A Cool Beverage Four-Pack

Beverages are highly touted as receiving antennas — learn how they work, what they offer the DXer, and how to double their benefit by creating a switchable Beverage array.

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Next to a rhombic, the Beverage has the greatest associated antenna mythology. While they're definitely longer and lower than your average skyhook, it doesn't require black magic to understand them or reap their benefit. This variation of a Beverage allows you to receive in two directions, while still using a single feed line. With some simple switching, you can make your own low-band receiving beam, a DXer's dream come true!

In 1921, Harold Beverage, W2BML, developed the antenna that bears his name to receive distant low frequency signals. Then, as now, operators had difficulty hearing the signals through the atmospheric static that gets stronger as frequency drops. Counterintuitively, the Beverage needs to be close to the ground, instead of high in the air, and is best over earth with a medium to poor conductivity. The trade-off is length — Beverages need to be at least ¾ λ long to provide useful performance. DXers active on 160 and 80 meters are big fans of the Beverage, which is widely covered in the amateur literature.[1, 2]

How Does the Beverage Work?

The first key idea behind the antenna is *wavefront tilt*. As the radio wave arrives from the ionosphere, the incoming wavefront is tilted, both from its angle of ionospheric reflection and because the velocity of propagation is slightly less at the ground than in air. The greater the angle at which the signal is reflected in the ionosphere and the poorer the ground, the greater the tilt. At amateur frequencies (MF and HF), the primary source of wavefront tilt is the reflection angle of skywave signals. Ground effects dominate at lower frequencies.

Why is tilt important? If a wavefront arrives with a perfectly vertical electric field, the electric field is perpendicular to the antenna and no current results. (Electrons only move in a conductor if an electric field is applied along the conductor.) When the electric field is tilted, however slightly, it becomes partially parallel to the antenna, as shown in Figure 1. This causes a current to flow, creating a voltage wave along the antenna. The vertical portion or *component* causes no current to flow along the wire, but the horizontal component does.

Figure 1 shows a *vertically polarized* signal, but what about horizontally polarized signals? A horizontally polarized electric field is parallel to the earth and attenuated by losses in the ground. Furthermore, if arriving along the axis of the antenna, the electric field is perpendicular to the antenna and cannot cause current to flow in it. That means the Beverage antenna is most sensitive to vertically polarized signals arriving along its axis. (Regardless of a signal's original polarization, ionospheric reflection causes a random rotation so that the arriving signal is usually a mix of vertical and horizontal polarization.)

What about signals arriving broadside to the antenna, such as noise or local interference? In this case, the vertically polarized signals have electric fields perpendicular to the antenna and can't create voltage waves. But the electric fields of horizontally polarized signals from these directions are parallel to the antenna. Why don't they result in a strong received signal?

The answer lies in a second key concept, which takes into account the time it takes for the induced voltage waves to move along the antenna. As a wavefront travels along the antenna, its phase changes along with that of the induced voltage. The result is a steadily

[1]Notes appear on page 36.

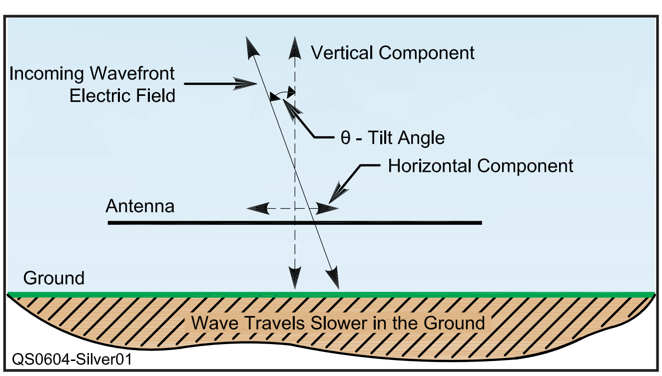


Figure 1 — Incoming wave fronts of signals tilt at ground level because they travel slower at ground level than in air.

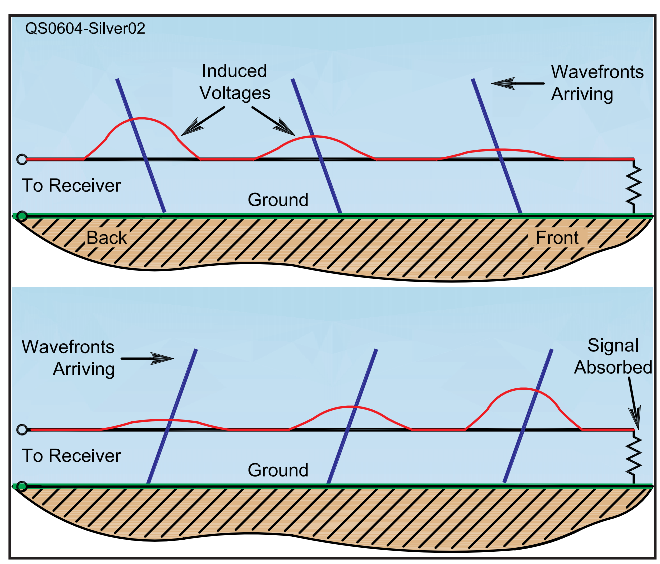


Figure 2 — Voltage waves build up along the antenna and are either transferred to a feed line or absorbed by a terminating resistance.

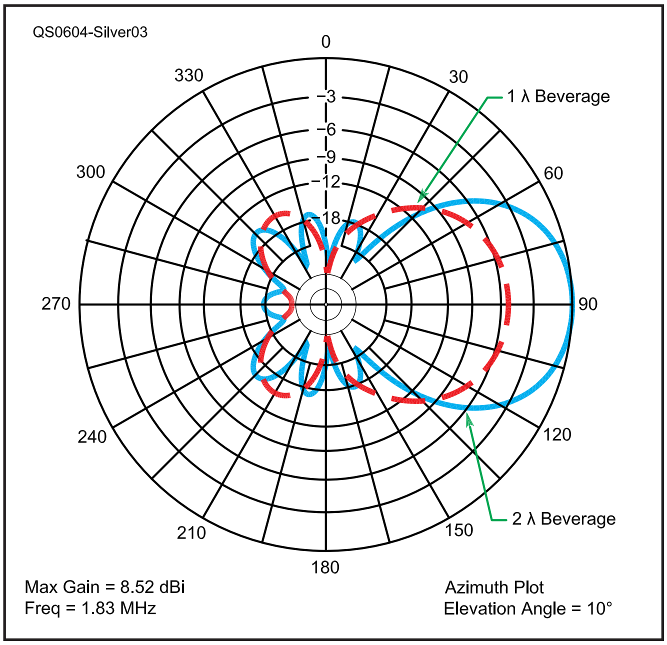


Figure 3 — The radiation patterns for 1 λ and 2 λ Beverage antennas show a broad forward lobe and good rejection of signals from the sides and back (From *The ARRL Antenna Book*, 20th Edition, Figure 35A, p 13-19.)

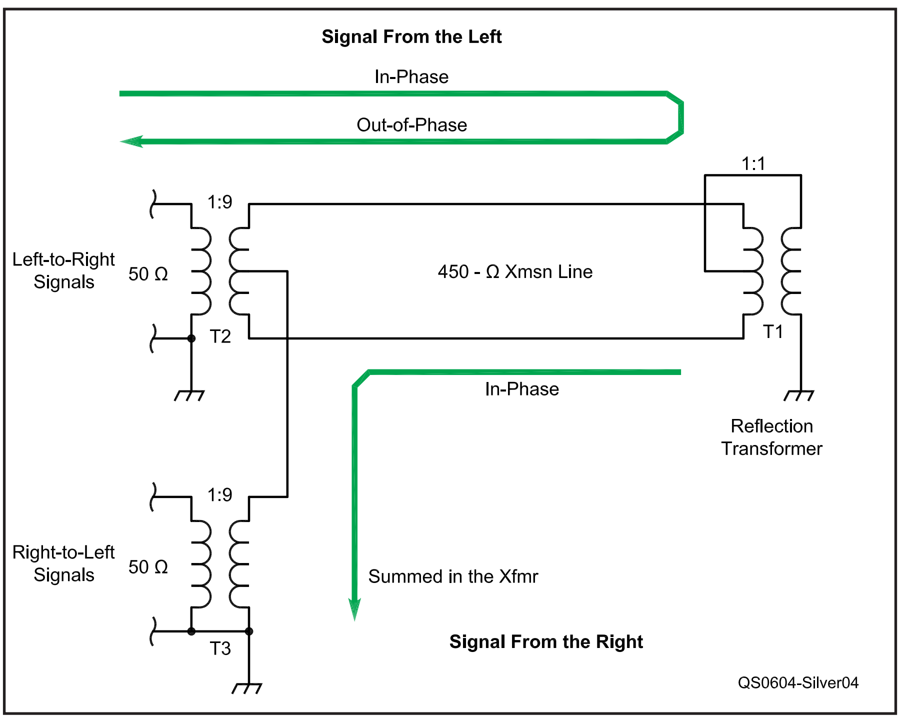


Figure 4 — The two-wire Beverage uses parallel wires as both an antenna and as a transmission line, allowing reception in either direction.

building voltage wave, like wind creating a water wave, peaking at the end opposite to the signal's arrival. If a feed line is connected at that end, the induced signal is transferred to the feed line.

If the signal arrives from the side or top, voltage waves are induced simultaneously all along the antenna. Since they all have to travel different distances to get to the end of the antenna, their phase differences cause them to mostly cancel each other. Therefore, signals from the sides or top don't create much voltage in the Beverage antenna.

We now understand why only signals arriving along the antenna's axis are received. How does the Beverage accept signals from the "front" and reject them from the "back" as in Figure 2? If the right-hand end of the antenna from the feed point is left open-circuited, the induced signal from the back would reflect off the end of the wire, just like in an open-ended transmission line, and return to the feed point, less a small amount of attenuation. This *unterminated* Beverage receives signals from both the front and back. If, however, the antenna is *terminated* with a resistance that's the same as its characteristic impedance, the undesired signal is absorbed, not reflected.

We now have an antenna that rejects signals in all directions except those arriving along the antenna from the direction of its terminating resistance. You can now see why this type of antenna is called a *traveling wave* antenna. It is also *non-resonant*, since the performance does not depend on the antenna dimensions being any fraction or multiple of the signal wavelengths. Beverages work well over a fairly wide frequency range where they are between ¾ λ and 5 λ long with peak performance around 1 λ to 2 λ.

Why the Beverage Helps

You may be surprised to learn that the Beverage antenna actually receives *less* signal than a transmitting antenna such as a ¼ λ vertical, inverted L or dipole. All that work to receive less signal? Yes, due to the rejection of signals from undesired directions, even less noise is received, which improves the *signal-to-noise ratio* (S/N).

Figure 3 shows an example of the radiation pattern for a terminated Beverage antenna. Taking a look at the pattern for the antenna that is 2 λ long, we can see that signals from the side and back of the antenna will be at least 18 dB (another 3 S-units) below those received from the front. If on an omnidirectional antenna the DX signal is S8, but the static crashes from the opposite direction are S9, it would be very difficult, if not impossible, to copy. The Beverage may give up 2 S-units of signal strength overall, but it also reduces the undesired noise by an additional 3 S-units.

Old S/N = Received level – Noise level = S8 – S9 = –6 dB (signal below the noise)

New S/N = S6 – S4 = +12 dB (signal 2 S-units above the noise)

Even with the Beverage's weaker received signal level, there is a net gain in S/N. The function of the Beverage is not to increase signal levels. It's actually quite inefficient and that's why it's not used for transmitting. Its purpose is to reduce noise and interference from unwanted directions. This principle of hearing better by reducing noise is a good one to remember, even when you're not using a Beverage.

Terminations should match the antenna's impedance, but Beverage impedances depend on height above ground, ground conductivity, wire characteristics and so on. A good compromise value is 450 Ω, and a range of 300 to 600 Ω is often found to be acceptable. To use 50 Ω feed line with a

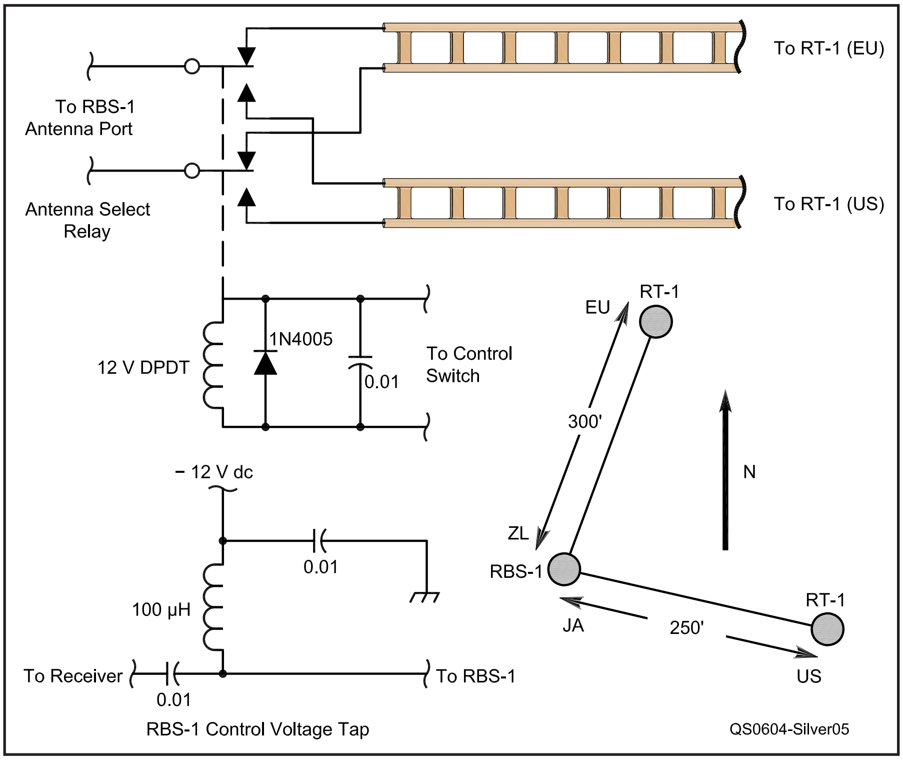
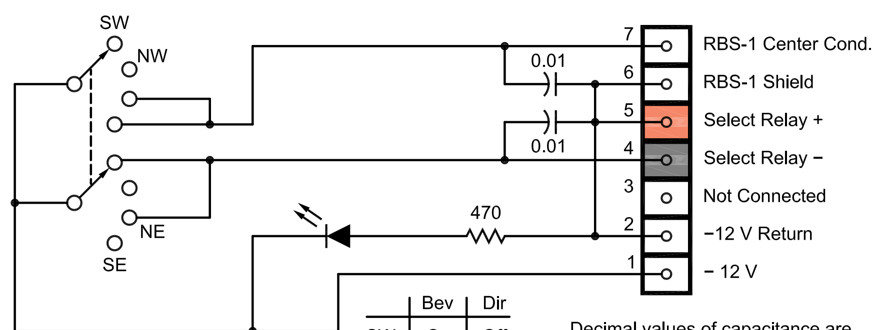


Figure 5 — A relay allows switching between Beverages. The RBS-1FP uses voltage supplied over its feed line to switch the direction of the selected Beverage.



	Bev	Dir
SW	On	Off
NW	Off	On
NE	On	Off
SE	Off	On

Decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); Resistances are in ohms; k=1,000, M=1,000,000.

Figure 6 — A rotary switch allows the operator to select the appropriate antenna and direction with a single control. BEV refers to the antenna select relay and DIR to the RBS-1 direction control.

Beverage, a 9:1 impedance matching transformer is used.

The Two-Direction Beverage

Having an antenna that can receive in two directions is a handy thing, just as long as it's not at the same time. Can we put the natural bidirectional characteristics of the Beverage to work for us? Of course! You could just run a feed line to each end of a single-wire Beverage, at the cost of a lot of extra cable.

A better solution is the Two-Wire Beverage shown in Figure 4. Instead of a single wire, a parallel-wire transmission line is used, such as the 450 Ω ladder line shown in Figure 4. (You could also use 300 Ω twin-lead or make your own, changing the transformer ratios accordingly.)

This antenna is described extensively in References 1, 2 and 3, but the operation can be summarized as follows. Signals arriving from the left induce equal voltages and currents on each wire, traveling from left to right. The reflection transformer, T1, inverts one of the currents, changing the signal to one traveling right to left *within* the transmission line. Very interesting — in one direction the open wire line acts as an antenna and in the other as a transmission line! When the signal reaches T2, the signal is transferred to the 50 Ω feed line. Signals traveling from right to left again induce equal voltages and currents on each wire. When they reach T2, they sum together in the center tap and T3 transfers them to the other 50 Ω feed line.

By using a relay to switch a single feed line between T2 and T3 (terminating the unused port), the operator changes the receive direction. Reference 3 also describes a novel way of varying the reactance of the unused transformer termination to move the antenna's nulls around and to adjust the resulting S/N.

Putting Up a Four-Direction Beverage Array

I have always wanted to try a Beverage antenna to help fight noise on the low bands for contesting and DXing. I have used a wide variety of loops and low dipole or "snake" type antennas from the pages of the *Low-Band Monitor* with varying degrees of success.[4] While the loops had good nulls, they only reduced noise from specific sources, not atmospheric noise or noise that arrived from several angles.

It was a pleasant surprise to learn that DX Engineering has packaged all of the transformers and switching circuitry in their RBS-1P Reversible Beverage System.[5] It contains T2, T3, the necessary circuitry to switch directions (RBS-1FP) and the reflection transformers (RBS-1RT). I quickly obtained a set to try in the fall contests.

Figure 7 — The relay board is installed directly on the RBS-1 antenna terminals under a rain shield.

From my QTH in the Pacific Northwest, there are four primary directions of interest: NE to Europe, SE to the Caribbean and South America, SW to the South Pacific, and NW to Japan and the Pacific Rim. If I used a pair of two-wire Beverages at right angles (see Figure 5), I would be able to cover all four directions. After locating the appropriate place for the feed point, I ordered 450 Ω ladder line and I got to work on a relay to switch the RBS-1FP antenna terminals between the two Beverages. The relay board mounts directly on the RBS-1FP as shown in Figure 7.

To support the ladder line, I used metal fence T-posts holding PVC pipes attached with plastic cable ties. A slot in the PVC pipe holds the line and allows it to move in the wind. At the termination end the line was lowered to about 3 feet off the ground, where the termination transformer was attached. I used copper pipe as a ground rod.

Beverages are not fussy antennas. You can change their height to clear obstacles, lay them on trees or other non-conductive supports, run them over uneven ground and still get good results. As you gain more experience and want to get the last drop of performance out of them, you'll want to pay more attention to balance, symmetry and optimizing termination impedances. When you are getting started, it's more important just to get the antennas up so you can begin to learn about them.

The RBS-1FP requires that power to switch the direction of the antenna be run through the receiver feed line. A schematic for a voltage feed tap is shown in Figure 5, or you can buy one from DX Engineering. (The RBS-1FP uses –12 V dc or 12 V ac to avoid ground loops with the shack +12 V dc supply that would couple noise into the antennas.) Bypass all diodes and power connections with 0.01 µF capacitors to keep unwanted RF out of the signal cable.

Switching a single high-impedance transformer connection between two antennas can result in the antennas interacting and unbalancing each other. To get the best performance out of the two-wire system, you should really use a separate transformer circuit (such as an RBS-1FP) for each antenna. A remote coax switch could then be used to select one of the antennas via the coax feed line. The remote switch needs to pass dc to allow direction switching.

In order to avoid having to throw two switches (one to select the antenna and one to change direction) I used a small rotary switch as shown in Figure 6. This simple item is key to making the system easy to use. You will find that noise and changing band conditions frequently change the optimum receive direction. By putting all of this on a single switch labeled by direction, operation of the array becomes intuitive and easy — especially helpful during those late night low-band DXing adventures! A tunable preamplifier is available to boost the signal level, but I find that I rarely need it.

Results

This set of antennas plays best on the 80 meter band, delivering noise-be-gone performance on occasion and making a noisy band very listenable. I usually see at least 2 to 3 S-units of S/N improvement over the transmit antennas (a pair of half-slopers at 50 feet) — a dramatic improvement. I can now hear another whole "layer" of stations and the lowered noise greatly reduces operator fatigue.

Although 300 and 250 foot Beverages are a little short for 160 meters, they do help me reject some of the noise. I hear up to 2 S-units of S/N improvement over my inverted-L transmit antenna. Usually, the improvement is enough that by fiddling with the direction and radio filters, I can achieve reliable copy. During the 2005 ARRL 160 Meter Contest, I worked many stations I would otherwise not have been able to copy.

There is not much improvement on 40 or 20 meters, probably due to my somewhat sloppy balance and grounding. There is room for improvement — I should go back and twist the line two or three times per yard to keep the line balanced with respect to ground, for example. Beverages are most often used below 7 MHz, so I do not expect to use them a lot on these higher bands, although it's nice to have them available as an option.

In the 2004 CQ WW CW Contest, I decided to give the array a real workout as an 80 meter low-power entry. The results were great — 251 QSOs in 38 countries and 18 zones from the West Coast! I kept comparing the Beverages to the transmit antennas and did not find a single instance where they were outgunned. I heard deep Zone 15 stations for the first time. I could hear JA stations that would have been completely inaudible before. When power line noise started up at 2 AM, I could work around it by selecting a different antenna and still hear the DX reasonably well. Now I have to start working on a better transmit antenna!

Summary

Needless to say, my first Beverage experience has been a successful one. I've found that the antennas are tolerant of my uneven installation techniques and spurred me on to understand more about how they work. I've constructed a very useful set of antennas as a result. I'll be able to take this knowledge with me on field trips or DXpeditions. Even if you don't have the space at home to put up a Beverage, plan on giving one a try at Field Day.

Notes

[1] J. Devoldere, ON4UN, *Low-Band DXing,* 4th Ed, Chap 7. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9140. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[2] *The ARRL Antenna Book,* 20th Ed, pp 13-16 to 13-21. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9043. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[3] V. Misek, W1WCR, *The Beverage Antenna Handbook*, 1977, self-published.

[4] *Low-Band Monitor*, PO Box 1047, Elizabeth, CO 80107, **www.lowbandmonitor.com**.

[5] DX Engineering, PO Box 1491, Akron, OH 44309-1491, **www.dxengineering.com**. RBS-1 (including the controller and one reflection transformer), price: $129.

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