

Six Antennas from Three Wires

*With these modified Beverage antennas,
you double your directions without doubling your cost.*

"Oh my, he's weak. Egads, what static. Oh well, let's turn the beam and see where he peaks up."

Sounds like a natural enough sequence, doesn't it? Well, at K1VR, we can do just that on 160 (and 80, and 40...) meters, and no antenna is higher than 15 feet. In fact, there is no "beam." Instead, we use three Beverage antennas, each reversible. Not bi-directional... reversible. This article will show you how we do it.

An Old Antenna

First described in a 1922 article by H. H. Beverage,¹ the Beverage is a receiving antenna described by one friend as an antenna that works poorly in general, but less poorly in one direction. Its principal advantages are:

- It increases your received signal-to-noise ratio (reduces QRN) for low-angle signals (i.e., DX!).
- It has a narrower beamwidth than typical 80-meter antennas. Belrose VE2CV

has described the azimuthal beamwidth as 77 degrees.²

● It is much less susceptible to precipitation static, so that a snowstorm in February is less likely to shut down low-frequency operations.

● It is capable of excellent front-to-side performance to reject all that static coming from around the equator.

● It reduces the need for inserting attenuation to protect the solid-state front end of your receiver or transceiver.

● If you live in the Northeast, it will quiet down all that QRM generated by those very loud W3, W4, and W8 stations who insist that they have a right to the band, too. It is not unusual to see 20-25 dB front-to-back.

A Beverage is a single-wire antenna used in receiving only. It is end-fed, 1/2 to

4 wavelengths long, strung horizontally from 6 to 15 feet above ground. Many Beverages are fed at one end, left open-circuited at the other, far end, and are bi-directional in line with the wire (see Fig. 1). Adding a terminating resistor to the far end, as in Fig. 2, makes the Beverage unidirectional, but you can't switch directions. Some Beverage users use a dc relay and switch the terminating resistor in and out, but this still does not provide unidirectional performance in each direction.^{4,5,6,7}

However, if you go one step further—feed both ends of a Beverage, select either feedline and terminate the other—you can indeed have two directions from a single wire. This is what we have done, not with just one wire, but three, for six directions!

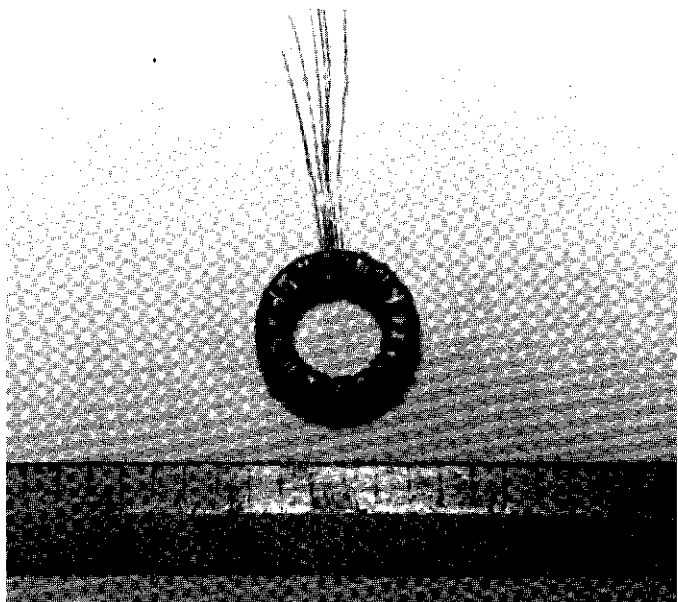


Photo A. View of toroidal matching transformer, showing method of winding.

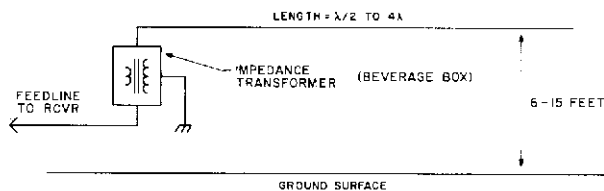


Fig. 1. A basic Beverage antenna. The directivity pattern is bi-directional along the axis of the horizontal wire. The Beverage Box contains a transformer which matches the impedance of the antenna to the impedance of the feedline.

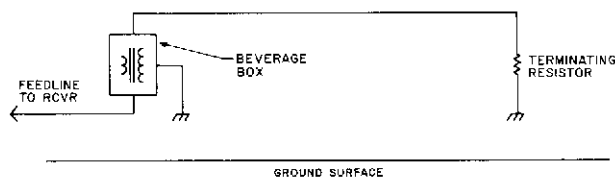


Fig. 2. A terminated Beverage is unidirectional toward the terminated end of the antenna. The resistor is a noninductive type, and experience suggests a value between 300 and 800 Ohms.

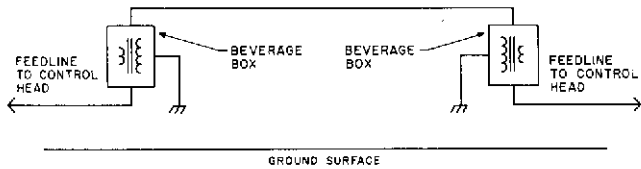


Fig. 3. The directivity pattern of the K1VR/N1RC Beverage is reversible. A control head at the operating position selects one of the two feedlines and routes it to the receiver while terminating the second feedline with a resistance. The antenna is directional toward the end with the terminated feedline. By using three such antennas and a rotary switch, six different directions can be selected.

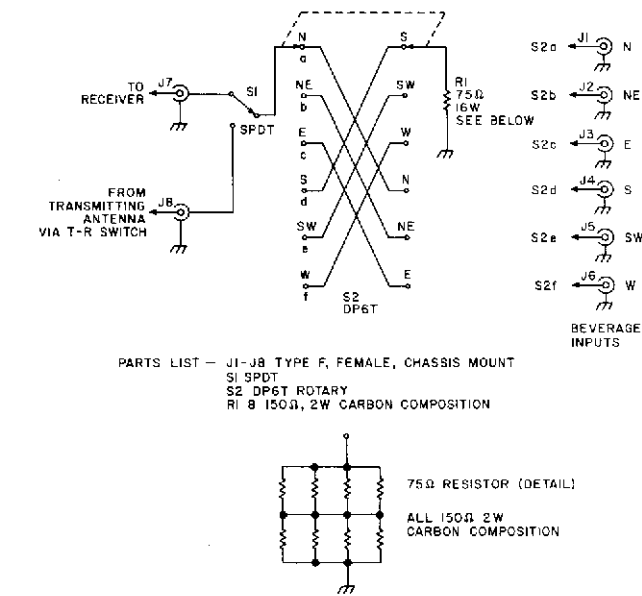


Fig. 4. Control-head schematic diagram.

A New Construction

The form of construction described in this article is desirable because few of us live on a piece of land large enough to stretch out a Beverage in each desired direction. But if you can have one wire, you can have two directions!

The system has the following components: a control head in the shack, three Beverages, six feedlines, and six "Beverage Boxes."

The control head has two switches: A Beverages/transmit antenna switch (to select the transmit antenna to listen on, if desired), and a rotary switch for selecting a favored direction.

Outdoors, we used three Beverages, which we strung between trees, but more or fewer can be used. Each end of each Beverage wire is connected through a Beverage Box to one of the feedlines. See Fig. 3. All feedlines end in the shack at the control head. Our Beverages range from 220 to 325 feet long, limited by the size of K1VR's yard.

It sounds simple because it is simple. Results: improved signal-to-noise, front-

to-back, and front-to-side operation when compared with dipoles and delta loops. And you thought you couldn't rotate an 80-meter antenna!

The Control Head

In the original control head, the transmitting antenna was assigned position number 1 on the rotary switch. With a little experience, however, we soon learned that comparing reception on the Beverage to reception on the transmitting antenna was much easier with a separate toggle switch. In addition, the rotary switch had a nice even number of positions, with no empty space opposite the transmitting antenna.

The double-pole, six-throw (DP6T) rotary switch we used was the type that lets you select the number of positions desired by successively removing stops. We "crosswired" the switch as shown in Fig. 4, so that when one feedline is selected, the feedline coming from the opposite end of the same Beverage is connected to the 75-Ohm terminating resistor. Thus, if we select, say, the northeast end of Beverage A, then the south-

west end of Beverage A is terminated.

Pay close attention to the wiring and labelling, or you will surely have to rewire several times, as we did, to make the switch go nicely around the compass, terminating the other end of the direction selected.

In locating the control head at the operating position, remember that while you may change bands only two or three times per hour at most, you will change directions for receiving repeatedly. So choose a location near the transceiver dial or antenna rotator, to be used by the hand you do not write with. The control head should also be plainly visible, so that you won't strain to hear someone only because you've forgotten to "point" the right antenna at him (or her!).

We used F connectors because they are cheap, readily available, take up much less back panel space than UHF connectors, and are much, much easier to install (a single 5/8" hole)! BNC connectors would also be appropriate. But note it is a good idea not to use a connector which may also be used in a transmitting application in your shack. Remember, Beverage antennas are for receiving only!

Finally, as we got around to attaching feedlines, it became apparent that as soon as they were identified, it was important to label them with Brady markers, tie-wrap tabs, or even masking tape to indicate direction. Without marking, eight identical RG-59 ends with F connectors quickly became confusing.

The jumper connecting the control head to the transceiver at K1VR was RG-59 with an F connector on one end and an RCA phono plug on the other. This was due to the need for RCA plugs in the Kenwood TS-520, 820, 830 series. Note that a small modification may be necessary to your transceiver to permit operation with a separate receiving antenna while maintaining the flexibility of switching back to the transmit antenna for receiving, if desired.

Feedline

Of course, the magic in the design of these antennas is that the feedlines are so inexpensive. With the advent of cable TV, so-called "drop cable" has become widely available at very attractive prices. This is the cable which is run from the telephone pole on the street to the home.

Drop cable comes in two sizes: RG-59 and RG-6. At 5 MHz, RG-59 has an attenuation of approximately .55 dB/100 feet; RG-6, which is more expensive, is approximately .45 dB/100 feet (source: Belden catalog). Therefore, since loss is inconsequential (the more feedline loss, the less attenuation you will have to insert to prevent front-end overload), choose the line on which you get the best deal. However, other considerations may contribute to your decision.

If you live near a strong local station or intend to operate in the multi-operator/multi-transmitter category in various contests, you may wish to consider the question of shielding. RG-59 is commonly available in 40% braid/100% foil or 60% braid/100% foil. The more ingress of signal that you expect, the more you should consider using 60% braid or even 95% braid. *In extremis*, these cables are also available with double shielding and double foil. Double-braided RG-6 is the cable of choice for direct burial installations.

In any ham station, the question of splicing wire often arises. A few words of advice are appropriate. If you have to put a cable in conduit to get out of your house and into the backyard, *never* put a splice inside the conduit. If you must splice outdoors, splicing and then putting the splice underground is bad business, as it is just too susceptible to water getting into the coax. Since this is a foam coax, the water will migrate without mercy. The coax is cheap; if you value your time at all, use unbroken runs of coax in conduit and underground!

Finally, when working with cable-TV coax, remember that the braid is generally going to be made of aluminum and will not solder. This dictates that all con-

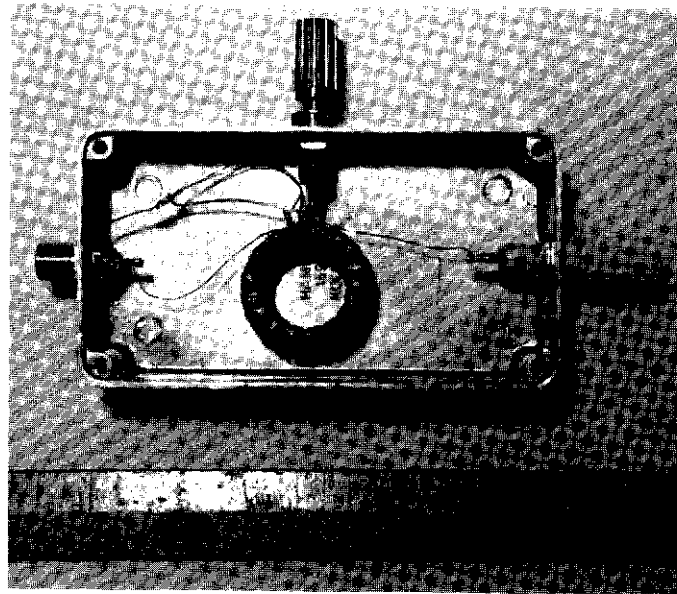


Photo B. Inside view of a Beverage Box.

nectors must be either crimp-on BNC or crimp-on F. As for the crimping, it may be awkward, but be sure to borrow or buy the correct crimping tool. Merely using a pair of pliers will not do the kind of rf-tight crimp which will last.

Beverage Boxes (The Terminations)

The Beverage Box is the interface between one end of a Beverage antenna and its 75-Ohm transmission line. It should have minimum insertion loss, operate efficiently over a wide frequency range, and be weatherproof.

As a starting point, we knew that, according to the literature, Beverage impedances could range from 400 to 800 Ohms or so, but that we could reasonably expect an impedance in the 500-600-Ohm range.^{10,11} Furthermore, we decided that rather than design a multiple-impedance matching transformer, a single 600-Ohm-to-75-Ohm design would be used. The thought of many treks into the woods to adjust taps aided in this decision!

The actual construction of the box was divided into smaller units of decision-making.

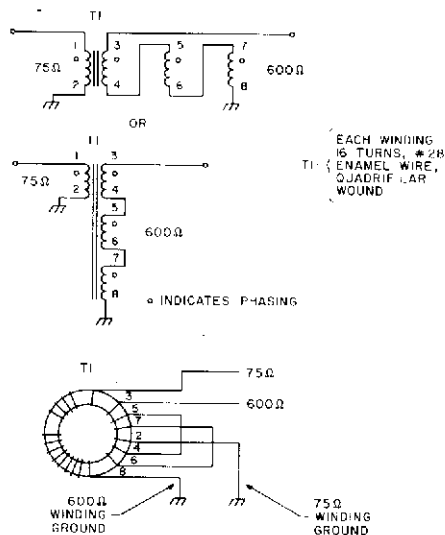


Fig. 5. Transformer winding details.

Connectors

F connectors were selected for the very same reasons we used them in the control head.

Also, watertight boots which go over F connectors are readily available. Filling them with silicone grease (not caulk) before tightening will make a very good setup. Remember to put the boot on before putting on the F connector. The authors have forgotten this rule more than once.

Binding Posts

We selected commonly-available posts and have very little to contribute to the discussion. However, it is a good idea to get the type with a hole through the post to ensure a good contact even after oxidation has begun. Also, note that some binding posts (the cheapest type) are not feedthrough types. That is, they are not insulated from the surface in which they are mounted. These should be avoided.

The Transformer

The transformer design meets the following criteria:

Impedance Ratio (Ohms)	600:75 (8:1)
Bandwidth	1.0 to 30 MHz
Insertion Loss	Negligible

The transformer was quadrifilar wound (Fig. 5), one winding serving as the 75-Ohm secondary, the other windings connected in series as the 600-Ohm primary. All windings were 16 turns, #28 enamel wire, close-wound (Photo A), on an Indiana General 626-12-Q1 core (available from Permagon Northeast Corp., 10 Fortune Drive, Billerica MA 01865; (617)-273-2890). Each winding had a self-impedance of 375 Ohms (5×75). The core of the transformer had a .75" inner diameter, a 1.25" outer diameter, and a .375" width.

Note that the late Jim Lawson W2PV found that in the presence of very high rf levels—a local AM radio

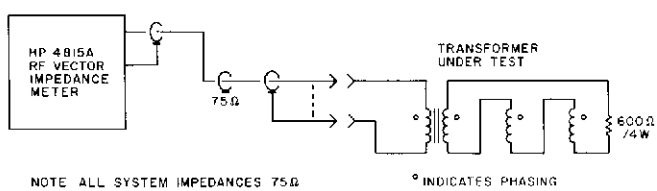


Fig. 6. Impedance-measurement test setup.

F(MHz)	Z (Ohms)	θ°
1.8	70	+6
2.0	70	+6
3.5	70	0
4.0	71	0
7.0	68	+2
7.3	67	+2
14.0	56	-2
14.35	54	-4
21.0	42	+8
21.5	42	+9
28.0	38	+30
28.5	37	+37

Table 1. Transformer vector-impedance measurements.

station—the toroid core saturated. He used L/C networks for transformers instead of toroids at his location.

Both a network analyzer and an rf-vector impedance meter (75-Ohm impedance) were used to verify transformer performances. Test setups are shown in Figs. 6 and 7; measurements are listed in Tables 1 and 2. Measurements made using the network analyzer are return loss as measured in decibels. "Return loss is the relation between the power returning down the line from a mismatched load to the power incident to that load." (Stephen F. Adam, "Microwave Theory and Applications," Prentice Hall, 1969.) It is related to vswr by the formula: $R1 = -20 \log_{10}(vswr - 1/vswr + 1)$. Equivalent vswr's are included in Table 2.

All measurements were made with the transformer terminated in a 600-Ohm load consisting of two 1200-Ohm, quarter-Watt, carbon composition resistors in parallel.

N1RC also tried a measurement setup which the average ham can do at home to get a rough indication of Beverage perfor-

mance. Although the transformer is designed for a 600-Ohm-to-75-Ohm impedance transformation (an 8:1 ratio), it can also be used for 400-Ohm-to-50-Ohm applications. Bob made a 400-Ohm dummy load of 8-50-Ohm, 10-Watt wirewound resistors and connected it to the 600-Ohm side of the transformer. After connecting the 75-Ohm side to the "Antenna" connector of a vswr bridge and applying enough power to get a full-scale deflection, he measured the vswr (quickly!) on 160, 80, and 40 meters. It was 1.5, 2, and 3, respectively, and into a reactive load.

Winding Tips

Leave about three inches of wire free on each end of each winding. Tin each end for about 1/4"; remove the enamel by burning it off with a hot soldering iron. Wipe the tip of the iron frequently on a wet sponge to clean it. When all eight ends are tinned, identify each winding using a continuity tester or VOM. Separate out one winding as the 75-Ohm winding. Carefully solder the other three windings in series, removing excess wire (you don't need six inches), and re-tin ends before connecting the two end windings to the center windings. Pay careful attention to polarity (phasing).

Box Assembly

Each transformer is mounted in the Beverage Box on a platform built up of clear uncured RTV. When this cures, the toroid will be held securely in place. The ground ends of the windings are connected together to the ground binding post and a chassis ground. The 75-Ohm and 600-Ohm windings

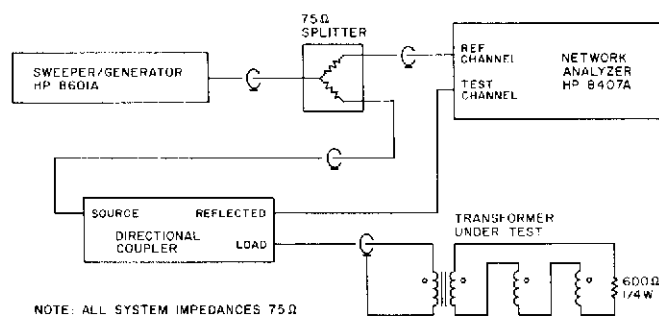


Fig. 7. Transformer return-loss test setup.

are connected to the F connector and input binding post, respectively. See Photo B. Be careful not to reverse these connections as we did, in one box. If you need to identify windings, disconnect the ground ends from ground and from each other. The 600-Ohm winding will then show continuity from the "hot" end to the connections between its center winding and outer windings.

Another consideration is the location of the 600-Ohm binding post, the 75-Ohm binding post, and the F connector. We placed the 600-Ohm binding post and the F connector on opposite ends of the long axis of the Beverage Box with the ground binding post placed on the side. In this way, the box could be "hung" from a Beverage. The F connector and 75-Ohm feedline hang vertically from the bottom of the box with no right angle bends in the cable and a natural drip path for the water off the box.

The Box

We chose an aluminum Hammond 1590 B box (109 x 58 x 25 mm), equivalent to Bud box number CU 124, because it was reasonably priced—in the \$6.00 area—and had an inner lip which protects the circuitry from the weather. All seams in the box and connectors were coated with clear nail polish to form an inexpensive and watertight seal. Photo C shows a completed box.

Grounding

This is a subject all its

F(MHz)	Return Loss (dB)	Vswr
1	20	1.22
2	30	1.06
2.7*	45	1.01
3	35	1.04
4	30	1.06
5	28	1.08
6	25	1.12
7	22	1.17
8	20	1.22
9	19	1.25
10	18	1.28
11	17	1.34
12	16	1.38
13	16	1.38
14	16	1.38
15-30	> 10	< 1.9

*Resonance in transformer produced (out of ham band) measurement anomaly.

Table 2. Transformer return-loss measurements.

own. But it is probably worth a few words here. The Beverage antenna will be erected only 8-15 feet off the ground. Therefore, it is unlikely to receive a direct hit from lightning.

To a certain extent, the feedlines to the Beverage Boxes act as counterpoises, since the most convenient route from the shack to the Beverage Boxes furthest from the shack was almost always along the ground beneath the Beverages. All feedline braids were grounded at each end. However, this counterpoise effect caused by the feedlines is not a designed-in part of the Beverage system and cannot be depended upon to either improve or degrade system performance. It just must be accepted as one result of this design.

In the installation of this antenna, several four-foot cable-TV ground rods were

used. In addition, several six- and eight-foot ground rods were used. Six-foot-by-3/8-inch or eight-foot-by-5/8-inch ground rods seem to be the grounding system of choice. But the best strategy seems to be this: Erect something, and if you are unsatisfied with performance, go out and add more ground rods a few feet away or add radials to the existing ground rod.

Incidentally, since no #6 copper ground wire was available, we simply used two strands of #12 (approximately equivalent to one #9 wire) to ground the termination boxes.

Place the ground rod a few feet away from the tree and you will have a better chance of avoiding thick roots when you drive the rod(s) into the ground.

Note that a six-direction Beverage system uses seven ground rods; the last one is for ground back at the shack. But you have already installed a good ground for your station, haven't you?

Wire and Height

Beverages will work best, it seems, at heights from 6 to 15 feet. Above that, they begin to look like conventional longwires. We caution you to put the wire up at least 10 feet, however, because one Massachusetts ham is now the defendant in a lawsuit resulting from a trespasser on horseback who was toppled from her horse when she hit the Beverage wire.

At K1VR, due to constraints imposed by lot size, the Beverages were only between 220 and 325 feet long. Widely-circulated folklore suggests that two wavelengths, or 450 feet at 80 meters, is optimum. There is some experience, at W4BVV and W1ZA, to suggest that 1000-1200 feet is too long at 80 meters.

Almost any wire will do, but we recommend stranded and insulated, approximately #16 or #18 AWG. Fi-

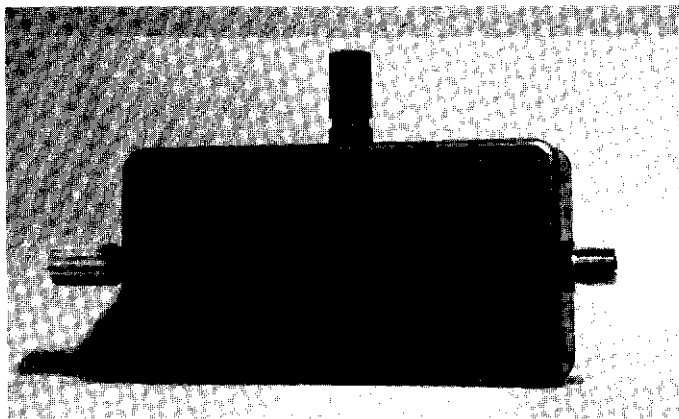


Photo C. Assembled and sealed Beverage Box. The system of three reversible Beverages at K1VR required six of these boxes.

nally, if you want the wire to be seen, because you cross an open field perhaps, make it white or yellow. On the other hand, if you live in a more suburban area and wish to hide it a bit, choose green, brown, or black insulation.

The best mounting method yet discovered is to use standard electric fence wire standoff insulators made of plastic. They can be hammered into a tree in seconds.

Remember, when installing your wire, to keep it as far away as possible from towers and other metallic structures which may have the undesired effect of capacitive coupling. In the case where a 300-foot wire is supported in the middle by your tower, it is more likely to behave as if it were a 150-foot wire.

We chose stranded wire because, over such long runs, supported by trees, a solid wire would be flexed frequently, leading to stretching and breakage.

Conclusions

We set out to make a unidirectional receiving antenna for the low bands which would be very good for DX and reject signals from the side and back. For a modest amount of work, on a lot of modest size, we attained that goal.

Once we had the antennas up and working, we did notice something about

their operation that deserved a bit of attention. Occasionally a signal seemed to peak on the wrong antenna. There are two reasons that this can occur. For one, a particular Beverage may not so much favor one direction as it nulls the interference coming from another. This gives the appearance of peaking a signal on the wrong antenna. In trying conditions, this means that some judicious switching is worthwhile. For another, Beverages are essentially low-angle antennas. As a result, a close (0-300 miles) station may actually be louder on the high-angle side lobe of a completely different direction Beverage than on the Beverage favoring that direction. At K1VR, this means that K2s often peak north or northeast. Locals, it seems, can peak almost anywhere.

Having established that we had a working antenna system and knowing full well that nothing good ever lasts, we decided to make records of baseline resistance measurements at the control head. There is variation due to feedline lengths, and maybe even grounding, but by measuring between the center conductor and ground at the output of the control head (removing the jumper that goes to the receiver), lines measured between 6 and 40 Ohms.

It is really neat to peak up

the weak ones and reject the strong ones by changing directions so easily. If you've long bemoaned the noise and crud on 40, 80, and 160, try a Beverage and double your fun by feeding both ends!

Acknowledgments

Thanks to W1CF who erected the prototype version on Martha's Vineyard. And thanks to W1FC who took the first cut at designing the transformer. Both men work at M/A-COM, where we used some lab instruments for testing. Thanks also to N1BC for some helpful hints. K1VR thanks his company, Channel One, for offering a good deal on some RG-59 left over from satellite cable-TV installations.

We would be happy to respond to any inquiries accompanied by an SASE. ■

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3. John Devoldere ON4UN, *80 Meter DXing*, pages 2-28-2-32, Communications Technology, Inc., Greenville NH. This work contains a discussion of Beverage antennas and an example of a relay-switched terminating system.
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5. Belrose, *op. cit.*
6. Victor Misesk W1WCR, *The Beverage Handbook*, 1977, Misesk, Hudson NH.
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8. Misesk, *op. cit.*, page 6.
9. Belrose, "Technical Correspondence," *supra*.