# The Beverage Antenna, 100 Years Later

Still relevant for its noise-rejection abilities, the Beverage will become more important during Solar Cycle 25 as increasing sunspot activity leads to weaker signals on 160 and 80 meters.

CYCLE 25

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On June 7, 1921, Harold Beverage, W2BML, (previously 2BML) obtained his first patent for his radio receiving system. Back then, as they do now, operators struggled to hear signals through the atmospheric static that grew stronger as the frequency dropped. The VLF-through-MF spectrum had very high noise levels that overloaded receivers and made consistent reception very difficult, particularly in the summer months.

Beverage's main discovery was that a long horizontal wire (known to have a bidirectional pattern) could be made unidirectional by keeping it close to the ground and terminating one end of the wire with a resistor. When the wire was aimed at the transmitting station, this had the effect of rejecting noise and interference from other directions, which increased the signal-to-noise ratio (SNR).

## A Basic System

The basic Beverage antenna system is shown in Figure 1. The antenna needs to be close to the ground (as opposed to being high in the air) and works best over a ground area with medium-to-poor conductivity.

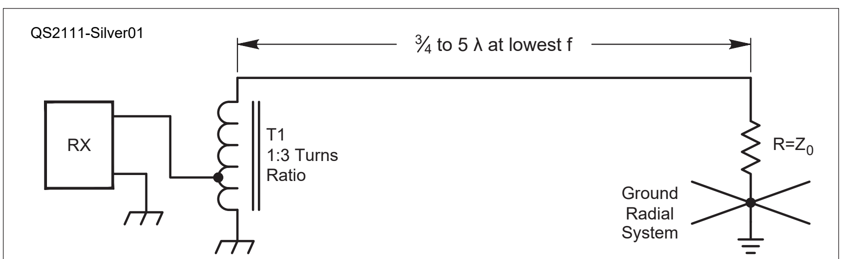


**Figure 1** — A simple one-wire Beverage antenna with a resistive termination and a 9:1 impedance transformer provides a good match to 50 Ω coaxial cable.

The trade-off is length — Beverages need to be at least ¾ λ long to provide effective noise rejection.

### Wave Front Tilt

A radio wave is an electromagnetic field (EMF) with an electric (E) and magnetic field strength (H) component at right angles. An EMF induces voltage and current in every conductor it encounters. How much voltage and current depends on the orientation of the EMF, with respect to the antenna. As a radio wave arrives from the ionosphere, its vertically polarized electric field component (E field) is tilted forward, as shown in Figure 2. Wave front tilt results from being reflected by the ionosphere. Higher arrival angles increase the tilt.

Figure 2 shows why tilt is important. For the wave to induce a voltage in the antenna, the E field must at least partially align with the antenna. There won't be any voltage if the wave front arrives with a perfectly vertical E field. When the E field is tilted, however slightly, it becomes partially parallel to the antenna. The vertical portion of the tilted E field doesn't create voltage in the antenna, but the horizontal portion does. The result is induced voltage along the entire length of the antenna.

### Vertical vs. Horizontal Polarization

Figure 2 shows a vertically polarized E field. A horizontally polarized E field that's parallel and close to Earth is severely attenuated by ground losses. Furthermore, if arriving along the antenna, the E field is at a right angle to the antenna and can't induce voltage in it. That means the Beverage antenna is most sensitive to vertically polarized signals arriving in line with the antenna. (Regardless of a signal's original transmitted polarization, ionospheric propagation always causes polarization rotation, known as Faraday rotation, so the sky-wave signal arrives with a mix of vertical and horizontal polarization.)

## The Side and Top

Even if tilted, the vertically polarized E field of signals arriving broadside to the antenna is at a right angle to the antenna and can't induce voltage. Horizontally polarized signals arriving broadside to the antenna have an E field parallel to the antenna, but don't result in strong received signals.

While the vertically polarized E field of a sky-wave signal is perpendicular or tilted with respect to Earth, the horizontally polarized E field is always parallel to Earth. When a horizontal E field is very close to Earth (much less than ¼ λ), it's significantly attenuated by ground conductivity and can't induce much voltage into the antenna.

When sky-wave signals arrive from nearly overhead, both horizontally and vertically polarized E fields are parallel to Earth. They are severely attenuated when close to Earth, before inducing a voltage into the antenna.

## Front and Back

The Beverage antenna develops a main forward beam because wave fronts arriving at angles offset from the antenna induce progressively less voltage into it as the angle increases.

Figure 3 shows the Beverage antenna accepting signals from the "front" and rejecting them from the "back." If the right-hand end of the antenna in the figure is left open-circuited, a signal from the back reflects off the end of the wire, just like in an open-ended transmission line. The signal then returns to the feed point, diminished by a small amount of attenuation from the lossy ground below the wire. This unterminated, bidirectional Beverage receives signals from the "front" and slightly less from the "back."

If the antenna is terminated with a resistance approximately matching its characteristic impedance, the undesired signal is absorbed at the end of the antenna and not reflected to the feed point. We now have an antenna that attenuates signals in all directions, except from the direction of its terminating resistance. Figure 4 shows the resulting pattern for 160-meter Beverages that are 1 λ (545 feet) and 2 λ (990 feet) long.

## Traveling-Wave Antennas

The Beverage antenna is a traveling-wave antenna because it never has standing waves from reflections from the ends of the wire. As a result, it's also non-resonant, and the antenna dimensions aren't required to be a specific fraction or multiple of the signal wavelength. Beverages work well over a fairly wide frequency range where they're between about ¾ and 5 λ long, with good performance around 1 to 2 λ.

## Transmission Line

The Beverage antenna has a characteristic impedance and not a feed-point impedance. Like a dipole antenna, current in the Beverage's horizontal wire creates an electrical reflection or image on the ground below it. The current in the wire and its image create an unbalanced transmission line with a characteristic impedance. If this Beverage transmission line is terminated with that same impedance, any signals flowing toward the termination are absorbed, as with any other transmission line. Most Beverages have a characteristic impedance of about

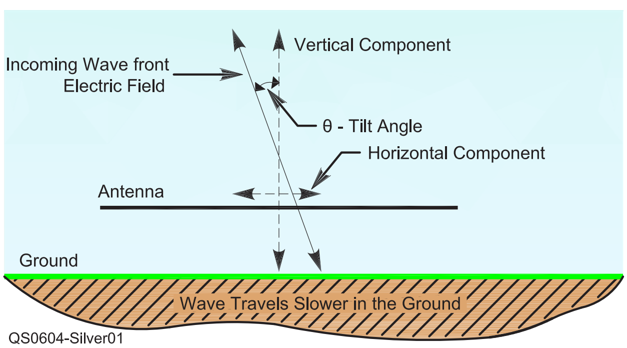


**Figure 2** — Incoming signal wave fronts tilt at ground level, due to reflection in the ionosphere and the effects of ground.

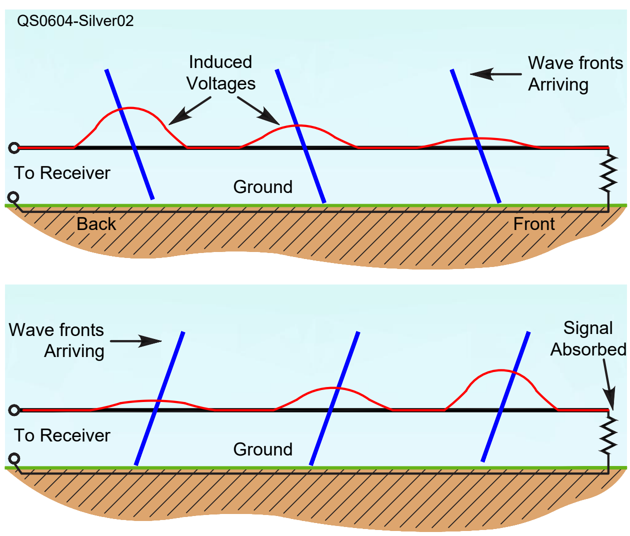


**Figure 3** — Voltage waves build up along the antenna and are either transferred to a feed line or absorbed by a terminating resistance.

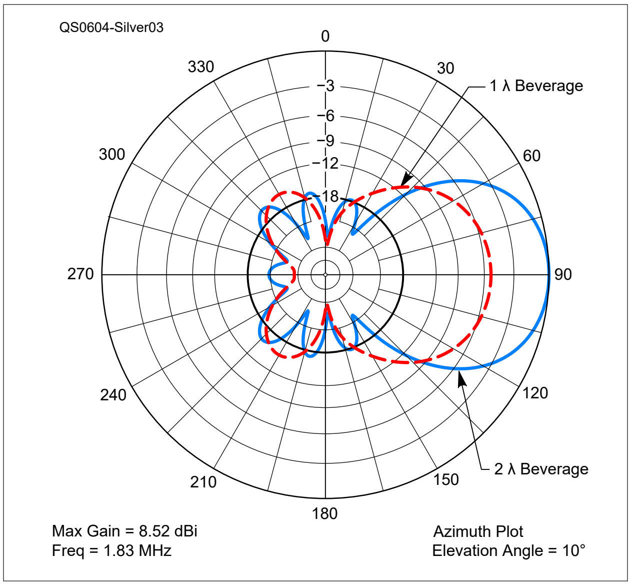


**Figure 4** — Radiation patterns for a 1 and 2 λ Beverage antenna. Both antennas have a broad forward lobe and good rejection of signals from the sides and back.

500 Ω. The exact value is relatively unimportant to the performance of the antenna.

### Ground Conductivity

Ground conductivity has a big effect on Beverage performance. Lossy ground enhances its performance, but high ground conductivity (especially salt water) severely degrades it. The horizontally polarized E field and tilted vertically polarized E field that induce voltage into the antenna when it's installed over lossy ground are shorted out. Unlike transmitting antennas, the Beverage requires medium or poor ground conductivity to work well.

## Building a Basic Beverage

Figure 1 shows a basic Beverage antenna. Any sturdy wire will do (insulated or bare), as long as it's strong enough under the necessary tension. Transformers can be purchased from various sources, or you can wind your own. Tom Rauch, W8JI, has published an informative website on constructing Beverage antennas at **https://new.w8ji.com/beverage-antenna-construction**.

The full benefits of a Beverage antenna begin to appear when the length reaches about 1 λ, but any length above about ½ λ will have some useful directivity (see Table 1). Consider that a Beverage antenna that's 1 λ long at 160 meters will be 2 λ on 80 meters and 4 λ on 40 meters. The antenna can be used on all of these frequencies. Longer Beverages develop a progressively narrower pattern and better interference suppression outside the narrower beam. With a length above 5 λ, sensitivity begins to decline because voltages and currents induced by the tilted wave front start interfering with voltages and currents traveling along the antenna to the feed point.

**Table 1 — Recommended Beverage Lengths**

| Band | Length |
|---|---|
| 160 meters | 500 – 1,200 feet |
| 80 meters | 300 – 600 feet |
| 40 meters | 200 – 500 feet |

Speaking from experience, the Beverage wire should be high enough that animals don't run into it. Typical heights range about 6 – 10 feet. The wire should have insulated support at about every 50 feet, but this isn't critical. Electrical fence insulators work well and can be nailed to wooden posts or trees.

The antenna isn't particularly sensitive to small variations in height above ground. Like small "wrinkles" in a two-wire feed line, unless the variations exceed about 0.1 λ, which is about 50 feet at 160 meters, they'll have little effect. Small detours around or over non-conductive obstructions also have little effect.

By using separate feed lines at each end or by using relays to switch between a terminating resistor and a transformer and feed line, signals can be received from either direction. You can also build a two-wire Beverage that can receive from either direction through a single feed line, as described in *The ARRL Antenna Book for Radio Communications* (**www.arrl.org/arrl-antenna-book**) or *ON4UN's Low-Band DXing* by John Devoldere, ON4UN (SK).


Ward Silver, NØAX, has been licensed since 1972. He is Lead Editor of *The ARRL Handbook* and *The ARRL Antenna Book*, and is the author of all three editions of the *ARRL Ham Radio License Manual* and study guides. He released the well-received *Grounding and Bonding for the Radio Amateur* in 2017 and recently authored the third edition of *Ham Radio for Dummies*. Ward can be reached at **n0ax@arrl.org**.

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