly with the TEST pushbutton switch closed (or shorted), unsnap the connector from the battery and install *IC1* in its socket (if you have not already done so during construction). Observe correct orientation. This done, snap the connector back onto the battery and plug the project's phone cord into any convenient telephone-line outlet.

Now have a friend call your number. When your phone rings, you will hear the project's 2-kHz "ring" signal in your FM radio, verifying that the project is operating properly.

Once you have tuned the project to a dead spot on the FM dial, it is best not to change the length of the antenna. If you do change its length, a very slight change in operating frequency may result, which will require slight readjustment of the radio's tuning.

To use the project, connect it to the telephone line and place your FM radio some distance away from it. To verify that the system is working, press the TEST button. That is all there is to it. You can now carry the FM radio with you and have confidence that you will not miss a call as long as you are within range of the project's transmitter. **ME**