THE WAVE ('BEVERAGE') ANTENNA
DESIGN AND OPERATION

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INTRODUCTION

Much has been written about the Wave Antenna, usually called the 'Beverage' after Dr. H.H. Beverage, who developed it operationally at Riverhead, Long Island for RCA's transatlantic radiotelegraphy service and described it in *QST* in 1922 [1]. Paul Godley used one on his famous receiving DXpedition to Ardrossan, Scotland in 1921.

For those who have the space to accommodate it, the Beverage is ideal for reception of signals from the lowest frequencies used for radio, through the low and medium frequency broadcasting and the Tropical bands to about 7 MHz. Beverages have been used to 30 MHz [17] but it becomes debatable where an antenna ceases to be a Beverage and becomes a terminated longwire.

It has useful directivity, responds to signals arriving from both very low and quite high angles, is famous for a high signal-to-noise ratio, works well over poor soil, and is relatively easy to construct. Being so close to ground it is inefficient, but for reception this is no problem. The all-important factor in reception is signal-to-noise ratio, and the most useful thing about the Beverage is that it attenuates the noise more than it attenuates the signal.

Inevitably, some of the statements made about it over the years are questionable, some are just plain *wrong*,and as a result some myths have arisen (like "the longer the better"). The assignment for this article is to answer two questions:

1. How sanitary do the design and construction have to be for it to work?
2. How sanitary do they have to be for it to work *well?*

This article dwells on the fundamentals of the design and operation. It is not intended to be a stand-alone guide to the construction of broadband transformers and phasing modules. But references are given that do include such information.

I saw a Beverage for the first time about 1937 at a BBC receiving station in southern England. I still remember the awesome change in signal quality as the operator switched from antenna to antenna while receiving a Swiss MW broadcasting station. A few years later I built one for a special purpose while serving in the RAF, and it performed just as well or better on frequencies around 4 MHz. I have been a believer ever since, and specializing in 160 metre operation, have played with and used several kinds of Beverages—long, short and steerable.

Most of the information here is derived from the advice of people much more knowledgeable than I am. I have tried to keep it simple. If you want to dig into the matter, beg, borrow or steal some of the documents listed at the end of the article. But be prepared for some heavy and sometimes conflicting reading. Remember that the man with one watch thinks he knows what the time is, but the man with three watches is never quite sure. Experts sometimes differ, and the deeper you get into it, the more complex it seems. If you want just one source of theoretical and practical information on the subject, make it Vic Misek's *Beverage Antenna Handbook* [2].

WHAT THE BEVERAGE IS AND HOW IT WORKS

John Hines of Ohio State [3] described the Beverage as:

> "...a long transmission line...also called the wave antenna. In its very simplest form...a single straight horizontal wire a few feet above grade level, the length being anywhere from one to several wavelengths. The characteristic impedance of this wire unbalanced to ground is roughly calculable by using the image in the ground as the second conductor in a parallel-wire system. The receiver is coupled in at one end of the line, and the other end is terminated in a resistance equal to the characteristic impedance. Stable ground systems are necessary at both ends."

His explanation of the way it works:

> "The long open-wire transmission line pointed in the direction of a passing wave has a high degree of exposure to the horizontal component of the wavefront because of the wave tilt that earth losses produce in vertically polarized low-frequency waves travelling along the surface of the earth. This

induces in the line a continuous series of emfs that are propagated along the wires in the form of a travelling wave. A passing wave sets up a travelling wave in the wire which starts at the distant end...and is propagated toward the end where the receiver is situated....The entire wire receives energy from the passing wave so the effects are cumulative at the receiver. Energy collected from a passing wave travelling in the opposite direction is ... dissipated in the terminating resistor so does not enter the receiver. Waves arriving from the side have comparatively little effect, hence the antenna has high directivity in the horizontal plane."

In 1986-87 VE7CRU and K7VIC tried some experiments at their respective locations (S-E British Columbia and northern Montana), with long straight wires on the ground and with some elevated a few feet. Results were difficult to analyze, so they asked Dr. Beverage for advice. He responded with some basic concepts and information [4].

Notes from Dr. Beverage:

The best length is one wavelength. A longer one may exhibit less attenuation of signal, but it will develop sidelobes and lose directivity. A shorter one will work somewhat, but will attenuate the signal more than necessary. The far end should be terminated with a resistor of about 500/600 ohms for a unidirectional pattern. A terminal ground system consisting of six 15' radials is usually sufficient. Height is not critical—5' to 10' above ground is OK. It should be as straight as possible, both horizontally and vertically. It is not imperative that it be on flat ground. It can be built up a mountainside as long as it is reasonably straight and points at the skyline.

In a letter to *QST* in December 1981, Dr. Beverage said: "With antennas more than two wavelengths long, there may be sufficient phase lag, such that the signal strength will actually decrease with an increase in the antenna length." In fact he called it the 'Wave Antenna' because it worked best when it was one wave long.

ESSENTIAL ELEMENTS

Each factor to be considered in the design of a Beverage is covered in turn. There is some repetition when there is interaction between factors, to make each discussion as complete as possible.

- **LENGTH** of the horizontal wire(s) determines the directivity, and to some extent the gain.
- **STRAIGHTNESS OF THE WIRE** affects the gain, the useful length, the stray pickup of vertically polarized signals.
- **TERMINATION** at the far end from the receiver makes the antenna unidirectional and operable on a broad band of frequencies.
- **HEIGHT** of the wire above ground affects the efficiency, the response to signals from all directions, the impedance.
- **ANTENNA LAID ON THE EARTH** is surprisingly effective, and could sometimes be the best way to do it.
- **GROUND CONDUCTIVITY** affects the gain and the stability.
- **COUPLING TO THE RECEIVER** has to include matching the antenna to the receiver and providing near-end termination to minimize back and forth reflection of signal currents.
- **LOCATION / ENVIRONMENT** includes consideration of the supports and nearby metal objects and wire fences.
- **DIRECTIVITY PATTERNS** are not so narrow and 'clean' as many believe they are.
- **THE TWO-WIRE BEVERAGE** has reversible directivity.
- **STEERING THE NULLS** in the directive pattern is possible.

We will first deal with the form shown in Figure 1, a single wire terminated at the far end with a resistor equal to the characteristic impedance of the wire. At the beginning of Hines' definition we run into a statement that needs some discussion: "length anywhere from one to several wavelengths". (In the comparisons that follow, you may wish to make a table of advantages and disadvantages, according to your own specific requirements and value judgments.)

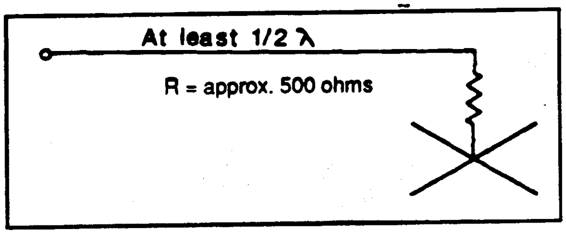

Figure 1.

LENGTH:

(1) When the antenna is terminated with a resistance equivalent to its characteristic impedance, it is aperiodic (not resonant), so no exactitude in length is necessary. An increase or decrease of 10% will not be noticeable at the receiver. But if you need an absolutely maximum front-to-back ratio, there are specific lengths that will achieve it. Misek suggests 1.6 to 1.7 wavelengths for 1.8 - 7.3 MHz and .53 to .56 wavelengths for the medium wave broadcasting band [1].

(2) For general purposes, about one wavelength long is the optimum for amateur or SWL purposes, if other essentials (straightness, wire gauge, isolation from parallel conductors for example) can be achieved.

A "one wavelength long" Beverage will be physically shorter than one wavelength calculated from the frequency of design, because the signal will travel more slowly along the wire than it does in free space. The ratio between the two speeds is termed the "velocity factor", expressed as a percentage or as a decimal fraction. 90% or .9 means the antenna thinks the wire is 100' long when it is actually 90'. The 100' may be referred to as the 'electrical length' and the 90' as the 'physical length'.

For a one wavelength Beverage, best directive properties are obtained with a velocity factor of 70-80% [5].

(3) If it is much shorter than one wavelength:

a) less signal voltage is developed at the receiver;
b) the main lobe is broader;
c) it responds to higher vertical angles of arrival;
d) there are less secondary lobes off to the side, so in this respect directivity is better;
e) Unless special measures are taken, the shortest practical length is about half a wavelength.

(4) If it is much longer than one wavelength:

a) the main (straight ahead) lobe is narrower;
b) it responds to lower angles of arrival straight ahead;
c) the longer it is, the more secondary lobes appear (vertically as well as horizontally);
d) there comes a length, depending on the velocity factor of the particular antenna, where the signals travelling along the wire and those arriving from space cease to add in phase, and signal strength at the receiver input drops in amplitude.

(5) I have seen designs aimed at optimizing a Beverage on several frequency bands, using traps and relays for selection of different lengths, but they seem very complex. It seems to me the soundest approach would be to make it about two wavelengths long at the highest frequency and settle for it being shorter than optimum at the lowest. But my personal bias shows through here. I firmly believe too short is better than too long. And I believe the simpler the better.

(6) An interesting idea for a multi-length antenna was described by WB3GCG [19]. It has the advantage that it is also reversible in direction, but there are many hundreds of feet of coaxial cable.

There is a 'grazing length' [6] defined as the length required for the induced current in the wire to reach a maximum. With a wave antenna several wavelengths long there is a broad ripple of current at half wavelength intervals. With an antenna longer than the grazing length the current settles down to a mean value somewhat less than the maximum amplitude of the ripple. The directivity pattern changes but there is no increase in gain. Knowing the grazing length helps keep the antenna length down to the length necessary to achieve maximum signal at the receiver.

At lower frequencies (say 1 MHz) the grazing length reduces by a factor of two for each 10 times decrease in ground conductivity. At higher frequencies (say 5 MHz) the grazing length tends to be proportional to the distance the wire is from the ground.

(5) If the antenna is left unterminated at the far end, avoid any length that is an odd multiple of a quarter wave. An unterminated transmission line of this length looks like a very low impedance at the near end—incidentally this applies to the random-length coaxial 'snake' antenna, and may explain why the 'snake' works for some and not for others.

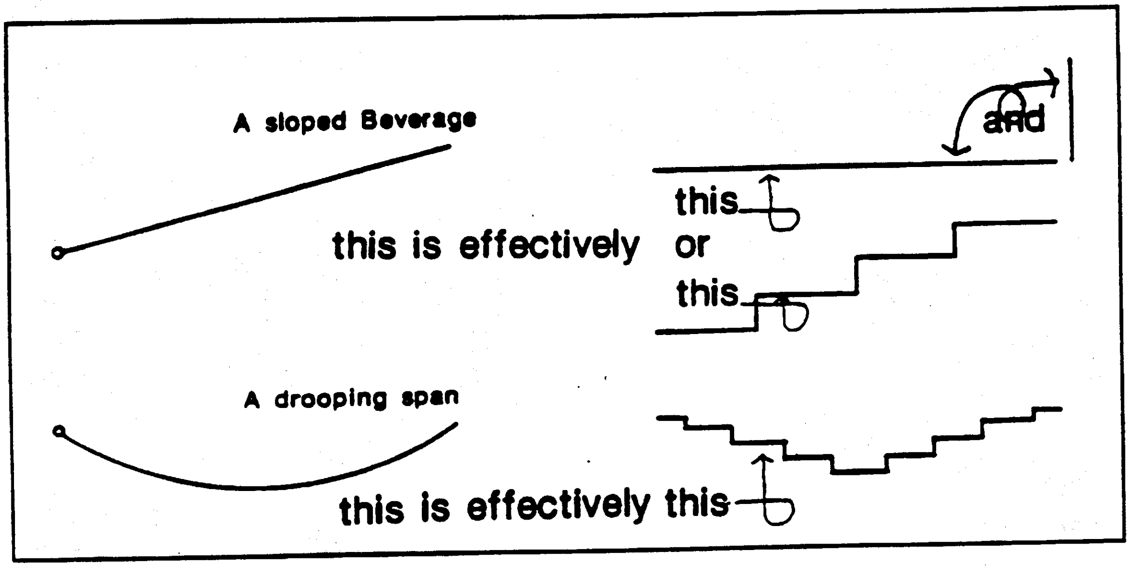

FIGURE 2.

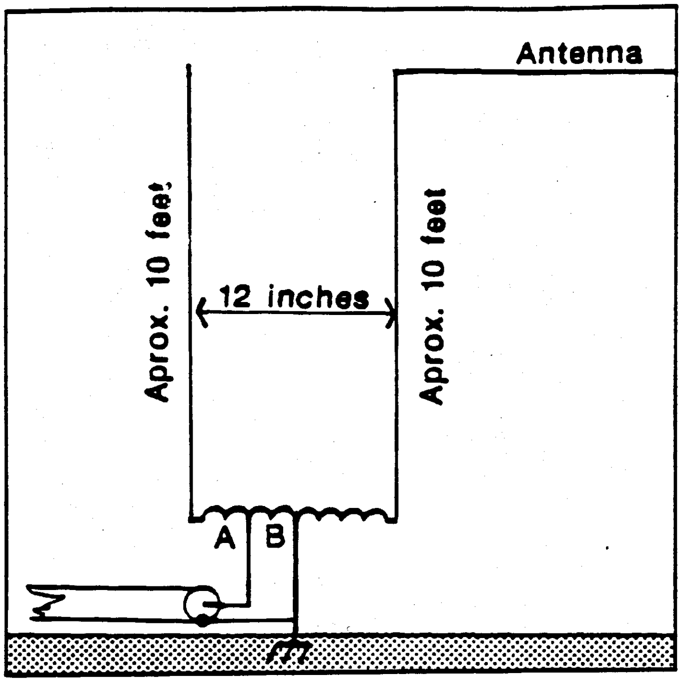

FIGURE 3. Broadband transformer suitable for frequency of interest.

STRAIGHTNESS OF THE WIRE

The wire should be as straight as possible *both horizontally and vertically.* There are several reasons for this:

(1) Current builds up best when the signal travelling along the wire keeps pace with the wavefront travelling in space. Any wiggle in the wire causes it to lag behind, because it has further to go on the wire while it travels straight in space. This is the main disadvantage of wiggle, as it also limits the length of wire usable before the signal on the wire begins to antiphase itself. As long as the wire keeps going in a constant average direction, the wiggles do not have much direct effect on the directivity;

(2) Any sag in the spans between supports not only makes the wire physically longer, it also introduces an effective vertical element. A sloping wire can be represented as two separate and shorter wires, one vertical and the other horizontal (see Figure 2). In the case of the antenna we are considering, any effectively vertical element will pick up signals from all directions, filling in nulls in the pattern. The most serious case would be strong local broadcasting stations off to the side, as they use vertical polarization, and the Beverage responds mainly to horizontally polarized signals coming in from the side. Three or four feet of total sag begins to act like the vertical whip antenna on an automobile.

(3) Don't run the wire up over bumps and down through gullies—keep it straight. A pole in a gully should be longer, and one on a bump shorter, keeping the wire straight.

(4) With the wire several feet above the ground and the terminating resistor connected to a ground system, there is bound to be an effectively vertical connection. Instead of having a vertical wire at the end of the antenna, a popular way of solving the dilemma is to taper each end of the wire with a slope of about 10 degrees from antenna level to ground level [1]. The effective vertical component is still present, but at least it is distributed over a distance. If it is not possible to slope the wire, the vertical pickup can be neutralized, as in Figure 3. It is also possible to terminate the antenna with a resistor plus an extra quarter wavelength of wire left open at the far end, thus doing away with the downlead altogether [2] [15];

(5) If you have to go round something, do it as in Figure 4, to ensure that signals induced in the diversion wires cancel out as much as possible.

For minimum sag on an elevated wire, the wire should be light and strong. For a receiving antenna, a high signal-to-noise ratio is the objective, so efficiency is not very important. Galvanized electric fence wire has been used for many Beverages and can be pulled very tight without stretching. There is no sag if you lay the wire directly on flat ground!

ANTENNA LAID ON THE EARTH

K7VIC found that a long straight insulated wire on the ground worked quite well on 1.8 MHz, and that when on the ground a wire unterminated at the far end acted almost as if it were terminated. John Bryant found that in a quiet environment, wire 'Onna Bush' had rather better gain and directivity than one laid on the ground [7]. Don Moman found that a wire on the ground had worthwhile rejection of local (15-30 km) broadcasting stations while leaving medium wave DX stations cleaner and of about the same strength as those from an elevated wire. A wire on the ground has the advantage that there is no effective vertical component, because there is no downlead to the far-end ground.

Arch Doty K8CFU [8] built two identi-

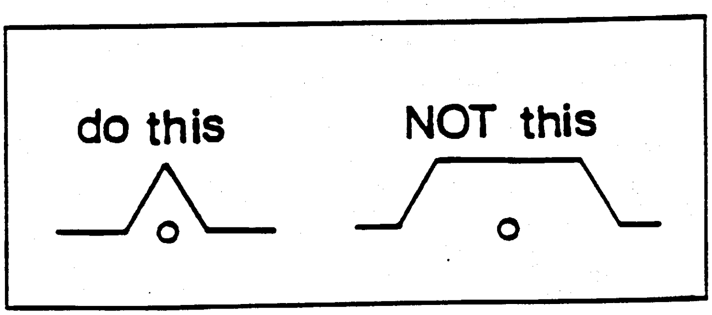

FIGURE 4.

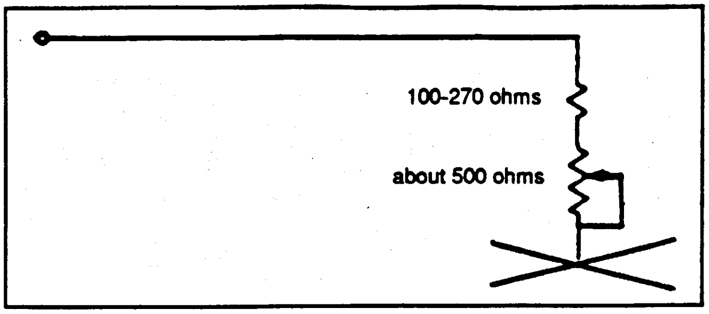

FIGURE 5.

cal 700' antennas, one 7' above the ground and the other lying on the surface (his ground conductivity is about 0.75 to 2.5 millisiemens/meter). In 500 comparisons on their performance, he could find no consistent difference between them.

Much depends on where you are and what you want to receive, but without doubt there is a lot to be said for laying the wire on the ground. And that's how Beverage started at Riverhead.

TERMINATION

The antenna should be terminated *at both ends* with something (a transformer or a resistor) equal to its characteristic impedance to prevent or at least minimize a standing wave on the wire.

(1) The termination at the receiving end is normally the transformer matching the antenna to the receiver (and of course a good match here ensures good signal transfer to the receiver input). If the match is not good, some of the signal energy will be reflected back along the wire. More about the transformer later, in the section on 'coupling to the receiver'.

(2) At the end distant from the receiver a non-inductive resistor equal to the characteristic impedance of the antenna system will dissipate most of the energy arriving from the 'back' end, an essential factor in creating a unidirectional pattern. If the far end is left open, reception from the rear will be almost as good as that from the front, and the gain in the forward direction will be as good as ever. If you are always using the antenna for signals from the west at dawn, this is quite a satisfactory arrangement.

(3) There is another benefit from termination. It ensures the antenna is not resonant at any specific frequency and makes it operate as a true travelling wave antenna. This is not the place to discuss the impedance transformation effect of a length of transmission line, but this aspect deserves some thought. The Beverage is in many respects like a transmission line.

The value of the terminating resistor is dependent upon many things. The gauge of the wire, the material and thickness of any insulating covering, the height above ground, the nature of the ground, the quality of the insulators for example. There are hundreds of Beverages with resistors of a guesstimated value between about 450 ohms for a low wire and about 600 ohms for a high wire (like 19 gauge wire 10 feet above ground). If you are not a purist these values are as good as any. Things change somewhat with a heavy shower of rain anyway. But if you want to establish the correct value, there are several ways to do so.

Remember that the terminating resistor is in series with the far end grounding system, so organize the grounding system first! If you use six or so 15' radials connected to a 2' ground rod there will probably be a few tens of ohms effectively in series with the resistor. Making the ground rod longer will not reduce the resistance of the ground connection very much. 8' and 10' rods are excellent for safety grounds, but are not necessary for r-f purposes. Also they may pick up some signal and harm the directivity, especially if the soil conductivity is poor. Underground antennas do work.

Connect a fixed composition resistor of about 100 to 270 ohms to the far end of the antenna, in series with a variable composition resistor of about 500 ohms, as shown in Figure 5. If for some reason (animals or people for example) you cannot slope the end of the antenna gradually to the termination, position the resistors at the antenna rather than at the ground, although for finding the best value it should make no difference.

The simplest method is to listen to a signal coming from the rear and adjust the variable resistor for minimum signal strength. A friend at the far end with a handie-talkie or a cordless telephone is very useful. If there is no convenient signal from the rear you can produce one. We did it once using an idling automobile with unsuppressed ignition!

MFJ Enterprises produce a very useful self-contained SWR (standing wave ratio) Analyzer (Model 207 for 10-160 metres, probably quite easily modified to cover the MW band). You could put this in place of the receiver and adjust the resistor for best SWR at the frequencies you are interested in.

Vic Misek [2] describes how to inject a signal into the antenna from a signal generator and adjust the resistor for maximum damping effect on the standing wave produced on the wire ('smoothing out' the change of signal voltage on the wire as the generator frequency is varied).

The classic article written by H.H. Beverage in 1922 [1] was reprinted with minor changes in *QST* in 1982 [10] and in its entirety in the book *Genius at Riverhead* [20]. It has a detailed description of antenna current measurements with and without terminating resistors, with plots of the change as the generator frequency is varied. It also shows a method of neutralizing the effective vertical element pickup, termed 'end effect'. This article is essential for anyone interested in the history of the antenna, and it shows how the original concept has carried through almost unchanged to the present day.

The required value of terminating resistor varies with frequency. On an antenna 360' long and 4' high the value varied between 400 and 550 ohms over a range from 2 to 10 MHz [17].

HEIGHT

There is little advantage in having the wire higher than 10 feet above the average level of the ground. Higher wire develops more signal, but not very much more. Increasing the height by 10 times increases the signal by about two times.

Increasing the height increases the effective vertical component, picking up some signal from all directions. I have not tried neutralizing this. Deep nulls make me nervous, as I think I may be missing something I want to hear! Increasing the height above 10 feet increases the characteristic impedance, but not by very much.

Decreasing the height limits the practical length, because the velocity factor becomes lower and end-to-end losses increase. Over most soils, the effective ground is well below the physical surface, which is probably the reason a wire will work well lying flat on the ground.

Misek [2] prefers to run an insulated wire or wires on the ground, grounded at each end and parallel to the antenna, providing an artificial high-conductivity ground screen below the antenna wires. This stabilizes the characteristic impedance and improves the operation at higher frequencies.

GROUND CONDUCTIVITY

For operation below about 3 MHz, a Beverage works better over lossy ground. This is because the lower end of the arriving signal wavefront is slowed by the ground, and the resulting tilt causes the antenna to respond well to signals arriving at a relatively low elevation angle (the antenna thinks they are arriving from a higher angle). Above about 3 MHz, the antenna responds to signals arriving from the sky, with a wavefront tilted in relation to the wire because of the arrival angle. Jack Belrose found that at 2 MHz gain decreases as earth conductivity increases, but at higher frequencies gain increases as earth conductivity increases [17].

At low frequencies the current induced in the antenna decreases by a factor of two for each 10 times improvement in conductivity [6]. Wire is thousands of times better than any soil, so this may be an argument against running parallel grounded wires under the antenna for MWBC and below. There are pros and cons for everything! If the ground conductivity is very poor, more radials are necessary at each end, but keep them symmetrical or they will degrade the directivity.

Ground conductivity charts are available for the U.S., parts of Canada, and several other countries. Unfortunately the ground immediately below the antenna is anyone's guess unless it has been actually measured for conductivity [11], and even the average ground in the far field is likely to differ from the map prediction.

As a rough guide to the conductivity of soil, Tom Sundstrom measured the d-c resistance of the ground return path of one Beverage as ten to fifteen thousand ohms [18].

COUPLING TO THE RECEIVER

The single wire Beverage is an unbalanced antenna, and will normally have a matching transformer designed to match the 500 ohms or so impedance of the antenna to the 50 or 75 ohms impedance of a length of coaxial cable. The coax is then plugged into the coax input connector of the receiver. The coax minimizes signal pickup on the lead-in. The transformer can be an autotransformer like the one in Figure 6 (a single winding with a tap a few turns from one end), or one with separate windings like 'R' in Figure 18. There is some useful advice on different methods of ground connection to matching transformers, and details of materials and winding procedures in *Proceedings* 1988 [14]. Vic Misek's book [2] has 80 pages of detailed information, calculations, specifications, on several variations of the Beverage, based primarily on operation at 1.8 MHz.

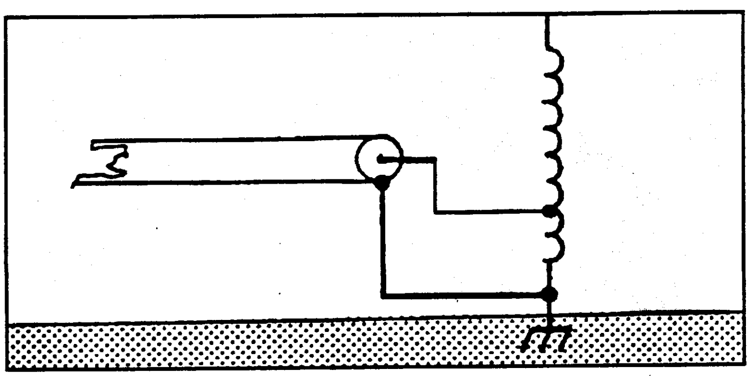

FIGURE 6.

If you want to cover several frequency bands, you need a broadband transformer, and any suitable design will serve. There are many designs in antenna and transformer handbooks. Remember that the impedance transformation is the square of the turns ratio, so for matching from 450 ohms to 50 ohms the turns ratio is 3:1. If you want to try making up your own, you had better read up on it first. For example using a core material suitable for the lowest frequency you intend to receive gives the best broadband effect, as the windings then have less and less inductance as the frequency increases.

It is advisable to mount the matching transformer in a metal box. Ferrite-cored transformers are quite effective antennas, and may pick up signals you would prefer not to hear.

A small ATU (antenna tuning unit) could be used instead of a broadband transformer to match to the receiver. It would have to be readjusted for different frequency bands, but has the advantage that it could be configured as a highpass or lowpass filter if there are problems from a powerful local station.

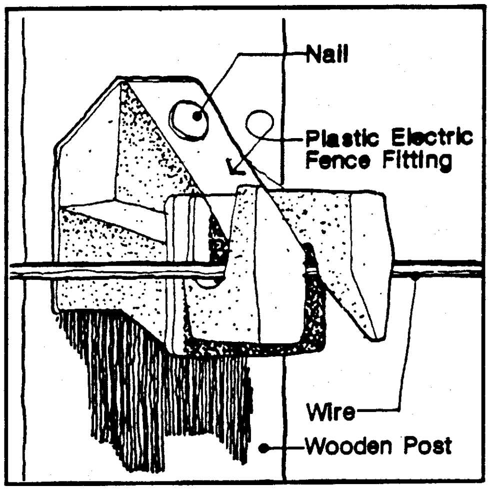

FIGURE 7.

You may need all the gain you can get if you are really serious about DXing. Many medium wave receivers are insensitive, but if you are fortunate or wise enough to have a sensitive receiver or preamplifier with high impedance front end (the antenna terminal intended for use with a random wire antenna), and the antenna ends close to the receiver, try connecting the antenna wire directly to that terminal, and you may get away without having to use a transformer.

There are many Beverages strung through woods and bushes and working well [7] [11].

A Beverage needs to be at least 200 feet from parallel antennas and other resonant structures. If there are several Beverages it is advisable to ground the ones not in use [18], although two Beverages crossing each other at 90 degrees appear to show no interaction [8].

Verticals are especially troublesome, as they reradiate vertically polarized noise and interference. Local electrical noise is not necessarily vertically polarized at its source, but the vertical component of it travels farther and is more likely to reach you. Try not to run a Beverage close and parallel to a wire fence, although some people have done so with no problems. If bare wire is used, and you don't live in an area with zero humidity and zero rainfall, insulators are necessary. I use standard electric-fence insulators like those shown in Figure 7. They are inexpensive and easily obtainable and seem to serve the purpose quite well. It is preferable to use insulators even with insulated wire, to reduce capacity to ground and as insurance in case the insulation wears through.

I use wooden posts, and for two-wire antennas, wooden crosspieces. I have a deeply rooted objection to vertical metal within the near field of an antenna, but metal posts seem to be OK [7] for people more psychologically stable. ABS plastic tubing would be ideal and the wire could be run through slots, without insulators.

DIRECTIVITY PATTERNS

The directivity of a Beverage depends on the elevation angle (the angle above the horizon from which the signal arrives). There are more and bigger sidelobes, the main lobe is wider, and the response to relatively high angle incoming signals is greater, than many people think. But this is just as well, because there are more high angle signals than many people think! A Beverage responds to vertically polarized signals from the front, and horizontally polarized signals from the side.

There are many ways to draw the pattern of any antenna. Plots are often referenced to the maximum amplitude of the main lobe. If the respective relative gains of a one wavelength and a two wavelength Beverage were not taken into account, there would not seem to be much difference except in the number of sidelobes. And if you compare one of them measured at 5 degrees elevation and the other at 30 degrees (or even the *same one* at the two different angles) you get an apparently confusing message. So check carefully before you decide there must be something wrong with the comparative directional patterns.

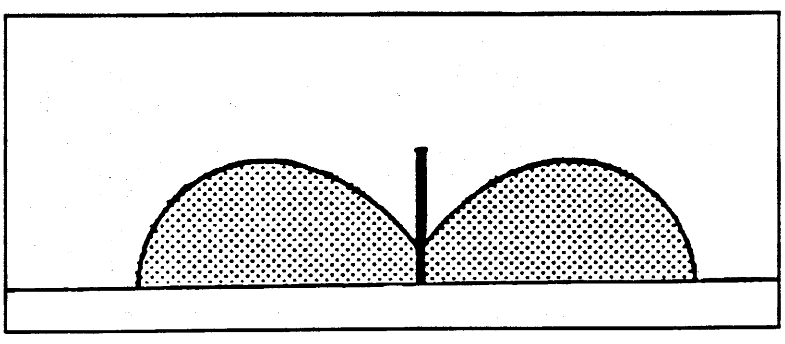

FIGURE 8.

It is not easy to draw three-dimensional patterns on a sheet of paper, and

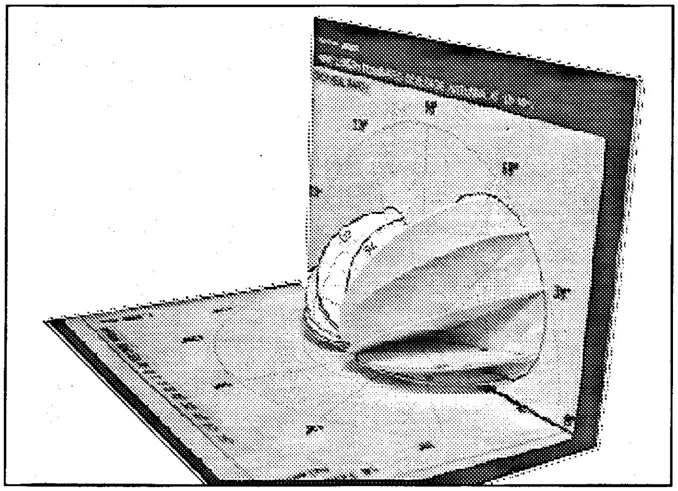

FIGURE 9.

authors often give up trying, which probably explains why many people do not have a clear idea what the true radiation envelope of an antenna looks like. Perhaps a good example is the pattern of a vertical monopole. The familiar vertical elevation pattern is that shown in Figure 8. The three-dimensional pattern looks like the top half of a doughnut with an infinitesimally small hole. Try drawing that, and then sympathize with the artist asked to portray a directional antenna with several sidelobes.

Figure 9 shows the three-dimensional pattern of a one wavelength terminated Beverage, as calculated by MN [16]. This is a photograph of a model constructed by John Bryant. A model is worth *ten* thousand words, and John's model has taught me enough about the influence of the ground on the response of an antenna to compensate for all the work of putting this article together! This image illustrates why a Beverage responds to different vertical angles and different polarizations of signal when the signals come from different horizontal directions. This means it *may respond to a particular signal better if that signal is not coming from dead ahead.* This is not unusual. A horizontal dipole responds best to high angle vertically polarized signals *off the ends*, not from a direction broadside to the wire. The familiar broadside 'figure 8' pattern of a halfwave dipole relates only to *horizontally polarized* signals at the optimum elevation. DX signals are unpredictable. They may come in from high angle, low angle or both at once. They sometimes come in from the wrong direction. The polarization is anybody's guess, and almost always there is some

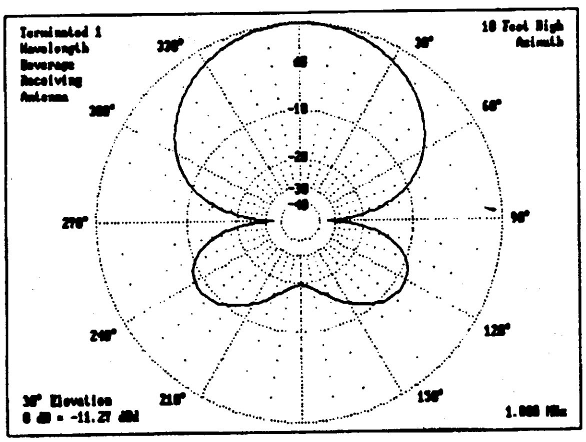

FIGURE 10.

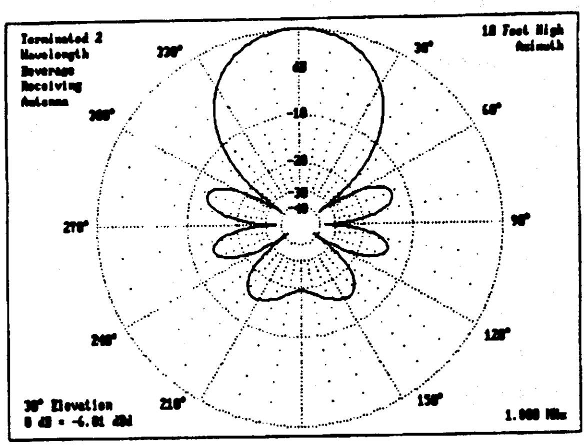

FIGURE 11.

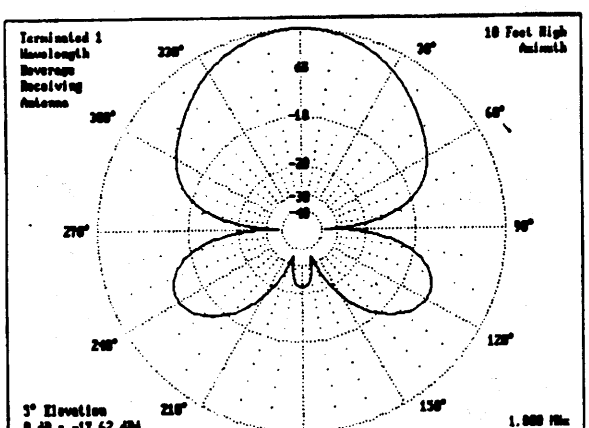

FIGURE 12.

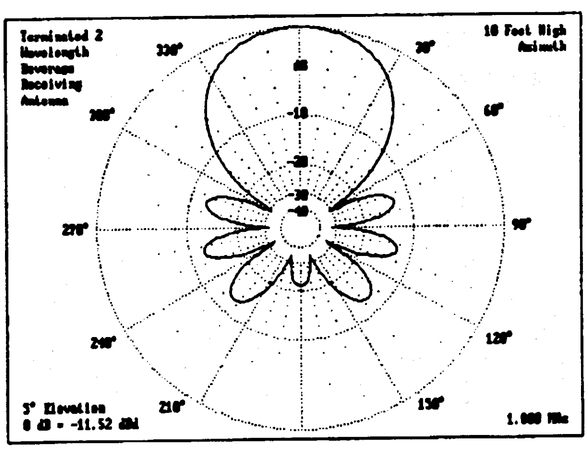

FIGURE 13.

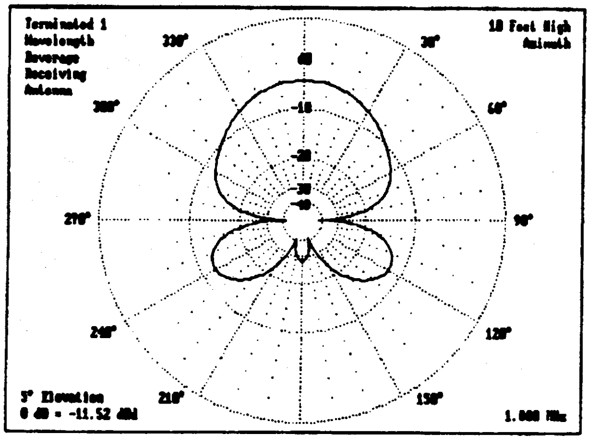

FIGURE 14A.

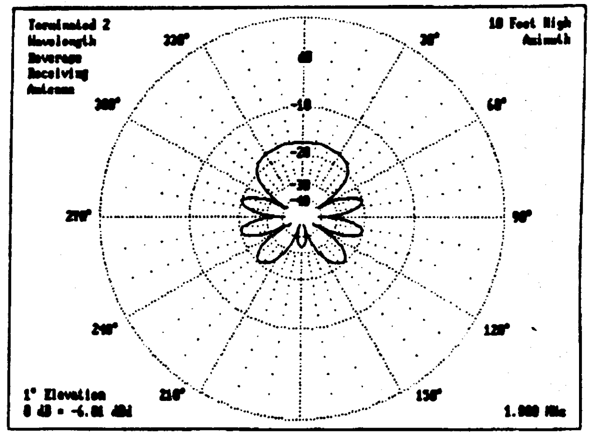

FIGURE 14B.

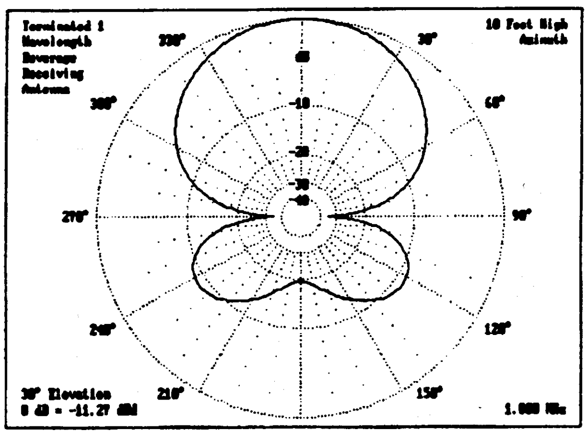

FIGURE 15.

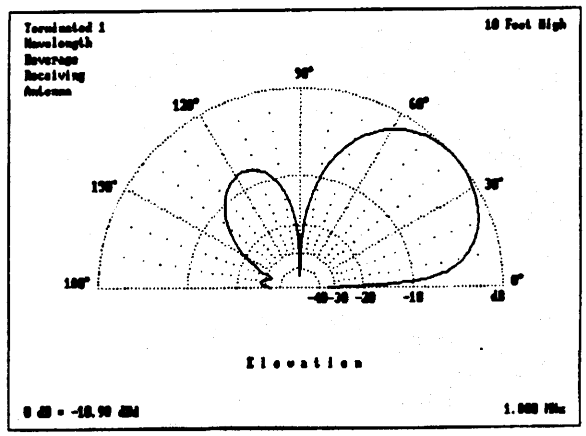

FIGURE 16.

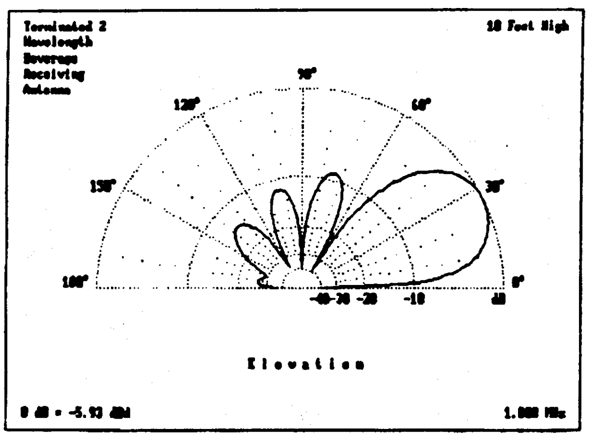

FIGURE 17.

of both. Only one thing is sure. The polarization will probably not be the same as it was when it left the transmitter.

Figures 10 to 13 show the directivity of two Beverages in the horizontal plane. For each antenna the pattern is shown at 5 degrees elevation and at 30 degrees elevation. Figure 14A shows one pattern of the one wavelength antenna 'normalized' to take account of the lower absolute gain (compare it with Figure 13, the two wavelength antenna at the same vertical angle). Figure 14B shows the pattern of the 2 wave antenna at 1 degree elevation 'normalized' to Figure 11. Normalizing gives a graphic reminder that the response in ALL directions is greatly reduced, making the unwanted lobes less fearsome. Figure 15 shows the one wavelength pattern plotted on a linear scale instead of a dB scale.

These have all been included to show the danger of comparing a pattern from one article with that from another without looking carefully at the specification of the plot.

Figures 16 and 17 show the elevation pattern of the two antennas when looking straight ahead. This is a vertical section through the lobes from 0 to 180 degrees of azimuth. These are all calculated patterns. In real life the nulls are not so sharp and deep, the lobes not so narrow.

The pattern plots were all developed using Brian Beezley's MN antenna analysis program for the IBM PC computer. Great fun to play with and extremely useful for analysis [16].

Jack Belrose measured the radiation of a 360' long and 4' high antenna at 18 MHz using airplanes and balloons, and found the measured lobes approximated those calculated [17].

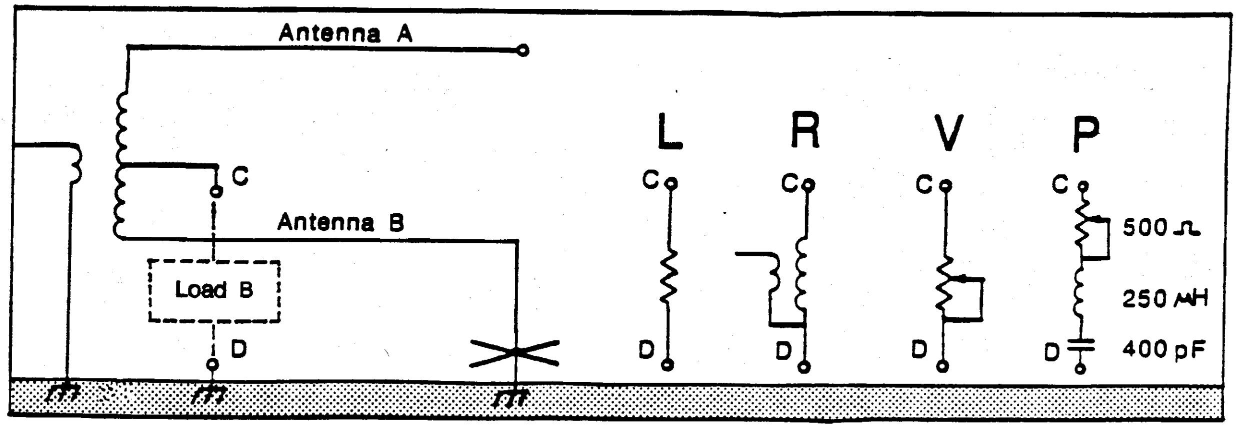

FIGURE 18.

THE TWO-WIRE BEVERAGE

There are disadvantages to the single-wire antenna. The termination is at the far end and sometimes not easy to get at. Characteristics tend to change with the seasons and the weather. A two-wire version, one variant of which [11] is shown in Figure 18, is a little more complex to build, but once in place it is more versatile and stable.

The two wires are parallel and about 12 inches apart. Length of each should be about half wave or multiples of a half wave. Height, kind of wire used, isolation from supports, are all the same as in the single-wire model. At the far end, one of the wires ends at an insulator. The other is grounded directly to a radial system WITHOUT a termination resistor.

The desired signal arrives from the left and travels along both wires, building as it goes. When it arrives at the end of the unterminated wire it has nowhere to go, so it is reflected back along the wire without a change of phase. It arrives back at the transformer A at the left end.

The signal travelling from left to right on the other wire meets a short-circuit at the far end, and is reflected with *reversal of phase*. When it arrives back at the transformer it is out of phase with the signal on the other wire. This is ideal, as they are connected to opposite ends of the transformer. +5 uV on one end at the same time as -5 uV on the other end puts 10 uV across the transformer. This in- phase addition recovers some of the loss incurred during the go and return trip the signal had to make along the wires. A signal arriving from the right travels along the two wires and arrives at the transformer. The signal is in the same phase on each wire. If you apply +5 uV to each end of a transformer winding you have no potential difference across the winding and no voltage will be induced across the secondary (the winding connected to the receiver). But this transformer has a center-tap connected through a load B to ground. Current will flow from each wire to the center of transformer A primary and from there into or through the load B.

If load B is a resistor (L in Figure 18) that matches the characteristic impedance of the antenna system it will

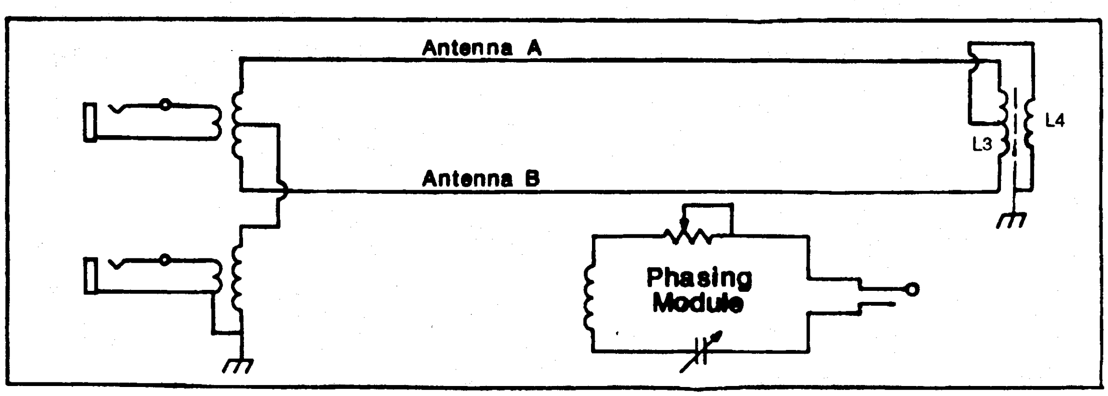

FIGURE 19.

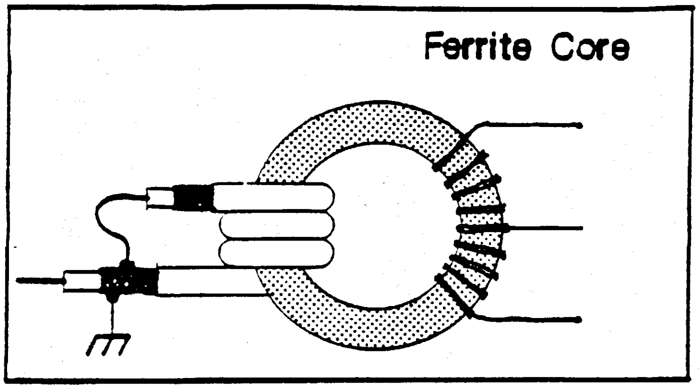

FIGURE 20.

dissipate the signal which arrived from the right, and we have a unidirectional system. If the load B is the primary of a transformer feeding a receiver (R in Figure 18) we have a system from which we can select signals from the left or from the right by plugging our receiver into the appropriate jack. To do the job properly a 50 ohms resistor should be plugged into the unused jack if there is no receiver there. It could be wired across the jack on an auxiliary contact, and automatically disconnected when a plug is in the jack.

STEERING THE NULLS

If the load B is variable (V in Figure 18) it can be custom adjusted to deepen the nulls in the pattern. If a tuning network is placed in series with the resistor (P in Figure18), the angle of the nulls can be moved [11]. The capacitor and inductor values depend on the frequency of operation. Adjustment is not easy, but if you first adjust the capacitor for a reduction in the interference (whether it be noise or undesired signal), then adjust the resistor to reduce it further, the improvement is sometimes like magic, especially if you are troubled by a ground wave signal from a local broadcasting station. Signals coming in from skywards are more difficult to null out, because the elevation angle from which they arrive is often changing quite frequently. The capacitor and inductor values shown are for 1.8 MHz. Double them both for MWBC operation (parallel the sections of a twin- gang 365 pF receiving capacitor), or try the 365 pF capacitor and ferrite loop from a portable radio.

Steerable-null antennas are best made an integral number of halfwaves long to simplify phase addition or subtraction [2].

An interesting variant of the steerable two-wire Beverage [11] is shown in Figure 19. The receiver is plugged into one jack, and the phasing circuit into the other. To reverse the directivity, the plugs are interchanged.

In this drawing, anti-phased reflection is shown as from a reflection transformer. In-phase signals arriving from the left flow from the center-tap of L3 to an unbalanced winding L4, and from there are induced into L3 again, but now the signals applied to the respective wires for sending back to the receiver are of opposite phase. A reflection transformer has to be carefully built to maintain balance, and should have a Faraday shield. It is easier to ground one wire and leave the other open instead of building a reflection transformer.

A shielded winding made from miniature coax cable is useful for the coupling to the receiver. RG58 or RG59 is better for the main run from the end of the antenna to the receiver position, unless the run is very short. Figure 20 shows how a Faraday shielded coax winding is constructed.

Detailed information on the construction of several two-wire steerable Beverages, center fed versions, a very short model, and several kinds of transformer, can be found in Vic Misek's 'Beverage Antenna Handbook' [2]. It is not practical to try to cover that kind of detail in the space available here.

CONCLUSION

How sanitary does a Beverage have to be to work? An insulated unterminated wire a few hundred feet long laid on the ground and pointed in the direction of the station to be received, connected directly to a sensitive receiver with high impedance input (like many MWBC receivers have) will have better signal to noise ratio than most antennas.

How sanitary does it have to be to work well? It depends what you want to receive and where you live. For hobby purposes you can be a bit careless and get away with it. Keep it as straight as possible and match it properly to the receiver. The rest of the answer to the editor's second question is a guide for experimental and educative fun.

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EDITOR'S NOTE: **Figure 15** is *not* drawn on a linear scale as indicated in the adjacent text. Rather, it is drawn on a dB scale due to a Staff error. Sorry, Bob!