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Remote-Controlled Termination

Beverage Antenna

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Beverage front-to-back ratio

As discussed in my forth-coming article "Beverage Antenna Termination: Why Bother?", the front to back ratio of the Beverage depends critically on the termination impedance. Figure 1 below shows the variation in front-to-back ratio versus termination resistance for a 279 meter Beverage at 1.0 MHz mounted 2 meters above moderately-poor ground at a wave-angle of 20.7 degrees. In the example, the terminator must be between about 513• and 654•, or about ±10%, to achieve a front-to-back ratio of 25 dB or more.

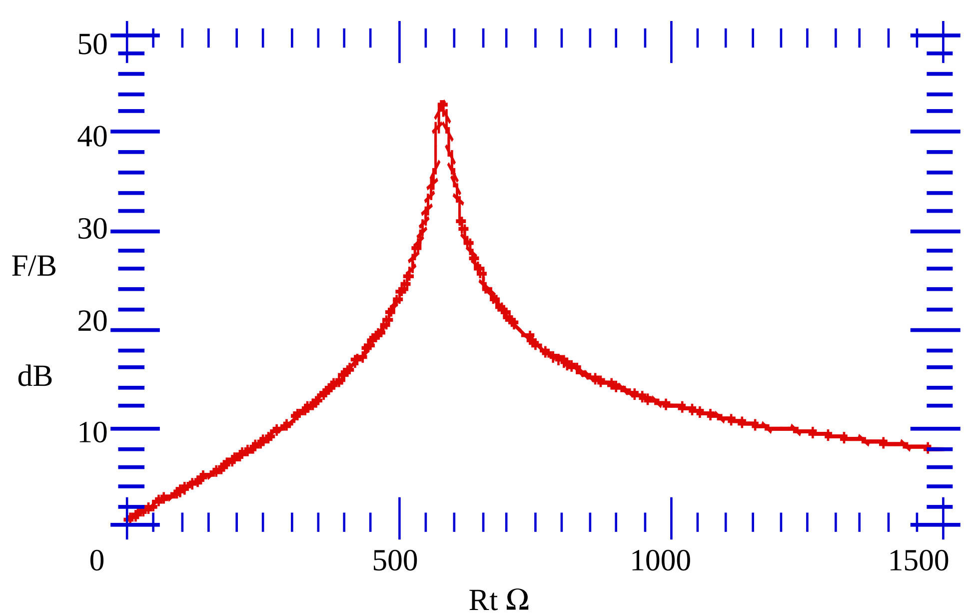


Figure 1. F/B ratio versus termination resistance.

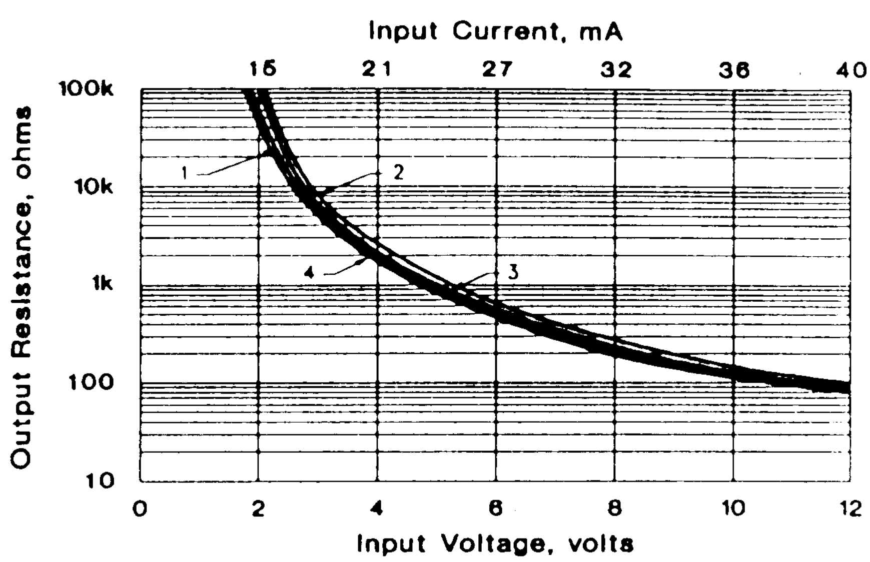
It isnít possible to predict the exact value for the termination resistor that maximizes the front-to-back ratio. The characteristic impedance of the antenna varies with the height above ground, ground conductivity, permeability of the earth, and frequency. The effective height above ground is difficult to determine since RF penetrates the earth to some extent and thus the effective height is greater than the height above the surface of the ground. The ground conductivity depends on the composition of the soil and its moisture content. This varies both seasonally and with the weather. According to measurements reported in Belrose, Litva, Moss, and Stevens (Ref. 1), the characteristic impedance of a Beverage varies approximately ±20% over the frequency range of 2 MHz to 12 MHz.

Ideally you should experimentally adjust the termination resistance for the deepest null to the rear. This is easier said than done since the receiver is typically 1000 feet or more from the terminator. One either needs a good pair of running shoes or a partner and a pair of walkie-talkies to adjust a potentiometer at the far end of a Beverage.

The Remote Controlled Termination (RCT) Beverage antenna

Iíve developed a method to remotely-control a termination resistor located at the far end of the antenna. I use a cadmium sulfide (CdS) photocell as the Beverage termination resistance. The brighter the light on the photocell, the lower its resistance. In my system a 12 volt incandescent lamp illuminates the CdS photocell. I control the resistance of the photocell by adjusting the voltage on the lamp with a potentiometer. I use #22 AWG stranded twisted-pair wire both as the antenna and to feed the control voltage to the lamp. The voltage across the twisted-pair drives the incandescent lamp at the terminator. Both wires in the twisted-pair are AC-coupled to the photocell, which is connected to the ground system.

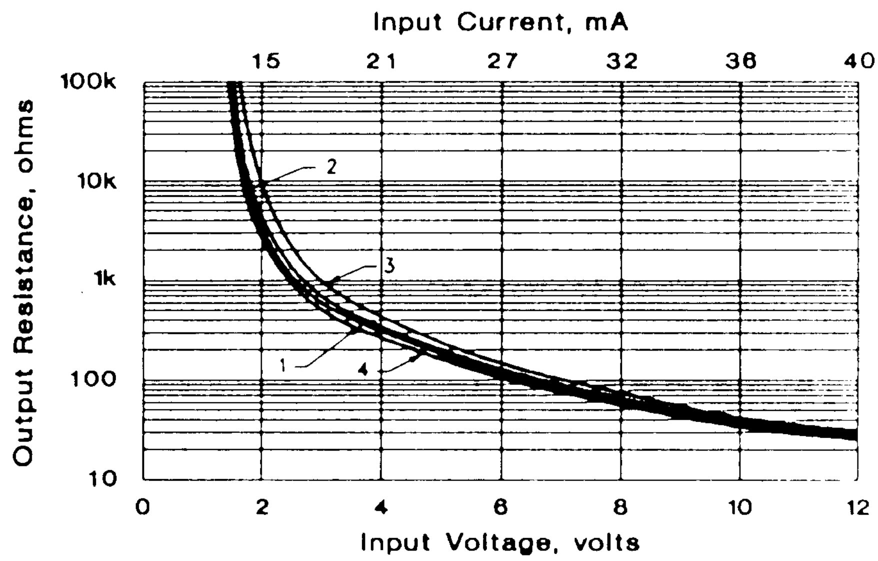
Cadmium sulfide photocells are good RF resistors. They are fairly linear so they do not produce much intermodulation distortion. They have low parasitic capacitance and inductance. For the cell that I use, at 466 ohms DC resistance, I measured the impedance at 10 MHz as 435 - j110 ohms using a General Radio 916A RF bridge. This is equivalent to a 463 ohm resistor in parallel with a 8.7 pF capacitor.



Curve 1: 25˚C - 24 hours @ no input
Curve 2: 25˚C - 24 hours @ rated input
Curve 3: +50˚C - 24 hours @ rated input
Curve 4: -20˚C - 24 hours @ rated input

Figure 2. typical resistance vs. voltage curve for VTL3A27.

I use a opto-isolator containing the CdS photocell and incandescent lamp encapsulated in an epoxy package. EG&G Vactec manufactures them and sells them under the trade name “Vactrols”. I use the type VTL3A27 "Vactrol" analog opto-isolator. The desirable characteristics for the CdS cell are a low on-resistance, a low light-history memory, a low temperature coefficient, and a shallow resistance versus voltage characteristic curve in the region around 500 ohms and below. The maximum on-resistance needs to be below a few hundred ohms since the resistance of the ground system is in series with the terminator, and the necessary termination resistance is somewhere around 400 to 500 ohms. A low light-history memory and a low temperature coefficient are desirable to minimize drift in the termination resistance setting. The shallow resistance versus voltage characteristic keeps the control setting from being too sensitive. The VTL3A27 meets these requirements best, but is not available through distributors like Allied Electronics. I bought mine in quantity from EG&G Vactec. Figure 2 shows the typical resistance versus voltage characteristic curve for the VTL3A27.



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Curve 2: 25˚C - 24 hours @ rated input
Curve 3: +50˚C - 24 hours @ rated input
Curve 4: -20˚C - 24 hours @ rated input

Figure 3. typical resistance vs. voltage curve for VTL3A47.

Allied does stock EG&G/Vactec type VTL3A47. This part has a lower on-resistance, a higher light-history memory and temperature coefficient, and a much steeper characteristic curve around 500 ohms. See figure 3. Mark Connelly has had success with these parts by using a 10 turn potentiometer to keep the control setting from being too "fiddly".

Figure 4 illustrates a simple application of the remote termination scheme. This uses a 9V transistor radio battery or a 12-volt lantern battery and a 1 KΩ series potentiometer connected across the twisted-pair antenna wire to provide the control voltage. The capacitance between the two wires in the twisted-pair couples them together for RF. The lamp in the opto-isolator connects between the two wires in the twisted-pair and the photocell connects from one wire to the ground system. A good ground is needed, preferably at least four symmetrically-arranged 30 meter long (about 100 feet) radials.

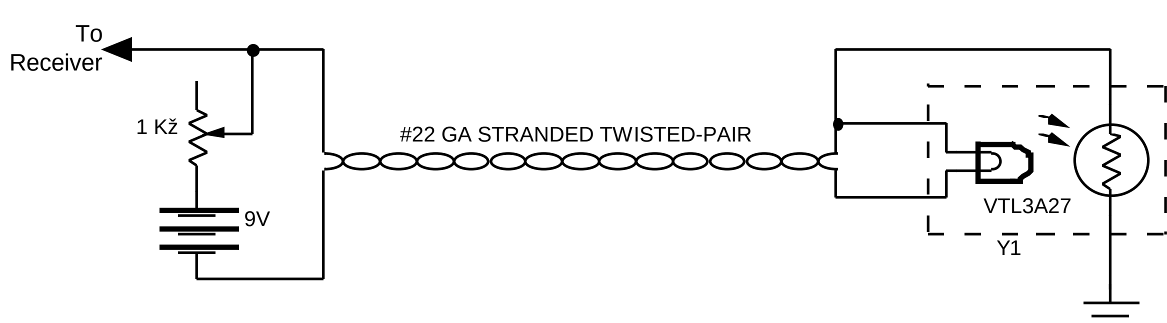


Figure 4. simple remote-termination circuit.

Mark Connelly has adapted the remote-termination concept to other types of antennas. Heís experimented with it for the termination of receive-only rhombic antennas and short phased random-wires. See Figure 9 in Markís DCP-2 dual controller/phaser article for the design of a flexible termination-box that can be configured for Beverages and random-wires or rhombics and terminated loops. (The article is found in the DXMs for June 15 and July 13 of 1996)

RCT Beverage description

Iíve developed a design for a remote-controlled termination Beverage that is well-suited for DXpedition use. It is designed for portability since most DXers donít have the space for a permanent Beverage installation.

The design uses rugged “low-tech” circuitry. The antenna has to survive the large voltages induced by nearby lightning strikes so I avoid the use of semiconductors such as FETs or LEDs. The incandescent lamp and CdS photocell in the terminator are quite rugged in this respect. Semiconductors are also likely to produce intermodulation in the presence of strong RF. The CdS photocell is a quite linear resistance; in my experience it does not cause any significant intermodulation products.

The RCT Beverage consists of a controller, an impedance-matching transformer, two 100 foot (30 meter) radials of #24 gauge wire for the ground system at the transformer, 1000 feet (300 meters) of #22 gauge twisted-pair antenna wire, the remote controlled terminator, and four 100 foot (30 meter) radials of #24 gauge wire for the ground system at the terminator. See figure 5.

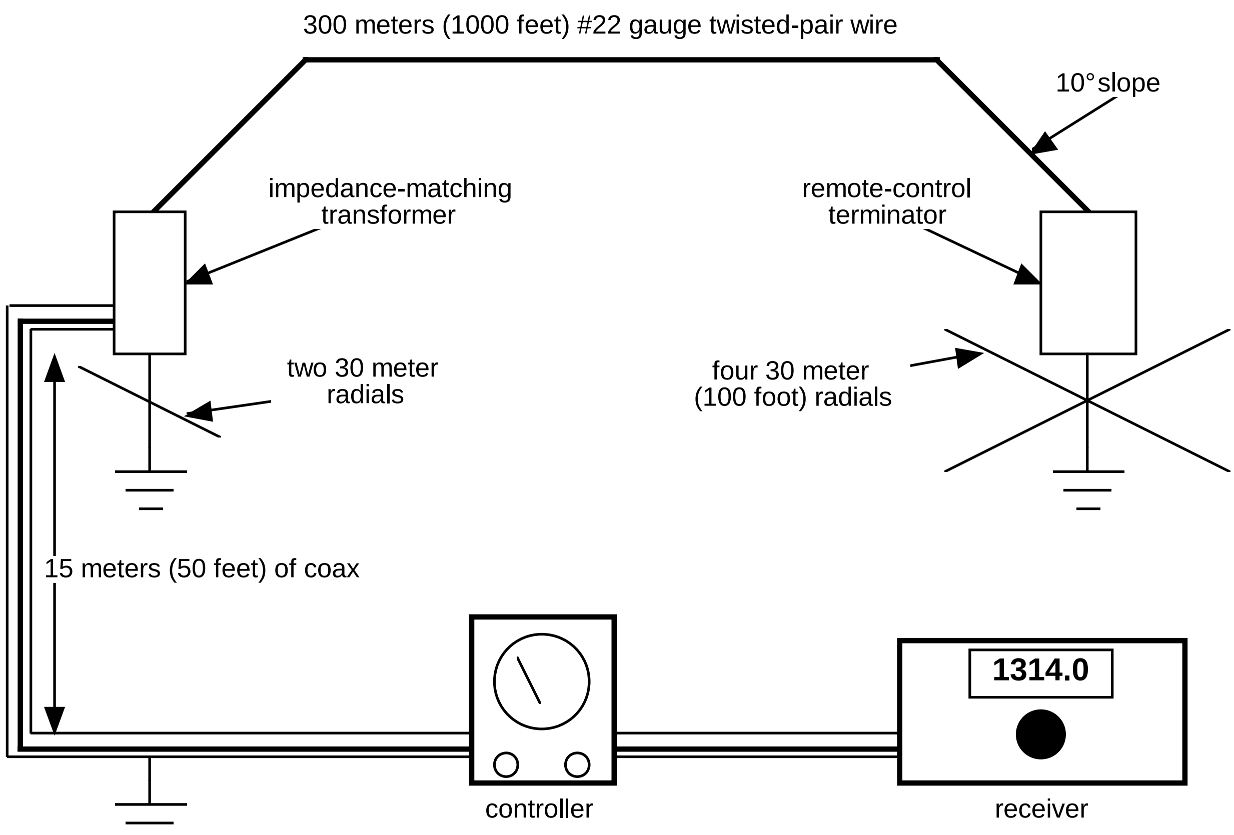


Figure 5. RCT Beverage components.

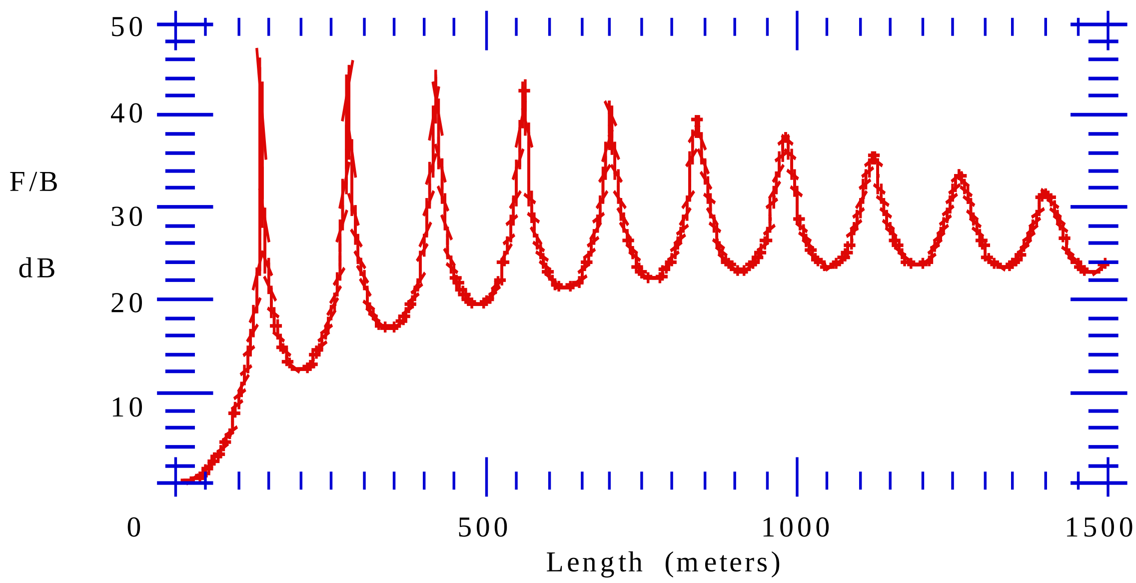
The antenna wire is spooled on a 14 inch cord-wheel. It connects to the terminator through a pair of banana plugs. A pair of insulation-piercing test clips connect the antenna wire to the matching transformer. The insulation-piercing test clips allow you to reel out the optimum length of wire for your frequency of interest. You simply clip-in to the wire leaving the remainder spooled on the cord-wheel. To ease the task of measuring the antenna length, Iíve had a special-run made of twisted-pair wire marked at 5 meter intervals.

As discussed in my forth-coming article “Beverage Antenna Termination: Why Bother?”, the front-to-back ratio of a Beverage varies considerably with the length of the antenna, reaching a local maxima at intervals of one-half wavelength. If you have a specific frequency for which you wish to optimize the antenna, adjust the length of the antenna to a multiple of one-half wavelength at that frequency, allowing for the velocity factor of the antenna which varies from 70% to 90% depending on the height above ground (Ref. 2 and 3).

Controller

The controller couples a variable DC voltage onto the coax feedline to the matching transformer. Coupling capacitor C6 blocks the DC from the receiver input. RF choke L2 blocks the RF signal from the control circuitry. V5, a Siemens gas-discharge tube, protects the controller and the receiver against transient voltages.

A #1815 incandescent lamp protects the controller against short-circuits. It limits the current to a maximum of 200 mA. The lamp in the opto-isolator takes a maximum of 40 mA so the current-limiting lamp has little effect unless there is a short-circuit. Then the lamp serves as a “short” indicator as well as current limiter.



1.0 MHz, 2 meters high, moderately-poor soil, 20.7° wave angle

Figure 6. F/B ratio versus antenna length.

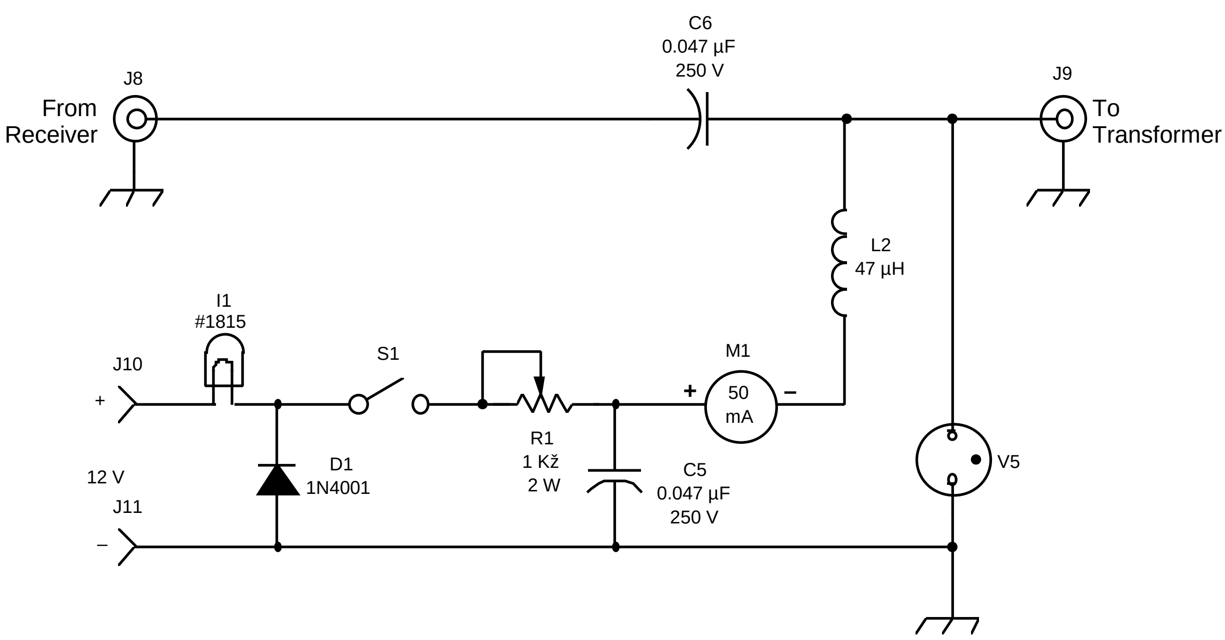


Figure 7. Schematic of RCT Beverage controller.

R1, a 1 KΩ 2-watt linear potentiometer, controls the DC voltage fed to the lamp. At its maximum resistance 12 mA flows through to the opto-isolator. This gives a termination resistance of greater than 100 KΩ, which is high enough to effectively be an open-circuit.

A 50 milliampere meter serves to detect an open-circuit if the clips donít pierce the insulation on the antenna wire, if the wire breaks, or if a moose drags off the antenna. It also allows you to make a rough estimate of the termination resistance. A 1N4001 diode connected in reverse across the DC input provides polarity protection for the meter. If the power source is connected with the wrong polarity, the diode will conduct and the current limit lamp will turn on, limiting the reverse voltage across the circuit to about 0.7 volts. This is small enough to prevent damage to the meter.

Matching transformer

The impedance-matching transformer contains a 9:1 unbalanced-to-unbalanced transmission-line transformer. It transforms the approximate 450 ohm impedance of the Beverage antenna down to 50 ohms to match the coax feedline. Without impedance-matching, there is a loss of 14 dB between a 450Ω antenna source and the 50Ω input of the receiver. The transformer consists of 5 trifilar tight-wound turns of #30 AWG Kynar wire-wrap wire on an Amidon Associates FT50-75 ferrite toroid core. I use Kynar-insulated wire rather than enameled magnet wire in order to raise the impedance of the trifilar transmission line. Similarly, the wires are tight-wound in parallel rather than twisted together in order to maximize the impedance of the trifilar line. The type-75 core material is high-permeability, so five turns is sufficient to give more than enough inductance to cover the low end of the broadcast band. The measured -3 dB point of the entire controller and matching-transformer system is about 200 kHz at the bottom and well above 10 MHz at the top.

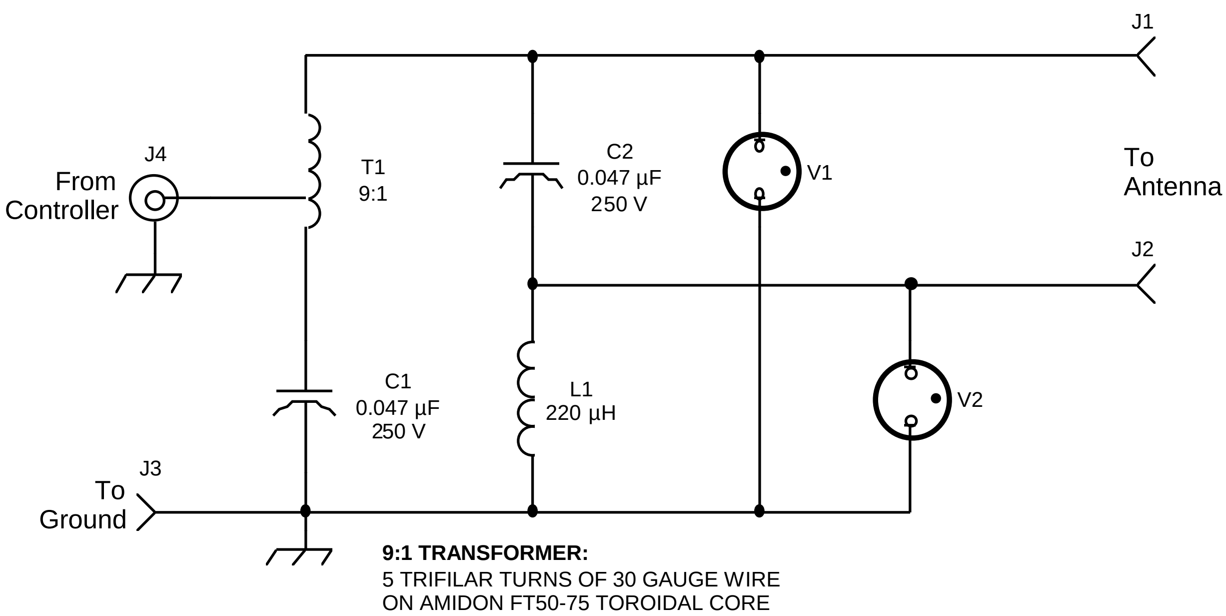


Figure 8. Schematic of RCT Beverage transformer.

Coupling capacitor C1 prevents the primary winding of the transformer from shorting the control voltage to ground. Coupling capacitor C2 couples the twisted pair antenna wires together for RF but blocks the DC control voltage. The transformer couples the DC control voltage on the center conductor of the coax feedline to one of the pair of antenna wires. RF choke L1 provides a DC connection to the coax shield for the remaining wire.

A pair of gas-discharge tubes (V1 and V2) protect the transformer from transient voltages.

Terminator

The incandescent lamp in Y1, the VTL3A27 opto-isolator, connects directly across the pair of antenna wires. Coupling capacitors C3 and C4 block the DC control voltage from the CdS photocell. The photocell in Y1 connects directly to the ground system.

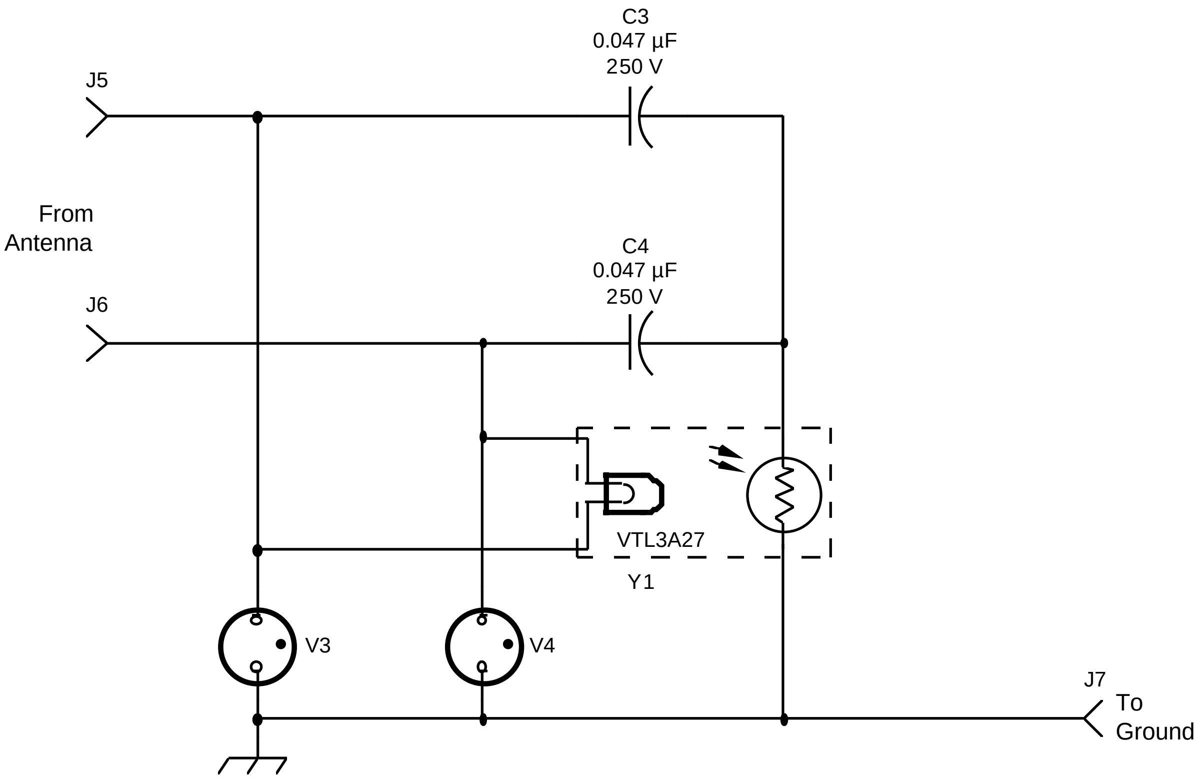


Figure 9. Schematic of RCT Beverage terminator.

Two gas-discharge tubes (V3 and V4) protect the opto-isolator from transient voltages. I used to use NEñ2 neon lamps as surge voltage protectors, but after a few nearby lightning strikes the NEñ2's give up the ghost. The failure mode is interesting in that there is no visible damage. They appear intact but the firing voltage is very high, possibly due to sputtering removing the rare earth coating on the electrodes. I was losing an opto-isolator every week in the summer until I finally discovered the bad NE-2's. The induced transient from the lightning strike would usually take out the incandescent lamp. This shows up immediately on the controller meter as an open circuit.

I occasionally encountered another failure mode where the photocell resistance gradually increases. Presumably the transient vaporizes some of the CdS material and slightly narrows the resistance track, which slightly increases the on-resistance. Over time, the minimum on-resistance goes up enough so that the antenna will no longer null. This can be a real puzzler - I initially suspected problems with the ground system until I finally found the bad photocell and NEñ2 lamps. I now use heavy-duty gas-discharge tubes rather than NEñ2 neon lamps.

Parts List

Most of the components are readily available from mail-order suppliers such as Digi-Key, Mouser, and Allied. VTL3A47 Vactrols are available from Allied. VTL3A27 Vactrols are available for $6.00 each plus $2.00 shipping and handling per order from:

Oak Ridge Radio
P. O. Box 2092
Littleton, MA 01460-3092
oakridge@ultranet.com
http://www.ultranet.com/~oakridge

Assembled RCT Beverage systems are also available from Oak Ridge Radio.

Qty	Designator	Description	Manufacturer	Part No.
6	C1-C6	0.047 µF 250V polyester capacitor	Allied	MDD-22E43KB
1	D1	1N4001 diode - 1 amp 50 PRV	–	1N4001
1	I1	1815 lamp -14.0 volt 200 mA bayonet T3-1/4	Chicago-Miniatu	1815
1	L1	220 µH RF choke 155 ma	JW Miller	77F221
1	L2	47 µH RF choke 340 ma	JW Miller	77F470
4	J1,J2,J5,J6	banana jacks, rib loc insulated solder terminal, yellow	Johnson	108-2307-801
2	J3,J7	banana jacks, rib loc insulated solder terminal, green	Johnson	108-2304-801
3	J4,J8,J9	SO-239 UHF panel receptacle	Amphenol	83-1R
1	J10	binding post, insulated standard, red	Johnson	111-0102-001
1	J11	binding post, insulated standard, black	Johnson	111-0103-001
1	M1	50 mA meter, rectangular, 2-1/2 inch	Simpson	5880
4	P1,P2,P5,P6	banana plugs, insulated solderless tapered handle, yellow	Johnson	108-307-001
2	P3,P7	uninsulated banana plug panel mount threaded stud	Johnson	108-0750-001
1	R1	1 Kž potentiometer 2 Watt RV-4 type	Clarostat	RV4N102
1	S1	SPDT miniature toggle switch	Alco	MTA-106D
1	T1	ferrite toroidal core for T1	Amidon	FT50-75
5	V1-V5	surge voltage protector - 90V, 20 KAmp	Siemens	A81-C90X
1	Y1	incandescent/CdS analog opto-isolator 12V, 160ž	EG&G Vactec	VT3A27
2	clips	insulation-piercing test clips	J.S. Popper	JP8783
5	clips	battery clip, 3/4" jaw opening, copper	Mueller	25-C
1		14" diameter cordwheel		
1000'		#22 gauge stranded twisted-pair - antenna wire		
600'		#24 gauge stranded wire - ground radials		

Figure 10. Parts list for RCT Beverage.

Antenna installation

I use four foot ground rods purchased from Radio Shack as mechanical supports for the terminator and matching transformer. A large Mueller battery clip grips the ground rod and the terminator or matching transformer enclosure plugs onto a banana jack attached to the battery clip. The ground radials also clip onto the ground rod using battery clips. I use two radials on the matching transformer and four at the terminator. The two on the matching transformer arenít really necessary. They do increase the received signal strength somewhat. The four radials at the terminator are absolutely necessary to get the ground impedance low enough to successfully terminate the Beverage. More radials are better. Arrange the radials symmetrically about the ground rod and antenna so that any signal pickup will cancel out.

Those hardy souls who DXpedition from a tent or cabin using battery power neednít bother with coax feedlines. For the rest of us, I recommend placing the matching-transformer end of the Beverage at least 50 feet (15 meters) away from any power-lines or structures containing electrical wiring. Most sources of radio-frequency interference are not very good antennas, so most of the noise pickup comes from the near-field. The intensity of the near-field diminishes with the third or fourth power of distance, so moving the antenna a little further away from local noise sources makes a tremendous difference in the received RFI noise level.

To avoid degrading the directivity of the Beverage by pickup in the feedline from the matching transformer to the controller, use only quality coaxial cable with a 95% or better shield braid coverage, such as Belden 8259 (a good RG-58 type cable) or RG-6 CATV cable. In particular avoid Radio Shack RG-58 cable as it has poor shield coverage and consequently is quite leaky.

I find it very helpful to use two grounds on the coax shield, one at the matching transformer and one near where the coax cable enters my shack or DXpedition cabin. The second ground helps prevent RFI from the house from traveling down the outside of the coax and coupling into the inside of the coax at the matching transformer.

For similar reasons, I recommend keeping the coax on the ground (or for permanent installations, buried) rather than suspended off the ground. The lossy earth absorbs RFI traveling on the outside of the coax.

Here in New England the forests contain a lot of brush which makes an excellent support for temporary Beverage wires. For situations where one canít improvise supports, I recommend procuring a bundle of hardwood or bamboo garden stakes.

I try to place the wire up about one-and-a-half to two meters off the ground. Lower is OK, but the increased loss reduces received signal strength and tends to blunt the nulls.

Gently slope the antenna wire down to ground level at the terminator and matching transformer rather than running it vertically. Vertical runs will act as short omnidirectional antennas and will spoil the directivity of the Beverage. Use about a 1:6 slope; i.e. for a wire 2 meters high, slope the wire down over a length of about 12 meters or 40 feet. This results in about a 10° angle.

If you have a specific frequency for which you wish to optimize the antenna, adjust the length of wire to a multiple of one-half wavelength at that frequency, allowing for the velocity factor of the antenna which varies from 70% to 90% depending on the height above ground (Ref. 2 and 3).

Antenna operation

In practice itís difficult to achieve null depths greater than 30 dB or so. The AGC range of most receivers is at least this large, so you wonít hear any audible change in signal strength unless you disable the AGC. I find it easiest to adjust the remote termination by switching off the AGC, adjusting the RF or IF gain to avoid overload, and slowly rotating the termination control until I hear the null. Iíve tried using the S-meter, but the controlled-carrier schemes used by many mediumwave stations causes the S-meter to bounce around with the modulation. This makes it difficult to locate the deepest null.

The local 50 kW clear-channel station WBZ-1030 is located on a bearing almost directly behind my tropical-band Beverage aimed at Papua New Guinea. This Beverage is 175 meters long and about 3 meters off the ground. For these antenna parameters, the theory predicts a ground-wave front-to-back ratio of about 22 dB. When the Beverage is unterminated, I measured WBZ at -29 dBm. When adjusted for maximum rejection of WBZ, the signal strength drops to -52 dBm, for a null-depth in this case of 23 dB. This measurement is in fairly good agreement with the theory.

References

1. Belrose, Litva, Moss, and Stevens, “Beverage Antennas for Amateur Communications”, QST Magazine, January 1983, pp. 22-27.

2. Beverage, H. H., “The Wave Antenna for 200-Meter Reception”, QST Magazine, November 1922, pp. 7-15.

3. Beverage, H. H., and DeMaw, Doug, “The Classic Beverage Antenna, Revisited”, QST Magazine, January 1982, pp. 11-17.