for instantaneous signal comparisons. The results were interesting but inconclusive. For example, a JA at S3 on the dipole became unreadable on the vertical, while just 5 kHz away a VK at S5 on the vertical literally disappeared when I switched to the dipole. And so it went, up and down the band—a 5M7 was stronger on the vertical while a YV5 was stronger on the dipole. Overall, the dipole seemed to do a little better on more signals, but it was hard to tell. In reality, anecdotal comparisons such as these prove little and make for poor science. Faraday rotation and other uncontrolled variables work constantly to skew the outcome in unpredictable ways. However, the vertical performed nicely and I made a lot of QRP-SSB contacts with it.

Conclusion

The DX-pole provides a simple demonstration of what can be accomplished by a small antenna when you apply capacitive loading techniques and pay attention to resistive losses. The hat structure makes construction a bit more complex than it might have been for a simple dipole or inductively loaded vertical. However, I think this is effort well spent because capacitively loaded antennas tend to be more efficient and exhibit greater bandwidth than their inductively loaded cousins. If you build the DX-pole carefully and install it in the clear, you'll be rewarded with a scrappy little 16-foot vertical that can take on antennas twice its size—and win!

REFERENCES

1. Rick Littlefield, "The 2-Meter Discpole Antenna," *Communications Quarterly*, Summer 1996, pages 77–81.

2. Rick Littlefield, "Build the Six-Meter Discpole Antenna," *CQ VHF*, March 1997, pages 44–50.

3. Rick Littlefield, "The Discpole Antenna," *RF Design*, publication pending.

FOOTNOTE

* NEC-based gain predictions for the discpole and DX-pole vary from 1.8 to 2.5 dBi in free space, depending upon the investigator and specific version of the program used. Range tests conducted by the author at 146 MHz using a MFJ-224 field-strength analyzer indicate no measurable advantage or disadvantage between the discpole and a half-wave reference antenna of known performance.

A Practical Reversible Beverage

Improve your DX capabilities on low frequencies with this popular antenna

Tom Rauch, W8JI

A Beverage is a longwire antenna installed very close to the Earth. To perform as a true Beverage, the antenna must be longer than 1 wavelength and installed at a height of less than 0.05 wavelength above Earth. The Beverage is usually terminated in a resistance at the end opposite the feedpoint. This termination ensures that traveling waves (as opposed to standing waves) appear on the antenna. The reduction of reflected waves from the far end of the antenna produces a unidirectional pattern.

Beverage antennas provide one of the least expensive and most reliable ways to improve DX capabilities on low frequencies. Even though their low height greatly increases losses (making them very inefficient antennas), their directivity can be used to advantage for receiving. Because of their simple construction and predictable performance, Beverage antennas have become one of the most common DX receiving antennas used on the lower amateur bands. With careful attention to design and construction, a single Beverage antenna can be made to cover two directions with excellent performance over a very wide frequency range.

Unterminated Beverages

A Beverage's front-to-back (F/B) ratio is equal to the one-way attenuation or "signal loss" (in decibels) over the length of the antenna. If the Beverage antenna had no loss or attenuation along its length, and wasn't terminated, it would provide a true bidirectional pattern.

Unterminated Beverages always exhibit some front-to-back ratio. The inherent F/B ratio in an unterminated Beverage is caused by attenuation of signals traveling the length of the antenna's conductor. The unavoidable reduction of signal along the length of the antenna is mostly due to ground-induced losses and radiation effects.

The actual attenuation (and unterminated F/B ratio) is dependent on antenna conductor size and resistance, height, length, and soil conditions below and around the antenna. Measurements of several Beverages, installed six to eight feet high over various soil types, have indicated one-way losses of approximately 6 dB per wavelength on 160 meters. Because the unterminated F/B ratio is equal to the one-way power "loss" in decibels, these antennas typically provided unterminated F/B ratios of 6 dB.

The Beverage's inherent distributed attenuation (signal loss) also limits performance improvements as the antenna is made longer. In properly terminated systems, directivity (and signal-to-noise ratio, or S/N ratio) generally stops increasing as antenna length is extended beyond one or two wavelengths.

Terminated Beverages

The use of a termination resistance greatly improves front-to-back (F/B) ratio by ensuring that all waves traveling toward the termination are absorbed. Proper termination removes or attenuates signals and noise arriving from the unnecessary "back" direction without affecting

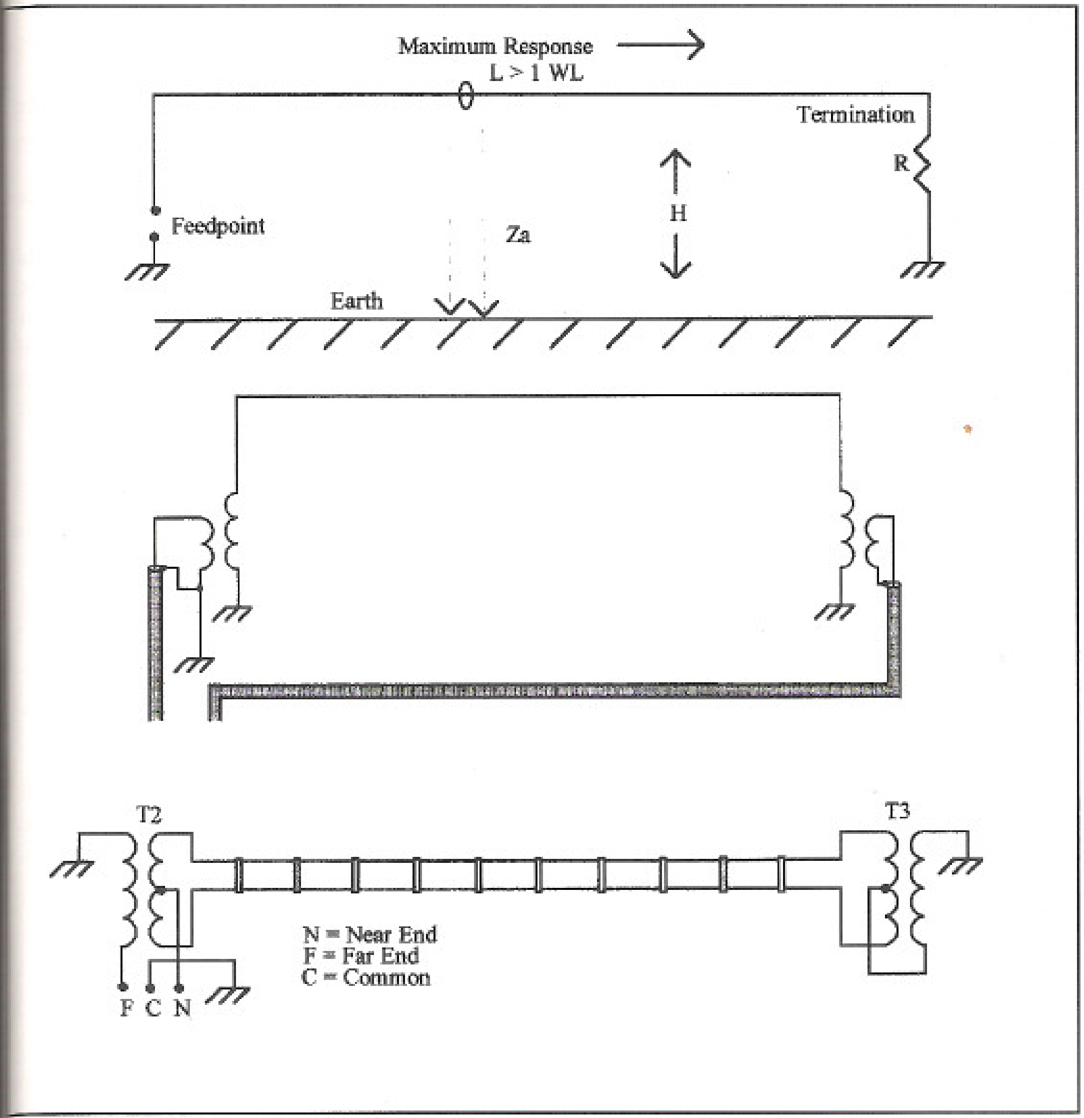

Figure 1. (A) Beverage antenna terminated at the far end. (B) Addition of a second feedline allows the Beverage to be terminated at either end. (C) The two-wire reversible Beverage.

sensitivity in the desired direction. Proper termination almost always improves signal-to-noise or signal-to-interference ratios.

The termination resistance is generally made equal to the antenna's common-mode surge impedance (Za) in **Figure 1A**. Although a perfect termination requires the compensation of reactive components in the antenna, the reactive components of Za are generally so small that they are ignored.

Figures 1A through **C** show the progression from a typical single wire unidirectional Beverage to a two-wire reversible Beverage. In **Figure 1A**, the Beverage is terminated at the far end. The termination reduces response in the direction opposite the end of termination; in other words, it reduces response in the direction of the feedpoint. Termination affects forward sensitivity very little, but can greatly improve S/N ratio if the noise is coming from the feedpoint's direction.

Reversible Beverages

Figure 1B shows the addition of a second feedline, allowing the Beverage to be terminated at either end. The transformers are designed to match the Beverage's impedance (Za) to the coaxial feedline's impedance. The direction of maximum response reverses whenever the receiver and termination resistance's feedline connections are exchanged. In a system of this type, termination resistance is made equal to the coaxial feedline's impedance. The transformers step the termination impedance up to the proper value, just as they step the receiving

Table 1. Reflection Transformers

Total Turns		
Primary	Secondary	Impedance Ratio
6	4	0.44
5	4	0.64
7	6	0.73
4	4	1.00
5	6	1.44
3	4	1.78
4	6	2.25
Zb/Za		

end's impedance down to match the cable.

Figure 1C is the next generation of the reversible antenna: the two-wire reversible Beverage. In a two-wire reversible Beverage antenna, the antenna element performs two very different functions. The two-wire antenna element not only functions as a simple longwire antenna, it also doubles as a balanced transmission line. This balanced transmission line provides the connection to the far end of the system.

A two-wire reversible Beverage requires the antenna element to operate a balanced transmission line, as well as a conventional longwire antenna. This means the parallel wire line used to construct the antenna must be excited under near-perfect balanced transmission line conditions, without disturbing normal antenna mode operation of the system. This is accomplished by exciting the two-wire transmission line making up the Beverage's element with equal 180 degree out-of-phase currents. Multi-frequency operation requires standing waves be minimized, so the impedance presented to the transmission line by the transformers must match the line's differential (transmission line) mode impedance. Any sacrifice of these parameters affects operation, and will generally result in a noticeable reduction of system performance.

The simultaneous requirement of operating the two-wire transmission line (making up the antenna's element) as a simple longwire antenna while it acts as a transmission line, means that the antenna's conductors must be excited by equal in-phase currents without disturbing transmission line (out-of-phase) currents. These separate functions are accomplished by connections made to the antenna's conductors through T2 and T3 (**Figures 1C** and **2A**). These transformers must be carefully designed to precisely isolate the two distinct antenna functions. At the same time, they must match system impedances properly and have low loss. The transformer primaries provide the transmission line (differential) mode out-of-phase connections, while the transformer secondary center taps provide the antenna mode (parallel or common mode current) in-phase connections.

The connections around T3 are of particular interest, especially the one at point "A." This is where the antenna mode connection (taken from the center tap) feeds directly into the differential or transmission line mode connection (the primary) of T3. The primary then excites the center tap of T3 with a differential mode signal, allowing the antenna's remote end to be accessed via its differential mode connection that eventually appears at point "F." Point "N" (the center tap of T2) provides the antenna mode connection at the feedpoint end of the system.

Simply grounding one wire of the balanced two-wire line at the far end won't produce correct termination, or the necessary differential mode currents for proper operation. "Self-reflecting" Beverages, or systems using poorly designed transformers, provide inferior performance when compared to systems using well-constructed reflection transformers.

Transmission line selection

The antenna mode impedance (Za) of a Beverage antenna is set by the effective conductor diameter and height. Za is typically in the range of 400 to 500 ohms. The transmission line used to construct the Beverage can easily be made any standard impedance value, but the logical impedance choice for the Beverage element is 450 ohms. A 450-ohm transmission line element allows use of simple 1:1 transformers in the system.

The advantages of prefabricated 450-ohm line are clear:

1. The line making up the Beverage element is available off the shelf from many vendors.
2. The line is easy to install, repair, or replace.
3. The line operates with a very low standing wave ratio using simple 1:1 "reflection" transformers.
4. Undesirable signal loss and unwanted signal ingress in the transmission line is minimized by the line's construction.

While 450-ohm line is readily available, it's important to use caution during the selection process. At least one line using 1-inch spaced heavy-duty #14 conductors is advertised and sold as a 450-ohm line, even though its impedance is just 370 ohms. Be sure you know the

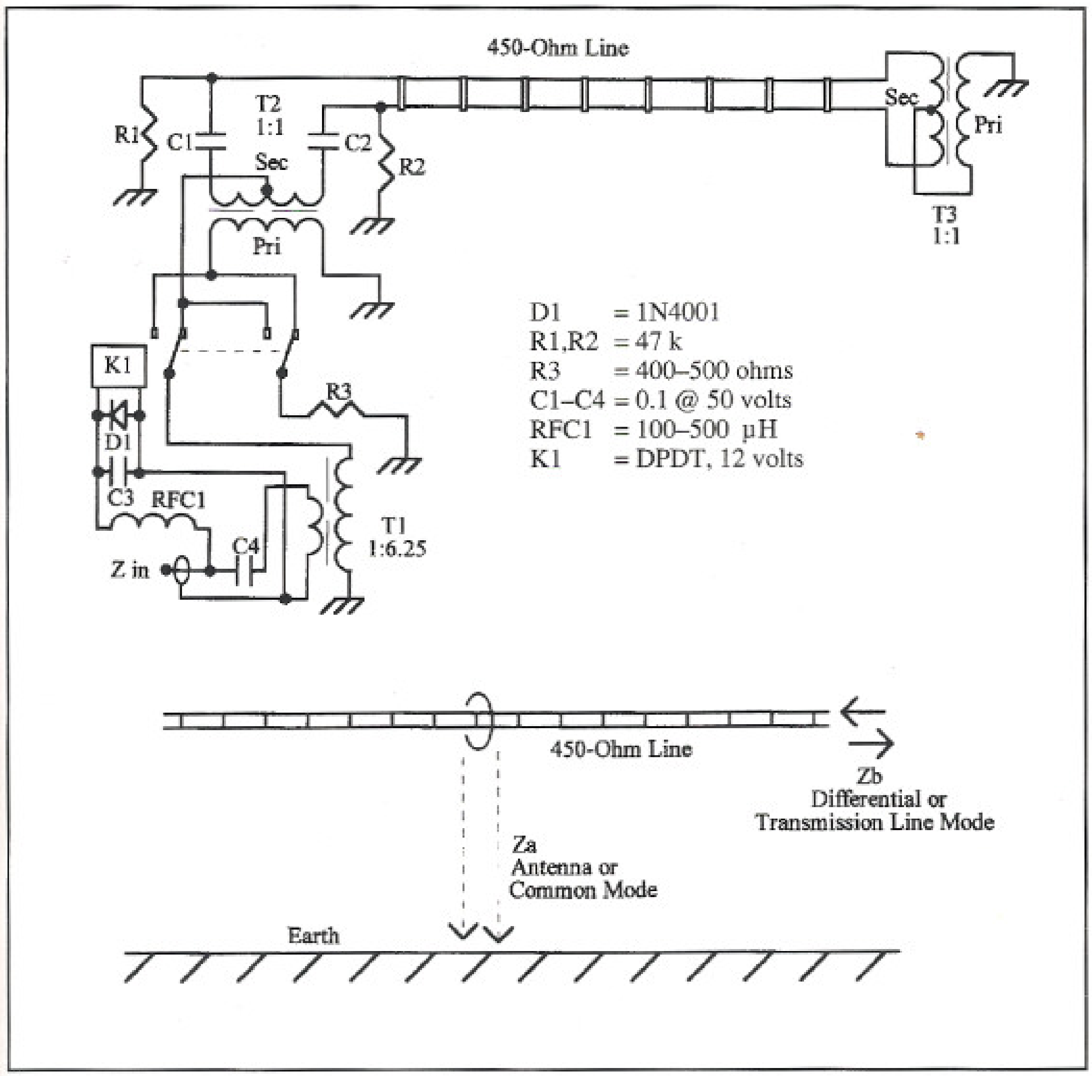

Figure 2. (A) Diagram of a typical reversible Beverage system. (B) Feedline (Zb) and Beverage common mode (Za) impedances.

real impedance of the line you select.

System construction

Figure 2A shows a diagram of a typical reversible Beverage system. Notice that the primary (receiver end) of T1 isn't connected to the Beverage antenna ground. T1 functions as an isolation and impedance matching device isolating the feedline from the antenna's ground. The floating primary ensures that equal and opposite currents excite the feedline. This confines all current to the inside of the cable. It also prevents common mode currents flowing on the feedline from being conducted into the Beverage's ground connection, reducing system noise. The feedline is grounded to a separate ground rod several feet from the Beverage's ground connection.

Proper feedline treatment reduces unintentional coupling of noise and unwanted signals into the Beverage system. If the feedline is routed near a transmitting antenna or a noisy environment, or if the receiver is located in a house with noise sources, additional decoupling of the feedline is advisable. A separate ground rod should be installed 50 to 100 feet from the Beverage, and a string of ferrite beads with a few hundred ohms of total impedance can be installed over the feedline on both sides of the ground rod. The combination of beads and a ground rod improves common mode isolation by providing both a high series impedance and low shunt impedance for common mode signals flowing on the shield.

If the ground system is nonsymmetrical, or is constructed using a few long counterpoise wires, it can actually behave like a small separate receiving antenna and diminish front-to-back ratio and noise performance. It's better to use several ground rods spaced several feet apart, rather than one ground rod or a few long radials or counterpoise wires. Because impedance Za of the Beverage is several hundred ohms, even 20 to 30 ohms of RF ground resistance is sufficiently low.

Transformer design

I prefer to use CATV-type cables, such as RG-6 or RG-59, because connectors are inexpensive and easy to install. A variety of hardware, such as ground blocks, is also available. For this reason, and because I also use 450-ohm ladder line about eight feet above ground to build my antennas, the transformers I use are designed for 75-ohm feedline with 450-ohm impedances for Za and Zb.

If you prefer to use other impedances, **Table 1** gives turns ratios for various feedline mode (Zb) and Beverage common mode (Za) impedances (**Figure 2B**). The secondary windings of T2 and T3 must have an even number of turns, allowing the center tap to be placed in the electrical center of the winding. This winding is a bifilar pair wound separately from the primary-ensuring balance and symmetry.

Three transformers are required. They are made from strings of FB73-801 or Fair-Rite 2673000801 beads. These beads are approximately 0.3-inch OD and 0.3-inch long, with a 0.1-inch center hole (window). A stack of five beads is used to make each transformer. The window is large enough to accept up to 12 passes (turns) of #26 wire.

The 75- to 450-ohm impedance matching transformer (T1) in **Figure 3A** uses two passes of #26 AWG formvar or enamel wire through the center hole of the bead stack for the primary. The secondary is five passes of #26 wire.

The "reflection" mode transformers (**Figure 3B**) use four-turn windings on both primary and secondary. The secondary winding is a loosely twisted pair making two (or in some cases three) passes through the core. The start of one wire is connected to the finish of the remaining wire, and this point provides a connection (center tap) between the second and third turns of the secondary.

When constructed in the manner described, 450-ohm transformers offer exceptional performance. Measurements of properly terminated transformers indicate an SWR error of less than 1.15: 1 from 1.5 to 10 MHz, with less than 1 dB loss. Reversible Beverage antennas require near perfect voltage balance in the reflection transformer secondary windings. These transformers have almost no measurable secondary winding voltage imbalance.

The slight impedance transformation error is primarily due to losses in the transformer's core. This inherent defect shows up as a slight amount of internal resistive loading of the transformer windings. In a practical antenna system, transformer SWR errors produce negligible performance changes from the lower AM broadcast band to perhaps 15 MHz, while offering acceptable performance mid-VLF to 30 MHz. A 500-foot long,160-meter Beverage system can be used for receiving, with some sacrifice in directivity on lower frequencies, from a few hundred kilohertz to 30 MHz.

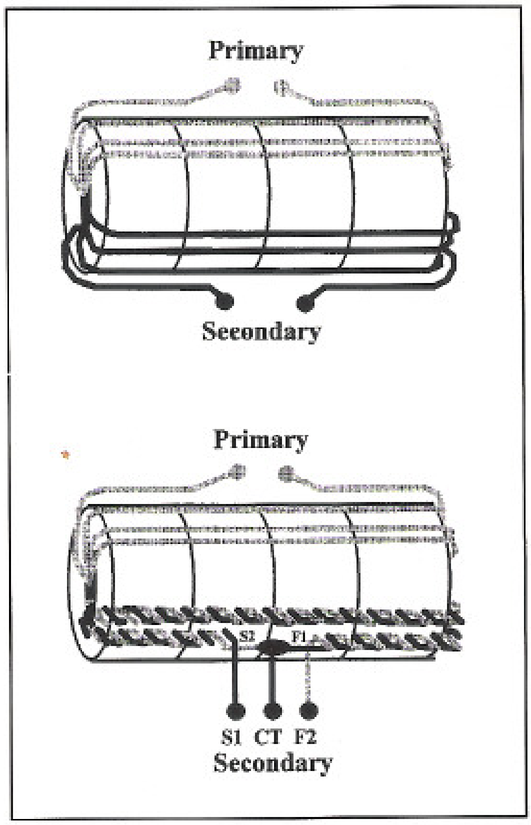

Figure 3. (A) The 75- to 450-ohm matching transformer (T1). (B) "Reflection" mode transformers use four-turn windings on both primary and secondary.

It's unnecessary, and actually undesirable, to isolate the primary and secondary windings with a Faraday shield. Stray capacitance must be minimized to ensure maximum performance and bandwidth of this system. Unnecessary conductors and dielectrics placed between the primary and secondary windings only serve to increase undesired winding-to-ground capacitances. Measurements have confirmed a Faraday shield actually increases common mode coupling and voltage imbalance.

Switching and control

In the design example shown in **Figure 2A**, a 12-volt sealed DIP relay is used to switch the termination resistor and feedpoint connections. The relay is activated by imposing a DC control voltage on the feedline. Capacitors isolate the line from the transformers, allowing measurement of system resistance from the feedpoint or far end of the antenna. A simple DC ohmmeter is used to verify the integrity of the antenna conductors.

Operation

The system can be adjusted with a SWR analyzer, receiver, or small transmitter and clamp-on RF milliammeter. The termination resistors are adjusted for minimum SWR change with frequency, maximum null depth, or smoothly tapering common mode current in the antenna.

If the clamp-on meter is used, remember that ground and radiation losses will result in almost 50 percent reduction of current over a distance of 1 wavelength. The goal is to eliminate peaks and dips caused by standing waves. Don't attempt to achieve uniform current at both ends of the antenna.

A properly installed and adjusted system will provide a typical front-to-back ratio of 15 to 25 dB over a frequency range of 3:1 or greater. I've used 450-ohm systems at locations ranging from wet, black, sandy loam with high conductivity to poor, rocky clay. In all cases, these systems offer exceptional performance. ■

TECHNICAL CONVERSATIONS

(from page 4)

A late catch

Dear Editor:

One of my corrections did not make it [into my article "Modern Receiver Design," *Communications Quarterly*, Winter 1997, page 22]. The capacitor C28 of 1 nF should go to ground, but should not be in series with the 221-k resistor.

Also, on page 28, there was an error on one of the equations. The equation:

F = 10 (970) 30 dB

should read as follows:

F = 10 log (970) 30 dB

Sorry for the late catch.

Ulrich L. Rohde, DJ2LR, KA2WEU, HB9AWE
Upper Saddle River, New Jersey

Notes from W0IYH

Dear Editor:

Here is an item that I put on the Internet and that you might consider for the next *Communications Quarterly* issue. This note refers to my article on a logarithmic speech processor in the Winter 1997 issue of the *Communications Quarterly*.

In order to use a low-impedance dynamic microphone, with a lower level of audio volts than a high-impedance mic, two circuit changes can be made. I tested these changes using a RadioShack 33-3005 mic and also a 33-984 (dual hi/low Z) mic.

In the microphone amplifier circuit, solder a 1-k resistor across R4. This increases the gain of the mic amplifier. Solder a 0.1-µF capacitor across C3. This preserves the frequency response of this stage. Connect a 680-ohm resistor at the mic jack, across the audio line. This terminates the microphone properly.

It is also possible to install a low-Z to hi-Z miniature transformer instead of the R and C changes. The hi-Z side should have a 12-k resistor load. I tested this also. These transformers are available from various sources. RadioShack has the 274-016 adapter that does the same job.

Other microphones may require somewhat different values of R4 for the correct amount of speech processing.

There is a problem concerning the parts list for my speech processor. The AD633JN is the preferred, as shown in the schematic of **Figure 10**. The correction that I made to the parts list was not incorporated in the article. One reader had a question about that.

The AD633JN multiplier chip is available from Newark Electronics. They have a large quantity in stock for $6.50 in small quantities. They also have a $25 minimum order requirement that can be filled with other parts for the processor. Call 800-463-9275 for the phone number of the nearest Newark office.

Bill Sabin, W0IYH
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