ELECTRONICS NOTEBOOK

Part-15 Low-Power Radio Transmitters

By Forrest M. Mims

There are many applications for low-power radio-frequency (r-f) transmitters. Moreover, building and experimenting with such transmitters can provide excellent practical experience in the basics of r-f circuit design and operation.

Several kinds of low-power radio transmitters can be built and operated without the need for a license or government approval. I'll describe the design and operation of several such systems below, but first let's review the legal requirements for such devices.

Legal Requirements for Low-Power Transmitters

In the United States, radio-frequency transmitters are regulated by the Federal Communications Commission. The text of these regulations is published in the Code of Federal Regulations, Title 47 (CFR 47), "Communications." Part 15 of CFR 47, which is entitled "Radio Frequency Devices," covers the operating specifications and permissible transmission frequencies of a wide range or unlicensed low-power r-f devices. The complete text of CFR 47 is available from the U.S. Government Printing Office (Washington, DC 20402).

Part 15 is much too long to reproduce here, but it's key features, which are subject to change, are worth reviewing. They include:

15.1 (a) An incidental and restricted radiation device may be operated under the restrictions and provisions set forth in this part without an individual license.

15.3 Persons operating restricted or incidental radiation devices . . . shall not be deemed to have any vested or recognizable right to the continued use of any given frequency . . . operation of these devices is subject to the conditions that no harmful interference is caused and that interference must be accepted that may be caused by other incidental or restricted radiation devices . . . .

15.5 Any equipment or device subject to the provisions of this part . . . [and] any technical data required to be kept on file by the operator of the device shall be made available for inspection by Commission representatives upon reasonable request.

15.104 . . . the use of a low power communication device for eavesdropping is prohibited.

15.152 . . . the operator of a low power communication device . . . which causes harmful interference to an authorized radio service, shall promptly stop operating the device until the harmful interference has been eliminated.

15.133 A person who constructs not more than five low power communication devices for his own use, and not for sale . . . shall attach to each such device a signed and dated label that reads as follows: I have constructed this device for my own use. I have tested it and certify that it complies with the applicable regulations of FCC Rules Part 15. A copy of my measurements is in my possession and is available for inspection.

These regulations are backed by severe penalties for violators. Though FCC regulations are rountinely violated, often unintentionally, the agency's field offices work closely with amateur radio operators and others to track down flagrant violations. It works hardest to locate illegal devices that cause interference with authorized communication devices.

The rules cited above apply to low-power devices in general. Now let's examine some of the transmission frequencies permitted by Part 15.

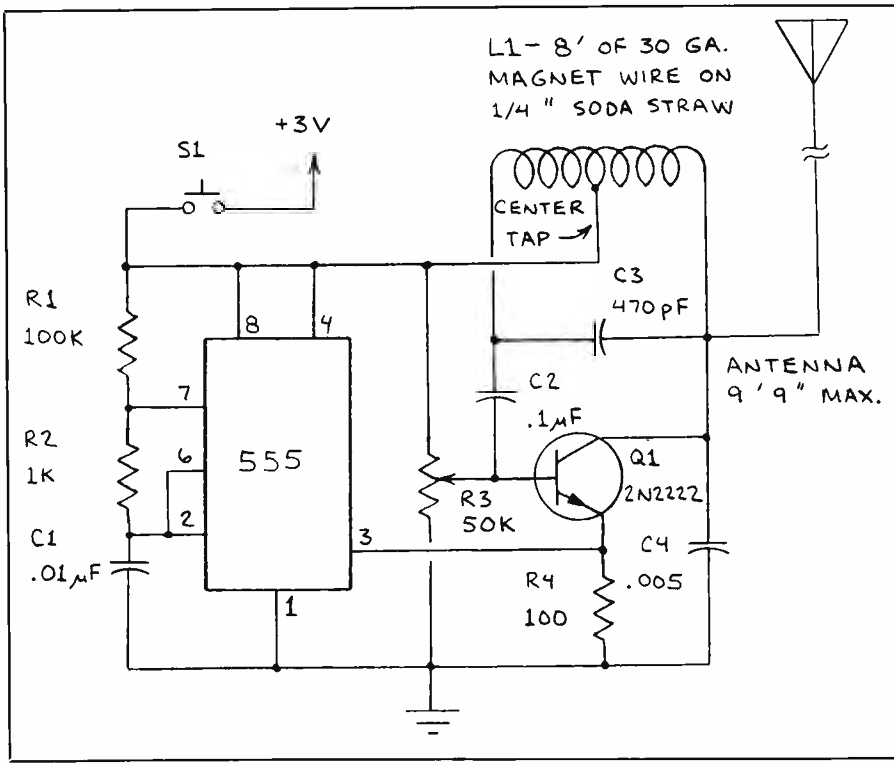

Fig. 1. A low-power broadcast-band tone transmitter.

Authorized Frequencies For Low-Power Devices

The FCC permits low-power devices to operate across a wide frequency spectrum. However, it is important to realize that some frequencies can be used only by FCC approved devices. For instance, a low-power wireless microphone operating in the 88-to-108-MHz FM broadcast band "... shall be type approved..." by the FCC (15.163 (a))

Fortunately, Part 15 imposes no type approval requirements for several frequency bands. But even these devices must meet specific requirements. The most important frequencies are the broadcast band, the 27-MHz CB band, the 49-MHz walkie-talkie band and a provision for periodic pulse operation at any frequency above 70 MHz.

Devices transmitting on the broadcast band are covered by:

15.113 . . . a low power communication device may operate on any frequency in the band 510-1600 kHz provided . . . (a) The power input to the final radio stage . . . does not exceed 100 milliwatts . . . . (c) The total length of the transmission line plus the antenna, plus the ground lead (if used) does not exceed 3 meters . . . .

Citizens band devices are covered by:

15.116 A low power communication device may be operated in the band 26.99-27.26 MHz provided . . . . (a) The device may not be used for voice communications . . . or for CW communications . . . . (b) The device shall operate on one or more of the following frequencies:

26.995 MHz	27.145 MHz
27.045 MHz	27.195 MHz
27.095 MHz	27.255 MHz. . . .

Low-power walkie-talkies can operate in a 49-MHz band. The applicable portion of the FCC rule is:

15.117 (a) A low power communication device may be operated on one or more of the permitted frequencies . . .:

49.830 MHz	49.875 MHz
49.845 MHz	49.890 MHz
49.860 MHz	

Special-purpose low-power tone transmitters can be operated at any frequency above 70 MHz if their field strength does not exceed specified levels and:

15.122. . . . (b) The device is provided with a means of automatically limiting operation so that the duration of each transmission shall not be greater than one second and the silent period between transmissions shall be at least 30 times the transmission duration but in no case less than 10 seconds.

Low-Power Transmitters

I designed the circuits to be described next for *Engineer's Mini-Notebook: Communication Projects* (Siliconcepts, 1987), a new Radio Shack book. The telegraph, intercom and lightwave communication portions of the book were straightforward. But developing and testing the radio-frequency transmitters required considerably more time than I had anticipated. The chief reason for this was the time required to meet the FCC requirements for radiated power and spurious emissions. I'll discuss this subject in more detail later.

• *Broadcast-Band Tone Transmitter.* The circuit in Fig. 1 transmits a clear audio tone to an AM radio tuned to around 700 kHz. It can send code signals or tone-encoded data (e.g., light level or temperature). It can be used as a tracking transmitter. And it can be concealed and used in a "fox hunt," the object of which is to find the hidden transmitter with the help of a directional receiver.

Referring to Fig. 1, *Q1* is connected as an r-f oscillator that generates a clean sine wave having a frequency determined by the values of *C3* and *L1*. The r-f signal is both amplitude and frequency modulated by an audio-frequency signal supplied by a 555 oscillator. The frequency of the modulating signal is determined by the values of *R1* and *C1*.

Coil *L1* is the only nonstandard component. Begin assembly of *L1* by punching a small hole near one end of a length of ¼-inch-diameter soda straw. Sandpaper the insulation from a 4-inch section at the center of an 8-foot length of 30-gauge magnet wire purchased from Radio Shack or an electronic parts store. Insert 2 inches of one end of the wire through the hole in the straw and wind the remainder of the wire around the straw until the uninsulated portion is reached. Secure the coil in place with tape and form the exposed section of wire into a 2-inch long loop. Then twist the sides of the loop together and insert it through a hole punched in the straw. Wind the remaining wire around the straw and insert the final 2 inches through a third hole. Clip off the excess end of the straw (but not the coil leads).

Test the circuit by connecting an antenna and closing *S1*. You should hear a tone when the radio is tuned to near 700 kHz. Note that the receiver must be carefully tuned, since the transmitter's transmission frequency is very narrow. Adjust *R3* until the sound of the tone is clear and free from any raspiness or other noise. The transmission range will exceed

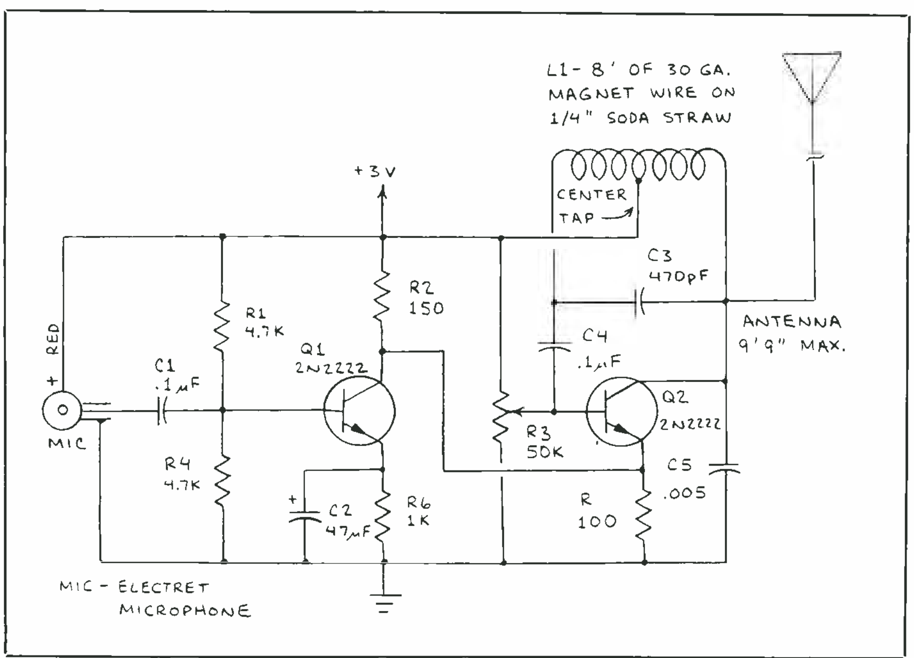

Fig. 2. A low-power broadcast-band voice transmitter.

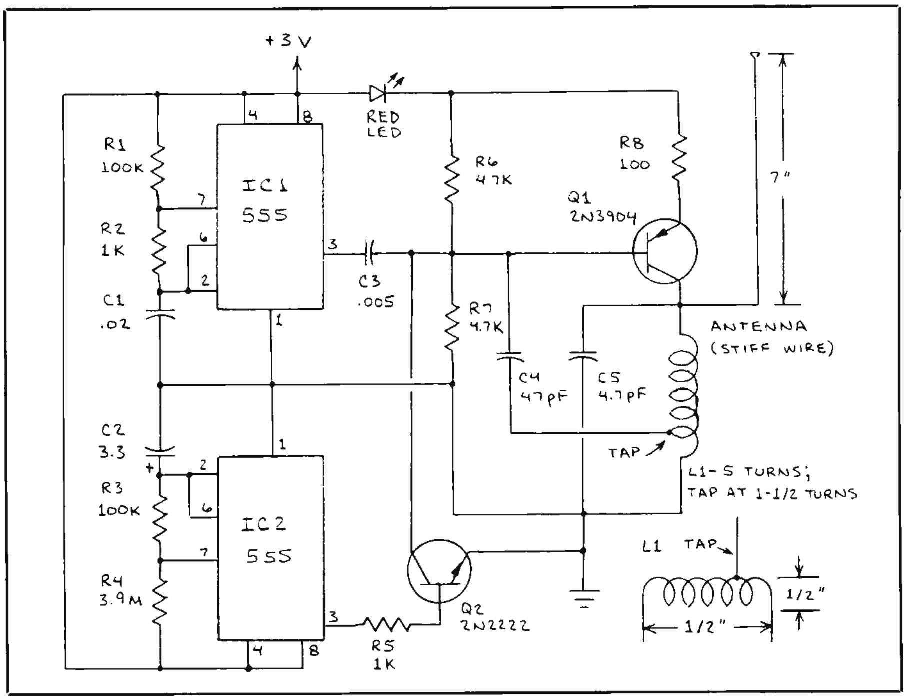

Fig. 3. A low-power vhf pulse transmitter.

20 or 30 feet when a 3-meter-long antenna is used.

If the circuit happens to transmit on the same wavelength as a local station, you will need to alter the frequency of the r-f oscillator. This is best done by substituting a 0-to-365-pF variable capacitor for *C3*.

Recall from the foregoing discussion of FCC regulations that the final stage of low-power broadcast-band transmitters must not consume more than 100 milliwatts. To measure this parameter, connect a current meter between the positive side of the battery and the circuit. The power consumed by the entire circuit is the product of the battery voltage and the current in amperes. If you want to measure only the power consumed by the r-f oscillator, insert the current meter between the junction of *R3* and *L1*'s tap and the positive supply.

For best results, assemble the transmitter in a small metal case. A metal case will make the transmitter less susceptible to the effects of body capacitance that can cause frequency shifts and other undesirable effects. Use a banana jack for the antenna terminal. Connect the ground side of the circuit to the metal case.

• *Broadcast-Band Voice Transmitter.* The transmitter in Fig. 1 can be voice modulated if the audio tone generator is replaced by a microphone and an amplifier, as shown in Fig. 2. Construction and operation of the r-f oscillator portion of the circuit is identical to that of the code transmitter described above. As for the voice amplifier, an electret microphone (Radio Shack Cat. No. 270-092 or similar) will give best results.

Test the assembled transmitter by placing an earphone connected to a tape player near the microphone to provide a source of sound. Tune a nearby broadcast-band receiver until the sound from the tape player is heard. Then adjust *R3* for best sound quality. Retune the receiver if necessary.

The sound from the receiver will probably be somewhat tinny due to the poor low-frequency response of the tape player's earphone. Nevertheless, when you have adjusted the transmitter for the best sound quality, it will be ready to transmit a faithful reproduction of your voice.

As with the previous circuit, the transmitter will give best service if it is housed in a small metal case. Refer to the previous circuit's description for details.

• *A Special-Purpose 100-MHz Pulse Transmitter.* Part 15.122 of 47 CFR permits periodic low-power transmissions at any frequency above 70 MHz. In the band from 70 to 130 MHz, the maximum field strength of the fundamental frequency is restricted to 500 microvolts/meter at a distance of 3 meters, for a transmission range of hundreds of feet.

Under the provisions of Part 15.122, periodic operation means the maximum transmission time is 1 second and the minimum interval between transmissions is 10 seconds. In any case, the silent interval must be at least 30 times the duration of the transmission. Therefore, if a pulse is transmitted once every 10 seconds, it's length must not exceed ⅓ second.

Figure 3 is a circuit I designed specifically for Part 15.122 operation. With the component values shown, the circuit transmits a ¼-second tone burst once every 10 seconds, as shown in Fig. 4. The transmission frequency falls within the 88-to-108-MHz FM broadcast band.

Referring to Fig. 3, *Q1* is connected as an r-f oscillator whose frequency is determined primarily by the values of *L1* and

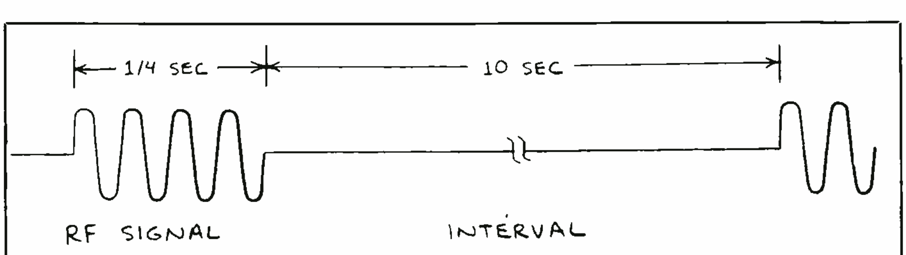

Fig. 4. The transmission format of the vhf pulse transmitter.

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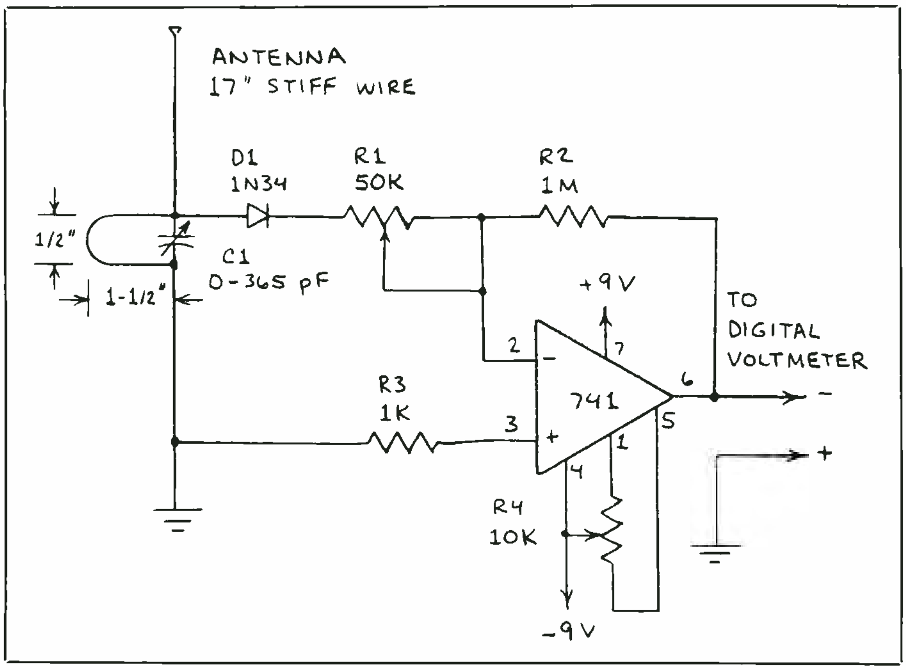

Fig. 5. A radio-frequency field-strength meter.

C5. Timer *IC1* is connected as an oscillator that amplitude modulates the r-f carrier signal with an audio-frequency tone. The frequency of the tone is determined by the values of *R1* and *C1*.

Timer *IC2* is connected so that it normally keeps *Q2* switched on to disable the r-f oscillator. Once every 10 seconds, *IC2* switches *Q2* off and the r-f oscillator is enabled for 0.25 second. Transistor *Q2* is then switched on again and the cycle repeats. Resistors *R4* and *R3* and capacitor *C2* control *IC2*'s timing interval.

With one exception, both standard and low-power 555 timer chips can be used for *IC1* and *IC2*. Or a single 556 can be used to replace both 555s. The exception is that when the Texas Instruments TLC555, a low-power version of the 555, is used for *IC1*, the carrier wave will not be tone modulated. Other CMOS and low power 555s I tried worked in this circuit.

Note the red LED inserted between the positive supply and the r-f oscillator. Though this LED glows when the r-f oscillator is transmitting, its primary purpose is to drop the voltage to the oscillator to around 1.5 volts. This proved necessary to keep the transmitter's power output within Part 15.122 guidelines.

Coil *L1* is the only special component in Fig. 3. This coil is simply 5 turns of solid wire wound around a ¾-inch-diameter form, such as a wood dowel. When the form is removed, the coil will spring outward slightly and assume an outside diameter of ½ inch. The tap is a wire soldered 1½ turns from the ground end.

To test the transmitter, first connect a 7-inch-long stiff antenna wire to the junction of *L1* and *Q1*'s collector. (A longer antenna will violate Part 15.122 field-strength restrictions.) Then temporarily disconnect *Q2*'s collector from the circuit, switch on the power and tune a nearby FM radio until a strong, steady tone is received. If the signal competes with that from a broadcast transmitter, you will need to alter the transmission frequency. One way is to slightly squeeze or stretch the turns of *L1*. Another is to add one or more 1-pF capacitors across *C5*. Still another is to replace *C5* with a small variable capacitor like those used in digital watches and other miniature crystal-controlled oscillators. You will need an insulated tuning tool to adjust the variable capacitor, since body capacitance will make substantial frequency changes.

When the circuit is working properly, *Q2*'s collector must be reconnected to meet the requirements of Part 15.122. There are many applications for the transmitter. It can be connected to a pressure-sensitive switch that switches the circuit on when mail is placed in your mail box. It can be used as a wireless doorbell or a tracking transmitter. It can even be used as a telemetry transmitter that transmits light-level, temperature or other data. All that's necessary is to replace *R1* with a suitable variable-resistance detector.

For best results, assemble this transmitter in a metal case. Be sure that *L1* is mounted firmly to the circuit board and that it doesn't touch the case. If *L1* vibrates, the transmission frequency will be frequency modulated.

Determining if the broadcast-band transmitters described above meet FCC guidelines is simple. That's because Part 15 permits the r-f oscillator's power consumption to be measured in lieu of an actual field-strength measurement. Unfortunately, Part 15.122 devices are characterized only according to maximum permissible field-strength levels. To comply with this requirement, I designed the simple field strength meter described below.

Simple Field Strength Meter

Figure 5 shows a simple field-strength meter. In operation, *L1* and *C1* select an r-f frequency flowing in the antenna. The selected signal is rectified by germanium diode *D1* and amplified by a 741 operational amplifier. The output from the 741 is fed directly into a digital voltmeter.

Even with no input signal, a small offset voltage will appear at the output of the 741. This can be nulled by carefully adjusting offset potentiometer *R4*.

For best results, the circuit should be installed in a metal case. A banana jack can be used to provide an antenna terminal. Coil *L1* is simply a wire bent into a hairpin loop as shown in Fig. 5. A standard 0-to-365-pF variable capacitor is used for *C1*.

While simple field-strength meters such as this one can provide a relative indication of field strength, they are not calibrated. I discussed the need to measure the field strength of the Part 15.122 device described above with Harry

Helms, an Extra Class amateur radio operator (KR2H) and a prolific writer of technical books and articles. Harry suggested a simple method for making ballpark estimates of actual field strength using my do-it-yourself meter. His suggestion was to monitor the signal from an FCC type-approved transmitter and compare this signal with that from the Part 15.122 unit.

I tried Harry's suggestion with the help of a pair of identical 49-MHz transceivers, both of which, according to the manufacturer, meet Part 15 specifications by emitting a maximum field strength of 10,000 microvolts/meter at 3 meters. The transmitters gave peak readings of 2.4 and 6 millivolts. The do-it-yourself Part 15.122 device (in continuous-transmission mode) gave a peak reading of 0.1 millivolt. When compared to the two type-approved devices, the Part 15.122 unit has a field strength of either 167 or 416 microvolts/meter at 3 meters. The legal maximum is 500 microvolts/meter. When the antenna wire of the Part 15.122 device is lengthened, the field strength increases dramatically. Therefore, be sure to keep the antenna length at 7 inches.

Going Further

For more information about the design of radio-frequency transmitters, see *The ARRL Handbook For The Radio Amateur*. This outstanding publication, which is updated yearly, includes detailed information about the design and operation of many kinds of transmitters. These principles can be applied to the design and operation of both unlicensed (low-power) and licensed transmitters. For example, the Handbook discusses the use of r-f filters to reduce the strength of unwanted harmonics.

The ARRL Handbook can be purchased from some electronics stores or purchased by mail order. For additional information about this and other publications of the American Radio Relay League, write the ARRL (Newington, CT 06111). ME