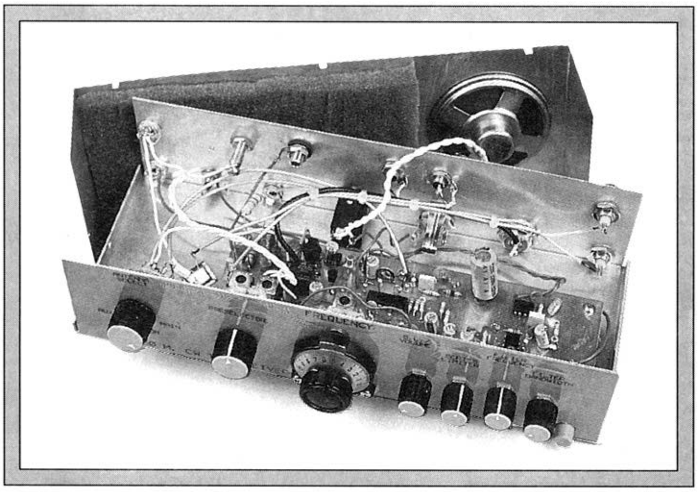
Build Your Own *Lowfer* Transceiver



Explore the 1750-meter band with this high-performance CW transceiver.

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Black crinkle finish, 82 pounds, 1944. What do these words have in common? Why the *RBL* low-frequency receiver, of course! And what makes the RBL LF/VLF receiver so special? The RBL symbolizes the Low Frequency/Very Low Frequency experience for the people who explore the depths of the 1750-meter band (160 to 190 kHz). They're the *Lowfers*, radio experimenters—many of them hams—who enjoy this band and manage to carry on useful communications despite low-power restrictions and high noise levels. *No license is required to operate on 1750 meters.* Anyone can use the band. All you need is the proper equipment.

Which brings us back to the RBL...

My first encounter with an RBL was at Fred Wilson's electronic shop in 1971. He had one sitting on a shelf, next to an old Tektronix 'scope. You could feel the warmth of the tubes and smell the capacitors when you opened the door to his shop. There was something alluring about his RBL receiver. Even the dials were impressive, especially when you turned the big frequency vernier.

One day we connected a wire antenna and heard...noise! Lots of noise. Fred sold it to me later for $40 and I used a garbage cart to take it around the block to my house. Sometime later Ken Cornell, W2IMB, gave me some details on how to make a simple loop antenna that worked very well with the RBL. Sure enough, I received dozens of distant aero/marine beacons late at night in the bedroom closet, lit only by the yellow lights of the RBL.

In due time I became a Lowfer after building my first 1750-meter station and working Todd Robert's "ABC" in January 1974. The "feel" of 1750 meters is in harmony with the RBL. The Lowfer band is filled with mystery, challenge, antiquity, and much history. These low frequencies are where radio communication began. During WW II the RBL was a symbol of the state of the art. Many of these receivers served our nation's interests, and remain to this day in sunken hulks at Pearl Harbor, and in ill-fated submarines.

The RBL design was the inspiration for this simple Lowfer CW transceiver—the *CW-893*. You can build it in a couple of evenings and you'll soon be on the air on 1750 meters!

Description

The receive portion of the CW-893 is a virtual duplicate of the RBL, but in modern form! The RBL had unbeatable stability and sensitivity with its regenerative detector. The transceiver described here does not use a regenerative detector, but a *direct conversion* approach instead. The front end preselector uses a tunable two-pole Chebychev bandpass filter to remove unwanted signals. Noise is always a problem at these frequencies, so two noise limiters are included that provide very effective limiting of man-made and natural noise.

Audio filtering is included, with variable frequency and bandwidth controls for precise filtering of the desired signal. Ample audio output drives headphones and most speakers. The CW-893 is capable of providing over 100 dB of receive gain with virtually no power supply hum.

The transceiver generates 1 W of input power with its Class-E MOSFET amplifier. FCC Rules limit Lowfer power to 1 W, which is why CW is the mode of choice for this radio. Semi-break-in operation is provided with an adjustable time delay. The frequency is VFO controlled.

Although this transceiver is basic in concept, it incorporates all the required features for successful two-way operation on 1750 meters. Your range will extend from about a mile to 200+ miles, depending on band conditions and the quality of your antenna.

As you probably know, purchasing components these days can be expensive, which was a major concern when I designed the CW-893. All parts are off the shelf, with part numbers provided.

Construction Notes

Several parts are soldered directly to the component side of the circuit board. This provides the ground connection for many components. Be sure to solder these leads to *both sides* of the PC board. All parts are easy to identify. The capacitors are disc or round shaped, while electrolytics are round with the polarity marked. Transistors are designated by the half moon shape, or round with a key. ICs are rectangular with notches at the ends.

I recommend soldering the ICs first. Notice that some pins must be soldered on the component side. The next step should be soldering L1, L2 and T1. Switch S1 should be installed after you mount the potentiometer. The switch is mounted on the solder side of the circuit board.

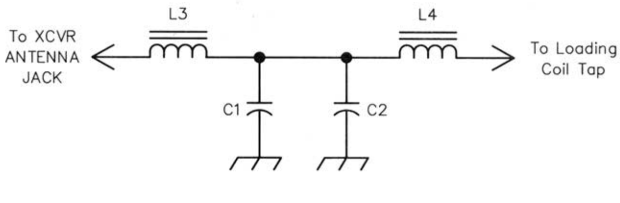


Figure 1—An auxiliary low-pass filter for the CW-893 transceiver. Installation is optional. L3 and L4 are made from 43 turns of #20 wire wound on an Amidon T-94-3 core. C1 and C2 are 0.01 µF polystyrene capacitors (Mouser 23PS310)

The auxiliary low-pass filter described in Figure 1 is not strictly necessary. It does offer a substantial reduction in harmonic output, however. To make absolutely certain that your transceiver conforms to FCC Part 15 Rules, I recommend that you build and install the filter in the enclosure.

Transformer T2 must be wound by hand on a T-68-3 toroid core available from Amidon Associates and other sources. The kit manual provides detailed instructions. In addition, see the *ARRL Handbook* for more information on winding toroid transformers. The T2 primary consists of 93 turns of #30 enamel-insulated wire. The secondary is made of 49 turns of #25 enamel-insulated wire. Wind the turns evenly and firmly. After you've finished, cut the wires so that about one inch remains from the toroid to the end of each wire. Remove the enamel insulation from the ends with sandpaper.

The CW-893 is available as a kit complete with a circuit board, parts and instructions. All you have to supply is a suitable enclosure and various knobs. You can purchase the kit directly from me for $94, shipping included (California residents please add sales tax). If you want to shop for your own components, you can buy only the circuit board at a cost of $22. I can provide information sheets on the CW-893 in return for a self addressed, stamped envelope and three units of First-Class postage.

Checkout and Alignment

Refer to Figure 2 and locate the following points:

- **A:** 50-Ω transmit/receive antenna jack.
- **B:** CW key jack.
- **C:** Speaker/headphone output.
- **COMM:** Common terminal for auxiliary relay.
- **D:** Frequency monitor port.
- **E:** Audio output for external amplifier, or AB1 deluxe audio board (available as a kit from the author).
- **GND:** Ground.
- **JP1:** Receive input select. Short JP1A and JP1B to use an antenna at port A for receive. (Receive-only antennas connect to JP1B.)
- **N/C:** Normally closed terminal for auxiliary relay control.
- **N/O:** Normally open terminal for auxiliary relay control.
- **VCC:** 12 to 18 V dc.

Connect a 12-V power source to the V_{CC} points and ground. A frequency counter or receiver covering 150 to 250 kHz will be required for the following steps.

Connect a frequency counter to point **D**. Switch the transceiver on. Adjust tuning capacitor C10 to its maximum clockwise position. Turn the slug in T1 until the frequency reads 189 kHz on the counter.

If you don't have a frequency counter, don't worry. You can also use a long-wave receiver, general coverage receiver, or ham transceiver that can accurately tune to 189 kHz. Attach a small piece of wire to the antenna jack. Tune your monitor receiver to 189 kHz. Listen for a tone while turning the slug of T1. Keep turning the slug until a zero beat is heard.

Next, align the preselector. Inductors L1 and L2 must be tuned to the same frequency. If you have a signal generator, adjust it for a low level (approximately 100 µV) at the antenna jack. Turn the **Preselector** and the **Filter Frequency** controls to their 12 o'clock positions. Rotate the **Series Limiter** and **Filter Bandwidth** controls fully counter-clockwise. Tune the **Frequency** control until you can hear the generator's signal. Adjust the slugs on L1 and L2 for maximum volume in your speaker or headphones, decreasing signal generator output as the generator tone becomes louder.

If you don't have access to a signal generator, connect a long piece of wire to the antenna jack and listen for any signals you can find (even an interference signal will do!). Once you find a usable signal, turn the **Preselector** capacitor to the same general setting as the **Frequency** capacitor. Now adjust the slugs in L1 and L2 for maximum signal strength.

Operating Tips

The audio gain stage (adjusted through the use of the **Volume** control) has a built-in limiting function. This can be used to increase the gain of a signal that's buried in man-made noise, effectively cutting off the peaks of the noise while leaving the signal unaffected. The **Series Limiter** clips any remaining distortion from the shunt limiter and lowers the volume to a comfortable level. The audio **Filter Frequency** and **Bandwidth** controls are adjusted for the amount of filtering desired.

While there is plenty of audio power available to drive a speaker, I recommend that you use headphones whenever possible. Direct-conversion receivers derive much of their gain in the audio amplifier stages. As a result, a high-gain audio amplifier—such as the one used here—may begin to oscillate if you turn it up too high. (You'll know this is happening if you hear a howling sound!) By using headphones, you'll hear the weak signals much better and you won't need nearly as much audio power.

Direct-conversion receivers are also prone to *microphonics*—amplification of mechanical vibrations. Care should be used if you install a speaker near the chassis or circuit board to avoid any audio feedback.

An important feature of the CW-893 receiver section is the input **Preselector** control. The preselector filter is very sharp, allowing only a small slice of the band to be received. If, for example, the signal you want to hear is on 180 kHz, tune the **Frequency** control to either 179 or 181 kHz. The signal will be heard as a 1-kHz tone (180 kHz – 179 kHz = 1 kHz, or 181 kHz – 180 kHz = 1 kHz). Choosing whether the upper or lower frequency is best depends on which provides the clearest reception. During two-way operation, for example, you might be transmitting at 182 kHz with the preselector peaked to your friend's signal at 182.4 kHz. By the same token, your friend's preselector would be peaked at *your* frequency (182 kHz). As you can see, tuning the preselector above and below your center frequency provides a lot of flexibility.

Transmitting with the CW-893 is as easy as plugging in a CW key, selecting a clear frequency, and using a *resonant* vertical transmitting antenna. Consider a call sign that uses the last two or three letters of your Amateur Radio call sign. (It's considered poor practice to use your full call sign.)

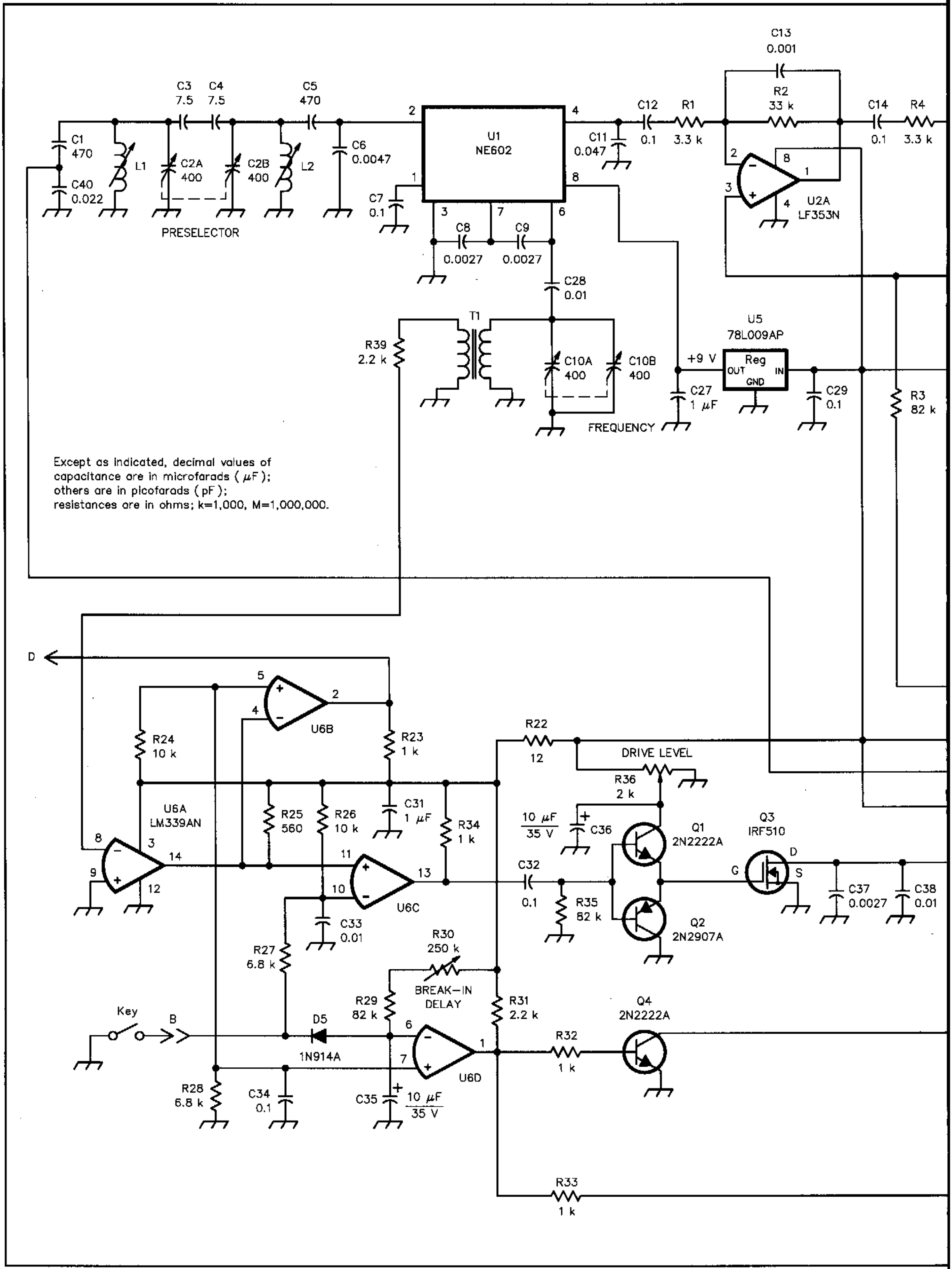
When transmitting, you'll want to adjust your TR delay potentiometer (R30) for the desired keying delay. In addition, the power amplifier drive control (R36) should be set for desired input power. You could install a 1-mA meter in the enclosure to monitor the power amplifier current. Meters can be expensive, however, so a VOM or VTVM can be used instead. Connect this to the meter – and + points on the circuit board. The voltage indicated corresponds to the input current to the power amplifier. One watt of input power is 83 mA at 12 volts, or *83 mV* on a VOM or VTVM connected to the – and + points.

When you're not enjoying a conversation, you can use the transceiver to send a beacon signal. Beacons are helpful to other Lowfers who want to know if they can hear you. It also helps with antenna experimentation and propagation tests. The transceiver is easy to use as a beacon. Simply connect your beacon ID generator (a CW keyer set to the "repeat" mode, for example) to the key input (point "B").

Antennas

The type and location of your 1750-meter antenna are of paramount importance. FCC Rules restrict the length of your *transmitting* antenna system to 15 meters. Just about any type of antenna design will do for casual, short-range experiments (less than one mile).

If your goal is optimum transmitting performance over greater distances, you *must* use a *resonant* vertical antenna (see Figure 3A). This involves resonating the antenna with a *loading coil* at the feed point and using a good ground system. The ground system can be composed of eight (or more) radial wires, each 30 feet or more in length. Terminate the radial ground wires with four copper pipes used as ground rods. If a ground system is required in rocky or sandy soil, or you want to roof mount the antenna, use a counterpoise resonant radial system. The cold water pipe in your home is an alternative if



C1 470
C40 0.022
L1
C3 7.5
C4 7.5
C2A 400
C2B 400
L2
PRESELECTOR
C5 470
C6 0.0047
U1 NE602
C7 0.1
C8 0.0027
C9 0.0027
C28 0.01
T1
R39 2.2 k
C10A 400
C10B 400
FREQUENCY
C11 0.047
C12 0.1
R1 3.3 k
C13 0.001
R2 33 k
U2A LF353N
C14 0.1
R4 3.3 k
U5 78L009AP
+9 V
Reg
OUT
IN
GND
C27 1 µF
C29 0.1
R3 82 k
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000.
D
U6B
R24 10 k
R23 1 k
R22 12
DRIVE LEVEL
R36 2 k
U6A LM339AN
R25 560
R26 10 k
C31 1 µF
R34 1 k
10 µF 35 V
C36
Q1 2N2222A
Q3 IRF510
U6C
C32 0.1
R35 82 k
Q2 2N2907A
C37 0.0027
C38 0.01
C33 0.01
R27 6.8 k
R30 250 k
BREAK-IN DELAY
R29 82 k
R31 2.2 k
Key
B
D5 1N914A
U6D
R32 1 k
Q4 2N2222A
R28 6.8 k
C34 0.1
C35
10 µF 35 V
R33 1 k

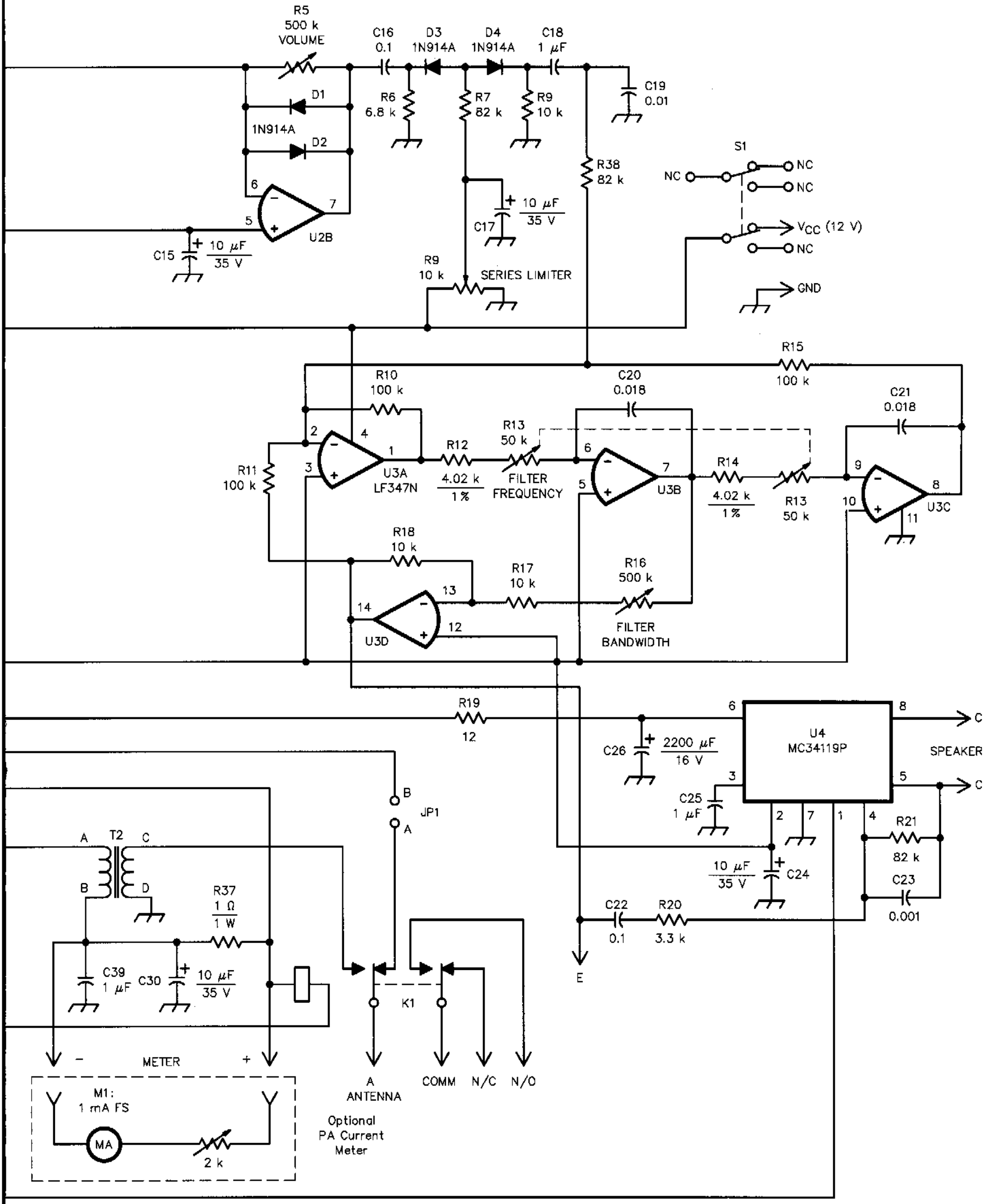


Figure 2—See caption on the next page.

Fig 2—Schematic diagram of the CW-893 transceiver. Resistors are ¼-watt, 5% tolerance carbon-composition or film except as noted below.

C1, C5—470-pF polystyrene (Mouser 23PS147).
C2, C10—400-pF variable (Mouser 24TR218).
C3, C4—7.5-pF ceramic disk (Mouser 21CB008).
C6—0.0047-µF polystyrene (Mouser 23PW247).
C7, C12, C14, C16, C22, C29, C32, C34—0.1-µF ceramic disk (Radio Shack 272-135).
C8, C9, C37—0.0027-µF polystyrene (Mouser 23PS227).
C11—0.047-µF film (Digi-Key P4521).
C13, C23—0.001-µF polystyrene (Mouser 23PW210).
C15, C17, C24, C30, C35, C36—10-µF, 35-V electrolytic (Radio Shack 272-1025).
C18, C25, C31, C39, C27—1-µF monolithic (Newark 90F1907).
C19, C33—0.01-µF ceramic disk (Radio Shack 272-131).
C20, C21—0.018-µF polypropylene 12% (Digi-Key P3183).
C26—2200-µF, 16-V electrolytic (Radio Shack 272-1020).
C28, C38—0.01-µF polystyrene (Mouser 23PW310).
C40—0.022-µF polystyrene (Digi-Key P3223).
D1, D2, D3, D4, D5—1N914A diode (Radio Shack 276-1122).
K1—DPDT relay (Digi-Key Z768-ND).
L1, L2—1.5-mH variable inductor (Digi-Key TK3203).
Q1, Q4—2N2222A (Radio Shack 276-2009).
Q2—2N2907A (Radio Shack 276-2023).
Q3—IRF510 power MOSFET (Radio Shack 276-2072).
R1, R4, R20—3.3-kΩ (Radio Shack 271-1328).
R2—33-kΩ (Radio Shack 271-1341).
R3, R7, R21, R29, R35, R38—82-kΩ.
R5, R16—500-kΩ, pc-board pot (Mouser 31CW505).
R6, R27, R28—6.8 kΩ.
R8—10-kΩ, linear taper, pc-board pot (Mouser 31CW401).
R9, R17, R18, R24, R26—10 kΩ (Radio Shack 271-1335).
R10, R11, R15—100 kΩ, 1% (Mouser 29MF250-100K).
R12, R14—4.02 kΩ, 1% (Mouser 29MF250-4.02K).
R13—50-kΩ, ¼-W, dual audio taper (Calrad 25-411).
R19, R22—12 Ω.
R23, R32, R33, R34—1 kΩ (Radio Shack 271-1321).
R25—560 Ω.
R30—250-kΩ trimmer (Mouser 32RM503).
R31, R39—2.2 kΩ (Radio Shack 271-1325).
R36—2-kΩ trimmer (Mouser 32RM302).
R37—1 Ω, 1 W (Mouser 29SJ901).
S1—DPDT switch (Digi-Key EG1003-ND).
T1—0.63-mH transformer (Digi-Key TK1201).
T2—Toroid transformer (see text).
U1—NE602 mixer/amplifier (Digi-Key NE602AN).
U2—LF353N low-noise op amp (Mouser 511-LF353N).
U3—LF347N quad op amp (Mouser 511-LF347N).
U4—MC34119P audio power amplifier (Newark MC34119P).
U5—78L009AP 9-V regulator (Mouser 333-78L009AP).
U6—LM339AN quad comparator (Mouser 511-LM339AN).

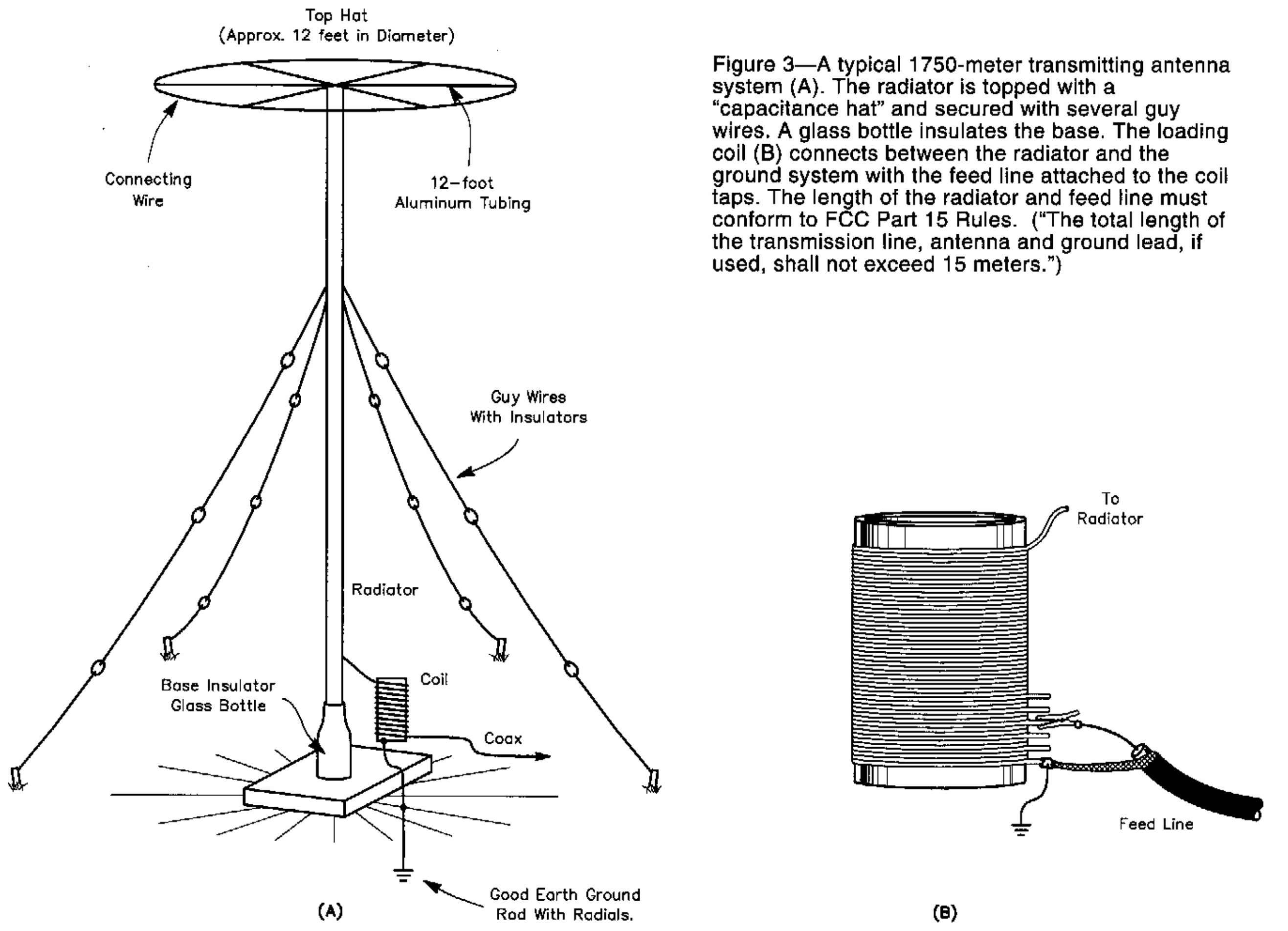


Figure 3—A typical 1750-meter transmitting antenna system (A). The radiator is topped with a "capacitance hat" and secured with several guy wires. A glass bottle insulates the base. The loading coil (B) connects between the radiator and the ground system with the feed line attached to the coil taps. The length of the radiator and feed line must conform to FCC Part 15 Rules. ("The total length of the transmission line, antenna and ground lead, if used, shall not exceed 15 meters.")

you have space limitations (performance will suffer greatly, though).

You can make the loading coil from a piece of *white* PVC pipe or Plexiglas tubing approximately six inches in diameter (see Figure 3B). Use #18 enamel-insulated wire, winding it tightly on the pipe to a length of five inches. Create taps at the cold end of the coil by sanding away the insulation of the first 10 turns. The braid of your coaxial feed line is attached to the ground system and cold end of the coil. The center conductor is soldered temporarily to the fifth turn of the coil. The top of the coil attaches to the antenna. Several small NE-2 neon bulbs can be soldered in series and used as a voltage detector. While transmitting a carrier, touch the bulb string to the antenna and watch for an indication. Place your hand near the antenna and note the illumination. If the capacitance of your hand makes the bulbs brighter, *add* more turns to the coil; remove turns if the bulbs dim. Once the best number of turns is determined, experiment further to find the best tap point. When you're finished, paint the coil with clear marine varnish.

It's important to note that there are no restrictions on the type and size of your *receiving* antenna. With that in mind, you may want to consider separate receiving and transmitting antennas. For example, many Lowfers use a broadband high-impedance probe with a built-in preamp called an *active whip* antenna. The small size of the whip antenna makes it convenient for it to be placed in a location where noise is at a minimum. A separate ground rod should be used as a noise-free isolated ground reference for this antenna. Active whip antennas are considered the best overall LF/VLF receiving antennas and can be purchased from LF Engineering, 17 Jeffery Rd, East Haven, CT 06513; tel 203-248-6816.

Lowfers also use loop antennas because of their ability to reduce or eliminate noise by rotating the antenna *null* for minimum noise pickup. Magnetic noise from residential wiring is a problem in city or suburban environments, so a loop is not recommended for these areas. But in a clear area such as a park, a loop can effectively remove strong carriers and noise that block the signal you are trying to receive.

Receiving and transmitting antennas should be located away from power lines, trees or buildings. Noise may wipe out reception completely, discouraging the casual listener from using this band. Smart antenna design and placement will significantly reduce the noise to an acceptable level. Man-made noise tends to rapidly diminish as you move away from the source. Light dimmer interference, for example, will radiate throughout the wiring in the home, eliminating useful reception from an antenna on the roof, or within 20 feet of the home. If the receiving antenna can be moved near the curb, however, the noise may disappear.

Conclusion

Much more needs to be said about Lowfer antennas and Lowfing in general, but I'd need a lot more space! The CW-893 kit manual includes a detailed discussion of antennas with several suggested designs. I also recommend that you pick up a copy of Ken Cornell's book, *The Low and Medium Frequency Radio Scrapbook*. It's available by mail directly from Ken at 225 Baltimore Ave, Point Pleasant, NJ 08742. The cost is $17.50 (shipping included). You'll find a partial list of 1750-meter CW beacon stations in WB8IMY's article, "Lowfing on 1750 Meters" in the October 1993, *QST*, page 67.

Lowfer newsletters are also available. If you join the Longwave Club of America, you'll receive the *Lowdown*. For details, write the LWCA at 45 Wildflower Rd, Levittown, PA 19057.

David Curry, WD4PLI, has been an active Amateur Radio operator and Lowfer for more than 20 years. He is a regular on the Los Angeles area 1750-meter SSB Net Saturday mornings at 9 AM on 183.5 kHz. He also participates in the 80-meter Lowfer Net Sundays at 8 AM on 3927 kHz. David is a professional musician and enjoys snow skiing, wind surfing and fine dining.