short Beverage for 40 meters

Discussion of a short Beverage antenna for 40 meters with particular emphasis on the matching transformer and termination

Basically, my problem is one of geography. Living in a moderately rare DX location, I have become weary of pile-ups and the quick signal report exchanges. The insipid hello, goodbye, PSE QSL routine fails to satisfy the rag chewer that I am, with the result that I now tend to avoid the higher frequency bands and seek refuge lower in the spectrum. The 40-meter band offers attractive rag chewing possibilities, but everything about my location militates against a 40-meter pipeline to the folks back home.

For a starter, the band assignment in this part of the Pacific is only from 7 to 7.1 MHz. This narrow band is cluttered with Asian BC stations, and from about 7.03 to 7.1 MHz there is one continuous roar of JA ssb signals. To copy any W/K signals above 7.03 is well nigh impossible without a highly directive antenna. The Asian signals so totally overwhelm the receiver as to completely bury the much weaker W/Ks arriving from over 9600 km (6000 miles) away. After many frustrating attempts at rag chewing while listening on my vertical, I was convinced that, without some highly directive receiving antenna, it was a losing proposition.

Extensive research and meditation on this dilemma brought me to the conclusion that some sort of Beverage antenna offered the only hope in my circumstances. For me, multi-element phased or parasitic arrays on 7 MHz were out of the question, but a patch of jungle behind the house offered possibilities for a Beverage-type long wire. At this point, I must acknowledge my debt to others for supplying me with the three basic premises upon which my project was founded.

First, a simple low-to-the-ground, properly terminated long wire can achieve astonishing rejection of signals from unwanted directions.[1] Second, such a wire will exhibit maximum front-to-back ratio if it is an odd number of quarter wavelengths long.[2] And third, although most publications show a simple 600-ohm resistor for termination, no simple resistor alone will ever give optimum termination. A little inductance will always be needed in series with the resistor.[3] (Apparently the intrinsic insulator and end capacitance of such a wire causes a slight mismatch which must be inductively cancelled out.)

After an hour of tramping about in the jungle, taking repeated compass sightings, I finally located a group of four trees that lay in a perfectly straight line, on the exact bearing needed to beam W/K. A coconut palm and a breadfruit tree about 58 meters (190

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feet) apart provided the end supports, with two trees in between providing intermediate support points along the span.

There is no simple formula by which to determine the height of the wire above ground. I wanted it low enough that I might perform all adjustments while standing on an ordinary kitchen stool, and yet high enough to be well above the hands of any pedestrian traffic through the woods. A height of 2.3 meters (7.5 feet) satisfied both requirements. A piece of number 10 AWG (2.6-mm) copperweld was cut to a length of 53.3 meters (175 feet), which is 1.25 wavelengths at 7 MHz. With a block and tackle it was stretched taut as a fiddle string, so that with the two intermediate support points, it hangs straight as an arrow. The coupling and termination enclosures were hung at wire level, and the ground system installed as shown in **fig. 1**. Any type of minibox enclosure may be used as long as it is all metal for total shielding and weather proofing.

The coil detail is shown in **fig. 2**. A surplus powdered-iron slug of unknown pedigree was used here because I had nothing else. A toroid could well be used in place of the slug; however, one precaution should be observed. The primary and secondary windings should be placed on opposite sides of the circle, with a tight electrostatic shield between them. The object is to prevent proximity coupling direct from the end of the hot wire over to the coax input. For best unwanted signal rejection, all coupling must occur through the core material.

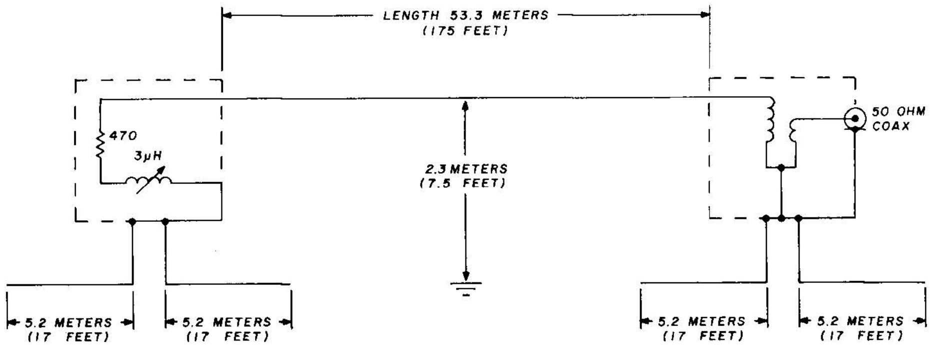

fig. 1. Diagram of the Beverage in use at the author's station. Each of the four ground wires is buried about 15 cm (6 inches) deep, on opposite sides and perpendicular to the Beverage wire. All wire used was number 10 AWG (2.6 cm), with the antenna made from Copperweld.

To compute the characteristic impedance of my wire, I used the standard single wire transmission line formula $Z_o = 138 \log_{10} \frac{2h}{p}$ where h is the height of the wire above ground and p is the radius of the wire measured in the same units. For my case, the computed Z_o is 489 ohms. Reasoning that the series coil would add a few ohms of rf resistance to the lumped resistor, I chose the next smaller resistor value, 470 ohms. A commercial slug-tuned coil was used for the inductance. After all adjustments were complete, the inductance actually in use was 3 μH, or an X_L of 132 ohms at 7 MHz.

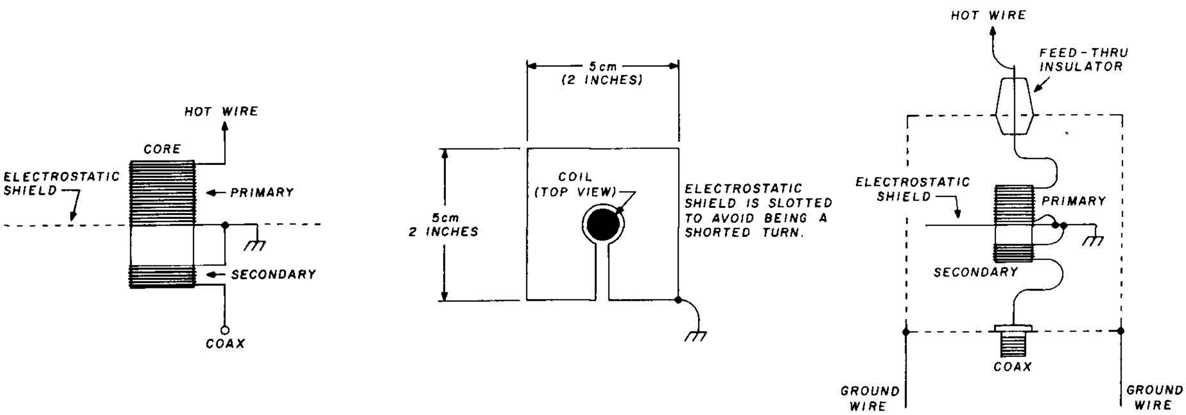

fig. 2. Diagrams of the matching transformer. The coil slug is made of powdered iron, 2.5 cm (1 inch) long and 1.3 cm (0.5 inch) in diameter. The primary is 30 close-spaced turns of number 26 AWG (0.4 mm) enameled wire, while the secondary is nine turns of number 26 AWG (0.4 mm) enameled, also close spaced. The two windings are separated by approximately 6.5 mm (¼ inch). The electrostatic shield is approximately 5 cm (2 inches) square and is made from copper foil; it is slotted to avoid being a shorted turn.

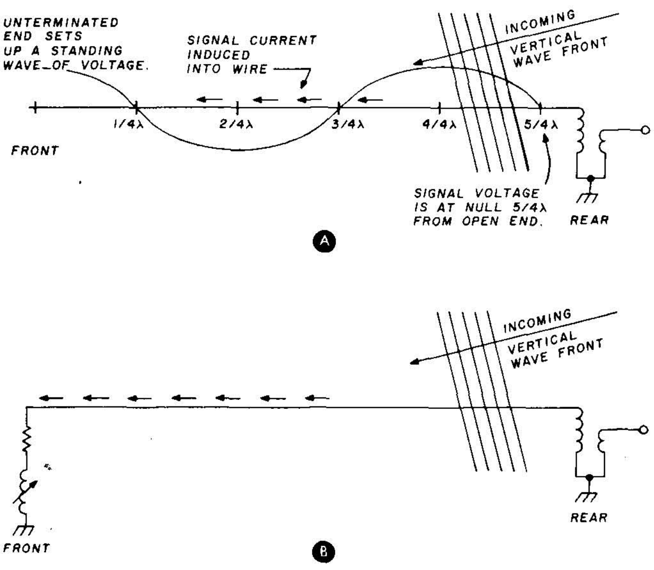

fig. 3. Diagram (A) shows the standing wave on the unterminated wire caused by an incoming signal from the rear. The signal voltage across the transformer is at a null 5/4λ from the open end. When the wire is perfectly terminated (B), the signals from the rear of the antenna are absorbed by the termination.

The Beverage antenna is located such that it is broadside to the transmitting antenna (a base-fed vertical dipole), and located 38 meters (125 feet) away. The feedline is 50 meters (165 feet) of RG-58A/U coax. Such orientation ensures minimal coupling between the two. Under key-down conditions, with 500-watts input to my trusty old 813, the measured rf voltage at the receiver input is only 0.15 volts rms.

Before step-by-step adjustments are described, a little discussion of the back rejection theory will be helpful. As shown in **fig. 3A**, incoming signals propagating along the wire from the back side will induce a signal current into the wire. If the wire is unterminated at the front end, a standing wave of voltage will be set up with a maximum at the open end. Reflections traveling backwards along the wire for an odd number of quarter wavelengths will create a voltage null where the coupling coil is located at the rear end. Because there is almost no voltage acting on the relatively high impedance of the coil, very little signal will be coupled through to the receiver.

This can be clearly demonstrated by simply removing the coil from the circuit and connecting the hot lead of the coax directly to the rear end of the wire. Under these conditions, a standing wave of current will appear in the wire with a maximum at the rear end, coupling very well into the low impedance of the coax. With the front end of the wire unterminated, take an S-meter reading on some sky wave signal arriving from the back side. This establishes the ability of the wire to receive a certain signal level, apart from any termination or phasing attenuation. Once an average level is noted, reinsert the coupling transformer. On my antenna, the rear-side signal dropped by 18 dB when the coil was reinserted, showing that some amount of front-to-back ratio is achieved through the phase relationship of the odd quarter wavelength. The drop in signal noticed is not related to coil losses when the coil is reinserted. A similar comparison was made with the signal from a Kuala Lumpur station broadcasting on 6.03 MHz. At this frequency, the wire is about one wavelength long, and it showed no front-to-back change at all when the coil was reinserted into the circuit. Coil losses with iron-core coupling are so insignificant that they do not show up in the meter readings.

After my termination was reconnected and carefully adjusted for minimum back pick-up, the front-to-back ratio was increased by another 15 dB, giving a total front-to-back ratio of 33 dB for both effects working together. Referring to **fig. 3B**, if the front end termination is a perfect match for the characteristic impedance of the wire, the induced rear side signal current is almost totally absorbed in the termination, and there is no reflection to speak of going back to the coupling end.

In my location there was no possibility of enlisting the help of a "local" 40-meter station to provide a rear side signal for tuning purposes. The closest dry land off my back is the island of Borneo, 4000 km (2500 miles) away! I selected a station in Kuching, Sarawak, (broadcasting on 7.16 MHz) to be my reference for all front-to-back adjustments. To get accurate measurements on a signal from that far away is difficult but not impossible. Taking readings on a vertically polarized local signal can be misleading. The Beverage does respond to vertical polarization, but it depends on the slight forward tilt of the incoming wave front to produce the small horizontal vector actually coupling into the wire. If a local vertical signal is used, the wavefront is so square to the ground that coupling into the Beverage is much less than a low-angle sky wave arrival would provide. Comparisons with a front-side vertically polarized signal from KG6RJ, only 3.2 km (2 miles) away, showed the Beverage about 12 dB less responsive than it would be to low-angle sky waves from the same direction.

An aged Hammarlund HQ180 receiver S-meter was used for all readings. The bandwidth was set to the narrowest position so the S-meter would respond only to the carrier of the station concerned and not to the buckshot of BC stations or QRN. The rf gain must be set to maximum for all readings. Since all readings are a comparison of the vertical reference (transmitting) antenna vs the Beverage, the first step is to establish a loss figure for the Beverage. Because it presents a very small "capture area" to incoming wave fronts, and being very long and close to lossy ground, the Beverage is very inefficient, compared with the vertical. In order to derive its intrinsic loss, the termination must be disconnected and the coupling coil temporarily removed from the circuit. The center lead of the coax is jumpered to the end of the Beverage wire for the first comparison.

The Kuching signal was then tuned in using the vertical antenna. The HQ-180 antenna trimmer was detuned to where the Kuching signal just peaked to the 20 dB over S9 mark. This is to avoid taking any readings at the compressed top end of the S-meter scale where the calibrations are very inexact. The meter is watched for about one full minute to get the feel of the QSB and to make sure the needle never swings beyond the 20 dB mark. Then the vertical coax is disconnected from the receiver and the Beverage connected.

With the Beverage antenna in use, the meter is again watched for about one full minute, noting the very highest swings of the needle. With mine, the peaks were an average of 20 dB lower, showing the basic Beverage wire alone has a receiving loss of 20 dB compared with the vertical.

Next, the coupling coil and termination were reattached. The same comparison procedure was followed; first tuning in the signal on the vertical, adjusting the antenna trimmer until the signal peaks 20 dB over S9; then attaching the Beverage antenna and noting the drop in S-meter readings. The QSB is accentuated on the Beverage because it is very selective to polarity, responding best to vertically polarized incoming wave fronts.

The procedure is repeated with different settings of the termination coil, changing it in increments of about two turns of the slug between trials. As the optimum point is approached, the S-meter responses on the Beverage will go lower and lower. When I got my termination to the optimum setting, the S-meter dropped dramatically from the 20 dB over S9 mark on the vertical to only S3.5 on the Beverage — counting downward from the 20 over 9 mark, allowing 6 dB per unit, a decrease of 53 dB.

Note that 53 dB is *not* the front-to-back ratio of the Beverage working alone! That is merely the difference between the two antennas. In the first test described, it was already established that the Beverage had an efficiency of 20 dB less than the vertical. Subtracting this constant from the difference readings between the two gives an absolute front-to-back ratio of 33 dB for the Beverage alone.

It must be remembered that S-meters are notoriously unreliable as regards absolute decibel calibration. While useful for noting changes in a given signal, they must be regarded with suspicion when seeking to establish accurate decibel levels. Listening experience with this antenna would seem to indicate the actual suppression is not quite as dramatic as these figures indicate. The Hammarlund HQ180 exhibits different sensitivity on each band, so, obviously, if the meter were accurate on one band, it would be lying on all the others. At 7 MHz, it seems to be a bit generous with its dB read-out. Nevertheless, the suppression of this antenna must be called excellent, more than worth the very small investment required for materials. It is hard to imagine more suppression per dollar than the Beverage offers.

Taking hundreds of readings by the same comparison method, I found that when the Beverage was terminated at its best front-to-back rejection, the front-to-side rejection was also best. A strong Chinese broadcast station (7.025 MHz) from somewhere in the rear quadrant was reduced 30 dB by the pattern of the Beverage alone. Japanese ssb signals arrive from a 30-degree-wide sector and do not all show the same front-to-side rejection ratio. The average values were from 36 to 40 dB front-to-side ratio for the Beverage alone (in the sector of 60 to 90 degrees relative in the pattern).

The proof of the pudding is always in the eating, and this antenna has certainly proven itself with my goals in view. The Beverage does not completely eliminate the undesired Asian signals, but it does knock them down far enough that distant signals, which would have been completely overwhelmed with the vertical, can now be heard. The only disadvantage noted is that because of its polarity selectivity, the Beverage antenna shows magnified QSB effects. That is a small price to pay for the rejection in unwanted directions. Rag chewing with W/K generals on 40-meter CW is now commonplace and pleasurable, whereas before it was a grim struggle if possible at all.

In conclusion, let me add that, due to my unique location, all of these rejection figures were derived on signals arriving from 2400 to 9500 km (1500 to 6000 miles) away, which implies low-angle arrival. I am unable to specify just how the rejection figures would work out for high-angle signals. Perhaps someone situated in the center of the United States could perform further experiments to add high-angle rejection data to what I have already established for DX-only responses. Any takers?

references

1. Barry Boothe, W9UCW, "Weak-Signal Reception on 160 — Some Antenna Notes," *QST*, June, 1977, page 35.
2. *The ARRL Antenna Book*, 13th edition, American Radio Relay League, Newington, Connecticut, 1976, page 172.
3. Edmund Laport, *Radio Antenna Engineering*, McGraw Hill, New York, 1952, page 310.

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