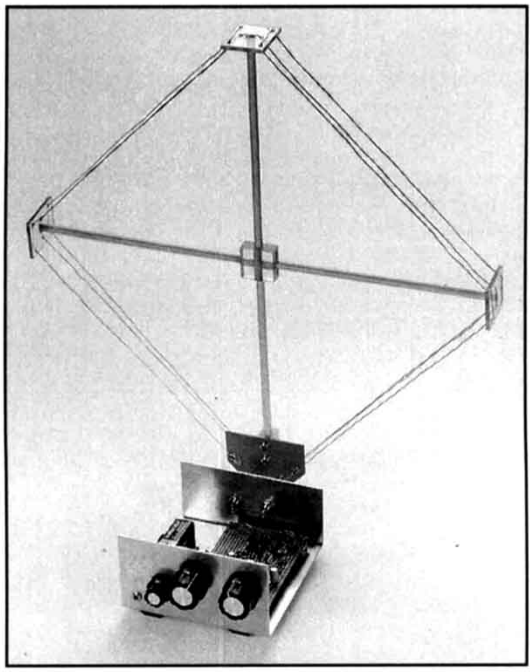
By Daniel Wissell, N1YBT

The 40M SLR—a Shielded-Loop Receiver



Picture yourself copying 40 meter DX—with no outdoor antenna!

As with many designs, this project started life in quite a different direction. Initially, it was a "quick" experiment to determine if the performance of a simple direct conversion (D-C) receiver using an NE602 active mixer could be improved. Many experiments and measurements later, the 40 meter Shielded Loop Receiver (40M SLR) was born!

Ideas Grow...

I started by using an instrumentation amplifier as a balanced load and audio preamplifier for the mixer. The results were encouraging. Well, if a balanced load at the *output* improved the receiver's performance, how much more would a balanced *input* help? I designed and tried several single-ended-input to balanced-output band-pass filters. They worked well, but were complicated to implement. Then, I wondered, why not use a tuned, balanced antenna—such as a folded dipole or a small loop to provide the front-end selectivity? So, I took a simple loop antenna, made it physically smaller and added a shield loop to improve indoor operation for use near a window in a commercial building or an aluminum-sided house. Next, I cleaned up the receiver's audio-section noise figure so that a 0.1 µV signal is detectable. Finally, the receiver's current requirement was reduced to less than 10 mA with the volume set for comfortable headphone operation, allowing operation from a 9 V battery.

The resulting combination of old concepts—such as the shielded loop antenna—combined with the newer NE602/SA602[1] active mixer and an instrumentation amplifier resulted in a simple, high-performance receiver that is easily built by a novice and readily enjoyed by experienced operators as well. There are only two adjustments required: setting the VFO on frequency and peaking the antenna for maximum signal strength. Both adjustments can be performed while on the air and with no additional test equipment. Although the combination of a good receiver and a good outdoor antenna system can't be beat, the 40M SLR allows amazingly good performance with an indoor antenna. It's ideal for beginners or operators with antenna restrictions who still want to enjoy HF reception.

The receiver presented here is for the 40 meter band, chosen because it's usually active any time of the day. Component values and loop-antenna dimensions are also provided for 80 and 30 meter versions. Experienced builders, however, can scale the design for any of the HF bands. (At 20 meters and above, however, the stability of the NE602 as an oscillator is such that an external VFO should be used.) All components required are available from standard mail-order sources.[2] A PC board and kit are offered, too.[3]

How the 40M SLR Works

As shown in Figure 1, this D-C receiver design is based upon the NE602 (U1), a device used in many recent simple receiver designs. A good overview of NE602 operation in a D-C receiver can be found in "The Neophyte Receiver."[4] The VFO is a standard Colpitts, employing NP0 capacitors to enhance stability. To reduce cost, electronic tuning using voltage-variable capacitors (VVC) is employed in lieu of a more expensive (and often difficult to find) mechanical tuning capacitor.[5] In several prototypes, 10-turn potentiometers are used as the main tuning control. They provide very good tuning control, giving a tuning rate of about 25 kHz per turn. However, new 10-turn pots, while readily available, are expensive, so I sought a cheaper substitute.

I decided to tune the VFO using the old technique of bandset (main tuning) and bandspread (fine tuning), using readily available, low-cost, single-turn potentiometers. This is a variation on another DeMaw design.[6] R1 is the **MAIN TUNING** control and covers the entire tuning range of the receiver. R6, the **FINE TUNING** control, covers about 10% of the **MAIN TUNING** control's range. R2 and R7 set the lower voltage limit for D1 at about 1.5 V, keeping tuning diodes D1 and D2 out of their highly nonlinear tuning range. Using the values shown, the receiver tunes from 7 to 7.25 MHz, approximately. U4, an LP2951 low-dropout regulator, provides a well-regulated 7 V supply from the 9 V battery. Because U4 maintains regulation with a input-to-output voltage differential of less than 200 mV, the 9 V battery can be used fully. The regulated voltage is used for D1, D2 and U1. Oscillator stability is more than adequate for general-purpose use, even without an enclosure.

Many prototypes were constructed to validate the design. Three are shown in Figure 2. The unit in the middle is a mechanically tuned version and served as the "standard" to which the electronically tuned versions were held. The right-hand receiver uses a single 10-turn potentiometer for tuning, while the final prototype of the 40M SLR on the left uses **MAIN** and **FINE TUNING** controls. The electronically

[1]Notes appear on page 38.

tuned designs proved as stable and quiet as the mechanically tuned version. All of the prototypes were constructed using perfboard, point-to-point wiring and copper foil to create a ground plane.

Receiver front-end selectivity is provided entirely by the loop antenna and its tuning network.[7] The antenna provides a band-pass function similar to that of a single resonator band-pass filter. A single peaking capacitor in the loop is adjusted for maximum signal strength. Antenna bandwidth is controlled by the loop's impedance. That impedance is a function of the inductance and the distributed capacitance of the loop itself, and the loop antenna tuning network, C1 and C2, in Figure 3. Several versions of the shielded loop antenna were built and tested. These include loops constructed from small (0.141 inch) diameter 50 Ω coaxial Hardline, etched PC boards, twisted wire pairs and the classic wire form presented here. Figure 4 shows a pair of completed loop antennas.

Although small-diameter coax makes an excellent shielded loop receiving antenna, I found it difficult to locate a supplier for the small quantities required. The classic wire version of the antenna works every bit as well as the coax version and the materials are available at local hardware stores for less than $4. There are no additional costs for insulators and feed line, and no trees are needed to support the antenna!

Loop size was determined empirically. Loop capture area, required bandwidth, load impedance and a reasonable physical size were all balanced. The overall quality factor (Q) of the loop is about 140, which provides sufficient bandwidth to allow good performance with the NE602 over the entire 40 meter band.

Using a shielded loop receiving antenna provides two additional advantages. As a very simplified model, recall that a radio signal has two components: an electric field and a magnetic field. Much of the local man-made electrical noise is radiated as an electric field. The loop's wire shield prevents the electric field from reaching the loop's center conductor, which acts as the actual antenna. Therefore, local electrical noise received by the antenna is reduced. However, the shield does not block the magnetic field from reaching the center conductor, where it induces a voltage on the center conductor. This induced "terminal voltage" is proportional to the radio signal being received and is detected by U1.

Secondly, the loop antenna is quite directional, especially for nearby signals. This allows you to null a local noise source by rotating the loop. The loop's null is very sharp and deep and can give an indication as to the location of an offending noise source.

Audio output from the NE602 is connected to the AMP-04 instrumentation amplifier (U2), which serves as the audio preamplifier. This is somewhat of a departure from standard designs in which an operational amplifier or transistors are used as the audio preamplifier. I chose the instru-

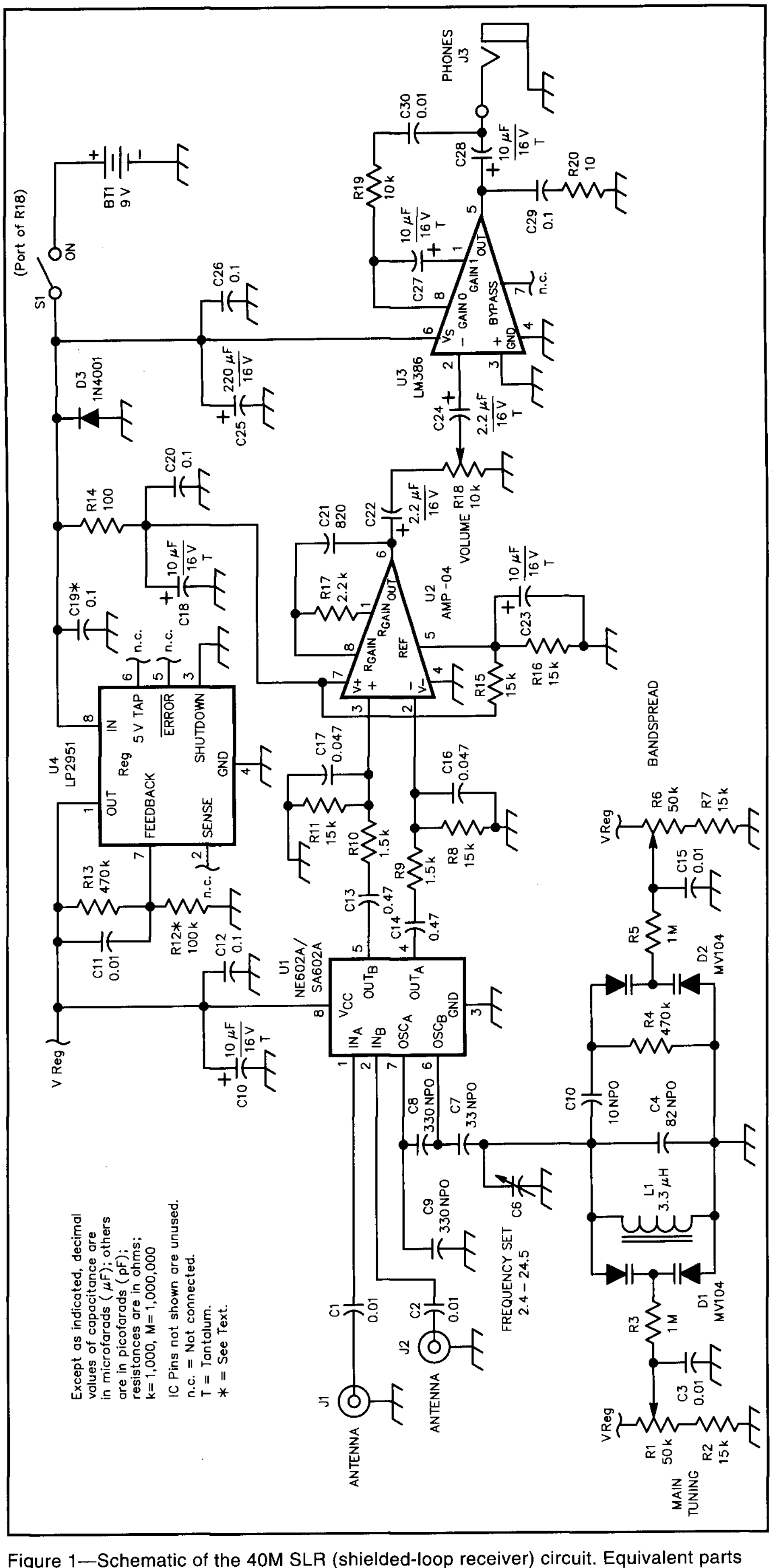


Figure 1—Schematic of the 40M SLR (shielded-loop receiver) circuit. Equivalent parts can be substituted. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units.

mentation amplifier for this application because of its extremely high common-mode rejection—typically over 80 dB[8]— and because it provides a balanced load for the balanced output of U1. This significantly reduces the AM breakthrough commonly associated with simple, single-ended NE602 receiver designs. In fact, one of the prototypes of this receiver was tested at a location only 200 feet from a 10 kW AM station. While listening to 40-meter DX, no AM breakthrough was heard at all! Although an instrumentation amplifier could be constructed from discrete components (such as op amps), for proper operation, it would require matched units and a differential power supply. Also, it is difficult to obtain the required bandwidth with a discrete design. U2 requires only a single-ended power supply and has adequate bandwidth for use as an audio preamplifier.

U1 connects to U2 via a balanced low-pass filter network. This network provides a proper RF termination for the NE602 at frequencies above approximately 3 kHz. More complex matching networks were tried, but this offered the best overall performance. C21, an 820 pF capacitor across the internal 100 kΩ feedback resistor in U2, provides additional low-pass filtering. U2's gain is set at about 33 dB by R17. Although a gain as high as 60 dB is available from the AMP-04, the bandwidth and noise figure

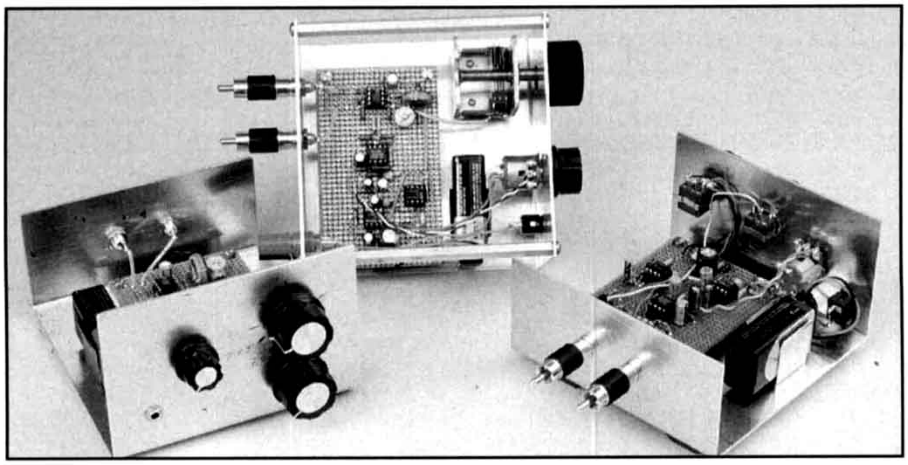


Figure 2—Three prototypes of the SLR.

Table 1
Parts List

Part Number (see Figure 1)	*Component Values* 40 m	80 m	30 m
C1, C2, C3, C11, C15, C30	0.01 μF		C3 not used; see text
C4	82 pF, 5% NPO	150 pF, 5% NPO (see text)	
C5	10 pF, 5% NPO		
C6	2.4 to 24.5 pF (Mouser 530-189-0509-5)		
C7	33 pF, 5% NPO	47 pF, 5% NPO	
C8, C9	330 pF, 5% NPO	470 pF, 5% NPO	
C12, C19, C20, C26, C29	0.1 μF		
C13, C14	0.47 μF		
C16, C17	0.047 μF		
C21	820 pF		1000 pF (0.001 μF)
C10, C18, C23, C27, C28	10 μF, 16 V tantalum		
C22, C24	2.2 μF, 16 V tantalum		
C25	220 μF, 16 V tantalum		
D1	MV104 Varicap diode		
D2	MV104 Varicap diode		Not used; see text
D3	1N4001		
J1, J2	Chassis-mount phono jack (RS 274-852)		
J3	Three-conductor phone jack, open circuit (RS 274-249)		
L1	28 turns #24 on T-50-6 (yellow) core (3.4 μH)	40 turns #28 on T-50-2 (red) core (10 μH)	23 turns #24 on T-50-6 (yellow) core (2 μH)
R1, R6	50 kΩ linear-taper potentiometer		R6 not used; see text
R18	10 kΩ audio-taper potentiometer (RS 271-215 B)		
R2, R7, R8, R11, R15, R16	15 kΩ		
R3, R5	1 MΩ		R3 not used; see text
R9, R10	1.5 kΩ		
R12	100 kΩ		
R4, R13	470 kΩ		
R14	100 Ω		
R17	2.2 kΩ		
R19	10 kΩ		
R20	10 Ω		
U1	NE602AN/SA602AN; DK		
U2	AMP04FP, precision single-supply instrumentation amplifier (Analog Devices); DK		
U3	LM386AN audio amplifier; DK		
U4	LP2951CN, 100 mA low-dropout voltage regulator (Micrel); DK		
Misc: 9 V battery and connector, enclosure, hardware			

Notes:
DK=Digi-Key. RS=Radio Shack. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Supplier addresses: Mouser Electronics, 2401 Hwy 287 N, Mansfield, TX 76062, tel 800-346-6873, 817-483-4422; fax 817-483-0931 e-mail **sales@ mouser.com**; **http://www.mouser.com**; Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677 tel 800-344-4539, 218-681-6674; fax 218-681-3380; **http://www.digikey.com**.

degrade significantly at gains above 40 dB.

If high-impedance headphones are available, the AMP-04 can drive them directly. Because Walkman headphones are common, U3, an LM386 audio amplifier, is used as a headphone power amplifier. The receiver has enough gain to drive a 3 or 4-inch-diameter loudspeaker using one 9 V battery. If extended speaker use is planned, power the receiver with an ac-operated power supply. A hiss filter (R19 and C30) reduces the infamous LM386 noise when it is used at other than minimum gain settings. Overall receiver gain is typically 96 dB. Sensitivity is such that anything that can be heard on the main station receiver (using a 330-foot-diameter loop antenna at 38 feet) can be copied on the 40M SLR.

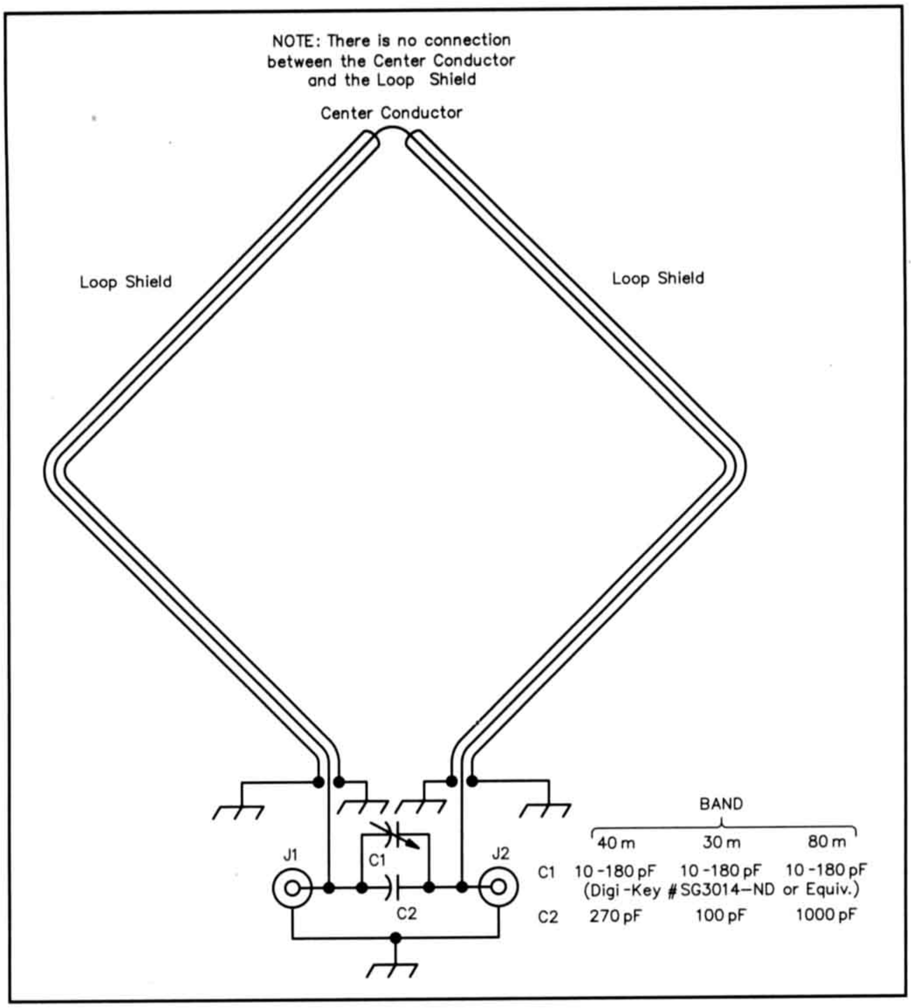


Figure 3—Diagram of the shielded-loop antenna.

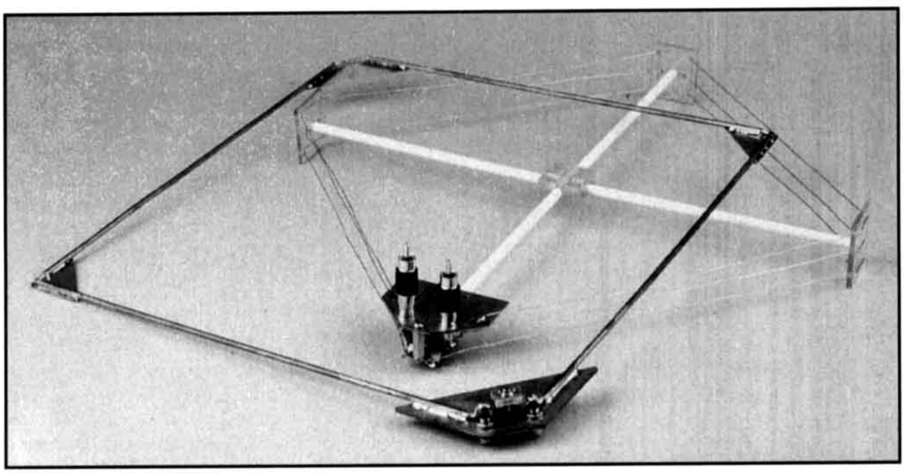


Figure 4—Different approaches to making the shielded-loop antenna. One of these uses small-diameter Hardline for the elements.

Building the 40M SLR

Table 1 lists the parts required for the 40M SLR along with component changes to modify the receiver for 80 and 30 meter operation. Although a PC board is available, the receiver can be built using "ugly" construction techniques on a piece of copper-clad board. If you're tackling this as a beginner's project, review NN1G's article;[9] it offers many good tips on building a project such as this. With the exception of the oscillator circuit at U1, and the placement of R12 and C19 at U4, layout is not critical. Use short, direct leads in the oscillator circuit. Good mechanical layout aids oscillator stability. At U4, place R12 directly at pin 7 of the device. This minimizes the noise generated by the regulator. Likewise, C27 should be located at Pin 8 of U4. Tuning potentiometers R1 and R6 are specified as 50 kΩ units, but you can use potentiometers in the range of 10 kΩ to 50 kΩ. If values other than 50 kΩ are used, you will need to recalculate the values of R2 and R7 to produce a 1.5 V minimum voltage at D1 and D2. Even though the design is fairly straightforward, don't skimp on bypassing and decoupling capacitors. The receiver has a gain of nearly 100 dB, and if not properly decoupled, it may oscillate!

The enclosure can be an open frame (used in the prototypes) or a commercial box, such as those offered by Radio Shack. You can build your own enclosure from 0.062 inch thick aluminum sheet or PC board scraps.

When building the receiver for 30 meter operation, omit R1, D1, C3 and R3. Use R6 as the **MAIN TUNING** control (with a bandwidth of only 50 kHz at 30 meters, a single turn potentiometer is adequate for tuning). Because operation on 30 meters is limited to CW only, increase the value of C21 to 1000 pF to further roll off the audio response.

On 80 meters, receiver tuning is restricted to about 130 kHz, so select a value of C4 to cover the portion of the band of interest. To cover the upper 250 kHz of 80 meters, make C4 150 pF; for the lower 250 kHz of the band, use a 180 pF capacitor. Increase C21's value to 1000 pF if CW is your primary interest.

Building the Shielded Loop Antenna

There are several ways to construct the loop antenna—I've built many versions using wood and plastic. The basic dimensions are shown in Figure 5; construction details can be seen in the title photo and Figure 4. (Also, see Note 3.)The choice of material is based more on local material availability than on electrical performance. Most hardware or building supply outlets carry an extensive selection of hardwood dowels and small dimensional stock. If you want to use plastic, many outlets sell reflective driveway markers for under $3. These markers are made of 1/4-inch diameter fiberglass rod about 48 inches long and have been used as the support arms in several loops. The wire support blocks are fabricated from unbreakable plastic material used as a glass replacement in windows and storm doors. The 40 meter version of the loop antenna covers both 40 and 30 meters with only a change in the value of C2. The values of C1 and C2 for the various bands are listed in Figure 3. Note that the overall dimensions of the loop are not too critical; variations of up to 1 inch longer or shorter will not impact performance.

Chassis-mount phono jacks are used with the loop antenna and the receiver. Gold-plated connectors are specified because they are more mechanically sound than lower-cost units. The antenna and receiver are interconnected using male-to-male phono-plug couplers. Other low-cost connectors (such as banana jacks or coaxial-style power connectors) have been used.

The connector support (D in Figure 6) is fabricated from 0.062-inch-thick, double-sided, copper-clad PC board. (A drilled and etched version of this board is provided in the kit.) C1 and C2 mount directly to this board. If you are building your own connector support, solder C1 and C2 across J1 and J2.

When the loop antenna structure is complete, add the center conductor using #20 or #22 wire (stranded or solid). Start by soldering one end of the wire to J1. Thread the wire through the innermost 1/8-inch holes (marked "Center Conductor" in Figure 6) in the wire supports. The wire need only be tight enough to keep it straight. Solder the remaining wire end to J2. Next, add the shield wires. Solder one end of the shield wire to the connector support standoff. Thread the wire through one side of the lower wire support block up to the top wire support block. At this point, it crosses over the upper wire support block and back down through the lower support block. Ensure that the shield does not touch the center conductor. Solder the free end of the shield wire to the connector support. Repeat the procedure for the other shield wire. Solder C1 and C2 directly to the center conductors of J1 and J2.

Checkout and Alignment

Before powering up the receiver for the first time, check and double-check your wiring and soldering. Although you've read this precaution in many construction articles, here it is again! Why? Because poor solder joints cause 99% of all problems. Defective components are rare! As mentioned earlier, a few prototypes have been built. In *every* case of receiver failure, a missed or cold solder joint was the problem!

Once you're satisfied everything is okay, apply power either from a 9 V battery or a bench supply delivering 8 to 13.8 V. Connect headphones or a small speaker to J3. As you advance the **VOLUME** control, the background hiss should increase. Connect the loop antenna and set the tuning controls to the low end of the tuning range (fully counterclockwise). If another receiver is available, set it for CW reception at 7.00 MHz. Adjust the **FREQUENCY SET** capacitor (C6) until the 40M SLR VFO beat note is heard in the receiver. Using the 40M SLR, locate a signal at about 7.1 MHz and peak C1 on the loop antenna for maximum signal strength. That's it for the antenna!

If you don't have a another receiver available, the receiver VFO can be ballparked by placing the tuning controls at their minimum-frequency settings and adjusting C6 until some CW signals are heard. Continue adjusting C6 until the lower end of the CW portion of the band is found. The CW portion of the band should use the lower 20 to 25% of the **MAIN TUNING** control. Set

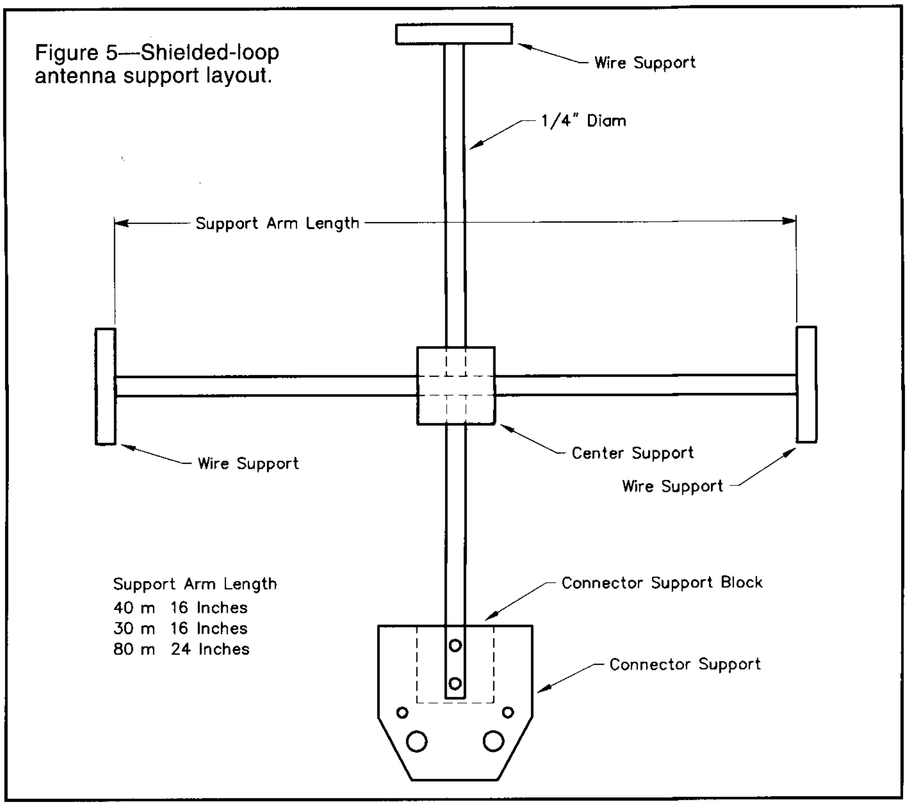


Figure 5—Shielded-loop antenna support layout.

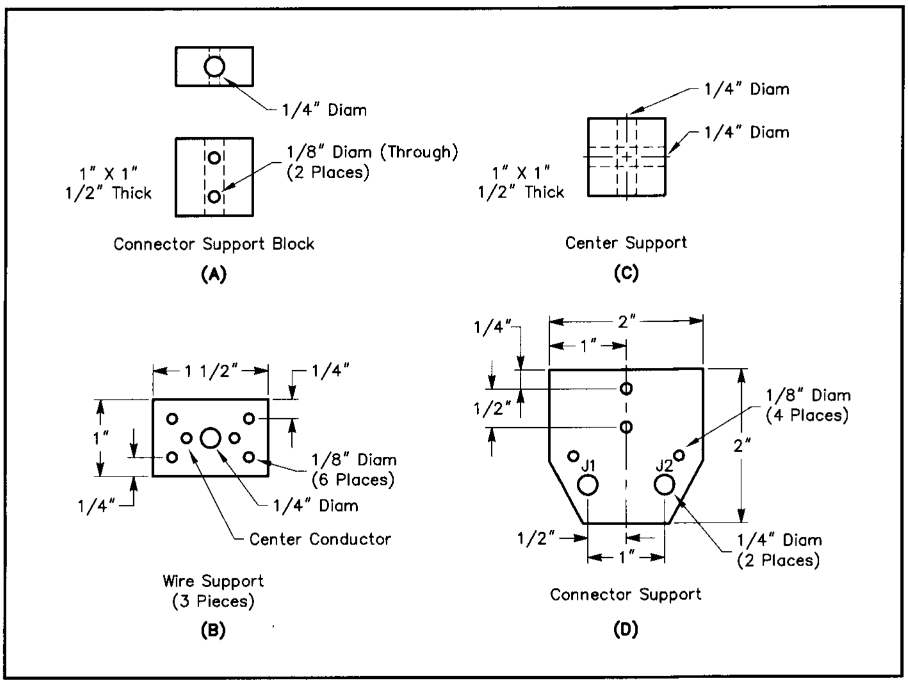


Figure 6—Shielded-loop antenna support-block dimensions. The connector support block (A) attaches to the rear of the connector support (D) by means of two screws and accepts the bottom portion of the vertical antenna mast. The center support (C) holds the inside ends of the four dowels. Wire supports (B) attach to the top and end of the support arms. See the title photo.

the **MAIN** and **FINE TUNING** controls to midrange and adjust C1 on the loop antenna for maximum signal strength. You're done!

Summary

Local hams who have had a chance to use the 40M SLR have received it enthusiastically. Bernie, N1DGO, an active homebrewer and QRPer, has tested it extensively and compared it favorably to anything he has run across in this class. Rick, K1LOG, who had not listened to a D-C receiver until trying the 40M SLR, currently has one under construction for use when he travels. A later prototype was taken to a local ham club meeting in the basement of an old school building. The attendees were amazed to copy CW and SSB signals from call areas 3, 4, 5, 8 and 9—and Cuba and Europe, too! Try one yourself!

Acknowledgments

My thanks to Rick Commo, K1LOG, and Bernie Nolan, N1DGO, for field testing the many 40M SLR prototype receivers and for their constructive criticism and encouragement on the receiver design and this article.

Notes

[1]Phillips is dropping the commercial range (0°-70° C) NE602A and replacing it with the extended temperature range part, the SA602A. The key parameters are the same.

[2]Components required are available from suppliers such as Digi-Key and Mouser.

[3]A complete kit (no enclosure), including PC board, manual, all board-mounted parts, most of the antenna parts (some odd pieces of wood, etc, needed): $95 plus $6.50 shipping and handling in the US. A drilled, silk-screened, double-sided PC board is available for $15 plus $3.50 shipping and handling in the US. Checks, money orders and most major credit cards are accepted. For domestic and foreign orders, please contact Jade Products, Inc, PO Box 368, East Hampstead, NH 03826, tel: 800-523-3776 or 603-329-6995; fax: 603-329-4499; e-mail **jadepro@jadepro.com**; **http: www .jadeprod.com/**.

[4]John Dillon, WA3RNC, "The Neophyte Receiver," *QST*, Feb 1988, pp 14-18.

[5]Doug DeMaw, W1FB, "Tuning-Diode Applications and a VVC-Tuned 40-m VFO," *QST*, Sep 1987, pp 25-29.

[6]Doug DeMaw, W1FB, "A VFO with Bandspread and Bandset," *QST*, Jan 1989, pp 31-33; see also Feedback, *QST*, Apr 1989, p 43.

[7]*The ARRL Antenna Book*, R. Dean Straw, N6BV, Editor, 18th Edition, (Newington, ARRL, 1997) pp 5-1 to 5-21.

[8]*1994 Design-In Reference Manual*, Analog Devices, One Technology Way, PO Box 9106, Norwood, MA 02062-9106.

[9]Dave Benson, NN1G, "A Single-Board Superhet QRP Transceiver for 40 or 30 Meters," *QST*, Nov 1994, pp 37-41.

Dan Wissell, N1YBT, was first licensed as WN2WGE and upgraded to Amateur Extra in 1984. His main Amateur Radio interests are designing and homebrewing QRP rigs and QRP DXing. Dan is a consultant engineer for Digital Equipment Corp where he has been employed for 17 years. He designs RF (sine wave) clock distribution systems and analog systems. Dan has five issued patents relating to RF and analog circuit design and six more patents pending. You can contact Dan at 7 Notre Dame Rd, Acton, MA 01720.

W1AW schedule

Pacific	Mtn	Cent	East	Sun	Mon	Tue	Wed	Thu	Fri	Sat
6 am	7 am	8 am	9 am					Fast Code	Slow Code	
7 am	8 am	9 am	10 am					Code Bulletin		
8 am	9 am	10 am	11 am					Teleprinter Bulletin		
9 am	10 am	11 am	noon							
10 am	11 am	noon	1 pm		Visiting Operator Time					
11 am	noon	1 pm	2 pm							
noon	1 pm	2 pm	3 pm							
1 pm	2 pm	3 pm	4 pm	Slow Code	Fast Code	Slow Code	Fast Code	Slow Code	Fast Code	Slow Code
2 pm	3 pm	4 pm	5 pm	Code Bulletin						
3 pm	4 pm	5 pm	6 pm	Teleprinter Bulletin						
4 pm	5 pm	6 pm	7 pm	Fast Code	Slow Code	Fast Code	Slow Code	Fast Code	Slow Code	Fast Code
5 pm	6 pm	7 pm	8 pm	Code Bulletin						
6 pm	7 pm	8 pm	9 pm	Teleprinter Bulletin						
6^{45} pm	7^{45} pm	8^{45} pm	9^{45} pm	Voice Bulletin						
7 pm	8 pm	9 pm	10 pm	Slow Code	Fast Code	Slow Code	Fast Code	Slow Code	Fast Code	Slow Code
8 pm	9 pm	10 pm	11 pm	Code Bulletin						
9 pm	10 pm	11 pm	Mdnte	Teleprinter Bulletin						
9^{45} pm	10^{45} pm	11^{45} pm	12^{45} am	Voice Bulletin						

W1AW's schedule is at the same local time throughout the year. The schedule according to your local time will change if your local time does not have seasonal adjustments that are made at the same time as North American time changes between standard time and daylight time. From the first Sunday in April to the last Sunday in October, UTC = Eastern Time + 4 hours. For the rest of the year, UTC = Eastern Time + 5 hours.

❑ ***Morse code transmissions:***

Frequencies are 1.818, 3.5815, 7.0475, 14.0475, 18.0975, 21.0675, 28.0675 and 147.555 MHz.

Slow Code = practice sent at 5, 7½, 10, 13 and 15 wpm.

Fast Code = practice sent at 35, 30, 25, 20, 15, 13 and 10 wpm.

Code practice text is from the pages of *QST*. The source is given at the beginning of each practice session and alternate speeds within each session. For example, "Text is from July 1992 *QST*, pages 9 and 81," indicates that the plain text is from the article on page 9 and mixed number/letter groups are from page 81.

Code bulletins are sent at 18 wpm.

W1AW qualifying runs are sent on the same frequencies as the Morse code transmissions. West Coast qualifying runs are transmitted on approximately 3.590 MHz by W6OWP, with K6YR as an alternate. At the beginning of each code practice session, the schedule for the next qualifying run is presented. Underline one minute of the highest speed you copied, certify that your copy was made without aid, and send it to ARRL for grading. Please include your name, call sign (if any) and complete mailing address. Send a 9×12-inch SASE for a certificate, or a business-size SASE for an endorsement.

❑ ***Teleprinter transmissions:***

Frequencies are 3.625, 7.095, 14.095, 18.1025, 21.095, 28.095 and 147.555 MHz.

Bulletins are sent at 45.45-baud Baudot and 100-baud AMTOR, FEC Mode B. 110-baud ASCII will be sent only as time allows.

On Tuesdays and Saturdays at 6:30 PM Eastern Time, Keplerian elements for many amateur satellites are sent on the regular teleprinter frequencies.

❑ ***Voice transmissions:***

Frequencies are 1.855, 3.99, 7.29, 14.29, 18.16, 21.39, 28.59 and 147.555 MHz.

❑ ***Miscellanea:***

On Fridays, UTC, a DX bulletin replaces the regular bulletins.

W1AW is open to visitors during normal operating hours: from 1 PM until 1 AM on Mondays, 9 AM until 1 AM Tuesday through Friday, from 1 PM to 1 AM on Saturdays, and from 3:30 PM to 1 AM on Sundays. FCC licensed amateurs may operate the station from 1 to 4 PM Monday through Saturday. Be sure to bring your current FCC amateur license or a photocopy.

In a communication emergency, monitor W1AW for special bulletins as follows: voice on the hour, teleprinter at 15 minutes past the hour, and CW on the half hour.

Headquarters and W1AW are closed on New Year's Day, President's Day, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving and the following Friday, and Christmas Day.