Beverage Antennas - A Practical Guide

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INTRODUCTION

This article is based on a Zoom presentation given to the GMDX Group (https://www.gmdx.org.uk/) AGM in April 2021. The emphasis is on the practical aspects of beverage construction, with references to the underlying theory. Beverages are useful over a frequency range from about 130 kHz to at least 8 MHz and are therefore of interest not just to Medium Wave Listeners but also to amateurs, utility DXers, tropical bands enthusiasts, and SWLs. What follows is relevant to all.

What is a Beverage Antenna?

It's a non-resonant travelling wave antenna – in simple terms a wire laying on the ground or at any height up to roughly 15m above ground, one to 5 wavelengths long (in shorthand λ to 5λ in length).

The wire forms a transmission line with the ground below, and wavefronts approaching the antenna induce an RF current into the wire which builds as the wavefront passes, as shown in Figure 1 (source: Wikipedia).

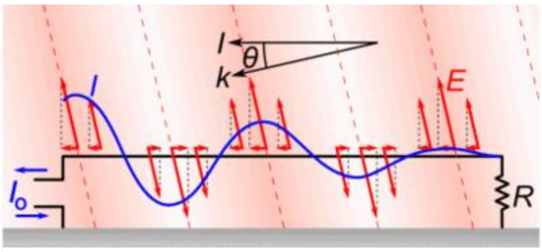

Fig 1: How a Beverage Receives Signals

Wanted signals arrive from the right of the picture and the current builds up over the length of the wire to be presented to the receiver at I_o. The furthest part of the antenna from the receiver is terminated in resistor R (elswehere in this article referred to a Z_o), which has a value equal to the characteristic impedance of the transmission line; it is connected between the end of the wire and ground. Waves travelling in the opposite direction and picked up by the antenna are absorbed by this resistor, so the antenna is unidirectional. However, if the resistor is replaced by an open or short circuit it will become bi-directional since the induced signal is reflected back to the receiver.

The antenna is named after Harold H Beverage who invented it in 1921.

Why Might We Want to Build a Beverage Antenna?

For an antenna λ in length and 2m above ground:

- Good DX antenna - low angle ~ 15° - 40°
- High directivity ~ 40° - 90° 3dB beamwidth
- Low noise, good front/back ratio
- Mainly used for receiving (for hams, in conjunction with a vertical for transmitting)
- Less susceptible to noise pickup than a vertical antenna
- Wideband, so suitable for LW, MW (530 – 1710 kHz) and multiple ham bands (e.g., 40m – 160m, or 600m); ideal for wideband recording with SDRs
- Simple to erect, non-critical, but needs lots of space

In summary, it's an easy-to-construct high performance DX antenna with no tuning required.

Why Am I Qualified to Write About the Subject?

- MW DXing – wideband 530 – 1700 kHz since 1962
- DX Loggings Editor for Medium Wave Circle since 1987
- Semi-rural use along field boundary in 1980's in the south of England
- Participated in 7 MW DXpeditions to Sheigra between 1990 and 1998
- Clashmore – beverages continuously in use since 1999
- Monitoring of 160m FT8 as propagation indicator for MW using WSJT-X and PSK Reporter as described in MWN December 2020 Vol 66#07.

Locations

This map in Figure 2 shows the location of Clashmore and Sheigra, referred to above. Clashmore is about 40 miles (64 km) south-west of Sheigra.

North-west Scotland is an excellent location for MW DX, especially between October and February, which is one of the many reasons I moved here.

However, it's one of the windiest places on earth, and that has major implications for the construction of beverages, especially when they are set up semi-permanently.

Fig 2: Location of Sheigra and Clashmore

Antenna Map

Figure 3 shows a map of the antennas I extensively use, and all but the African beverage were erected for the 2020-2021 winter season. I normally keep the South American and East Coast North American beverages in place over the summer. The antennas are terminated at different posts some distance from the house (marked with a red dot) and fed through buried coaxial cable, in order to keep noise pickup to a minimum. It's normally recommended that buried coaxial cable have a PE sheath (e.g., Messe & Paoloni ExtraFlex Bury, available from ML&S in the UK, see https://www.hamradio.co.uk/) although I use cheap RG-213 with a thick PVC sheath that's lasted for more than 10 years in a very wet environment.

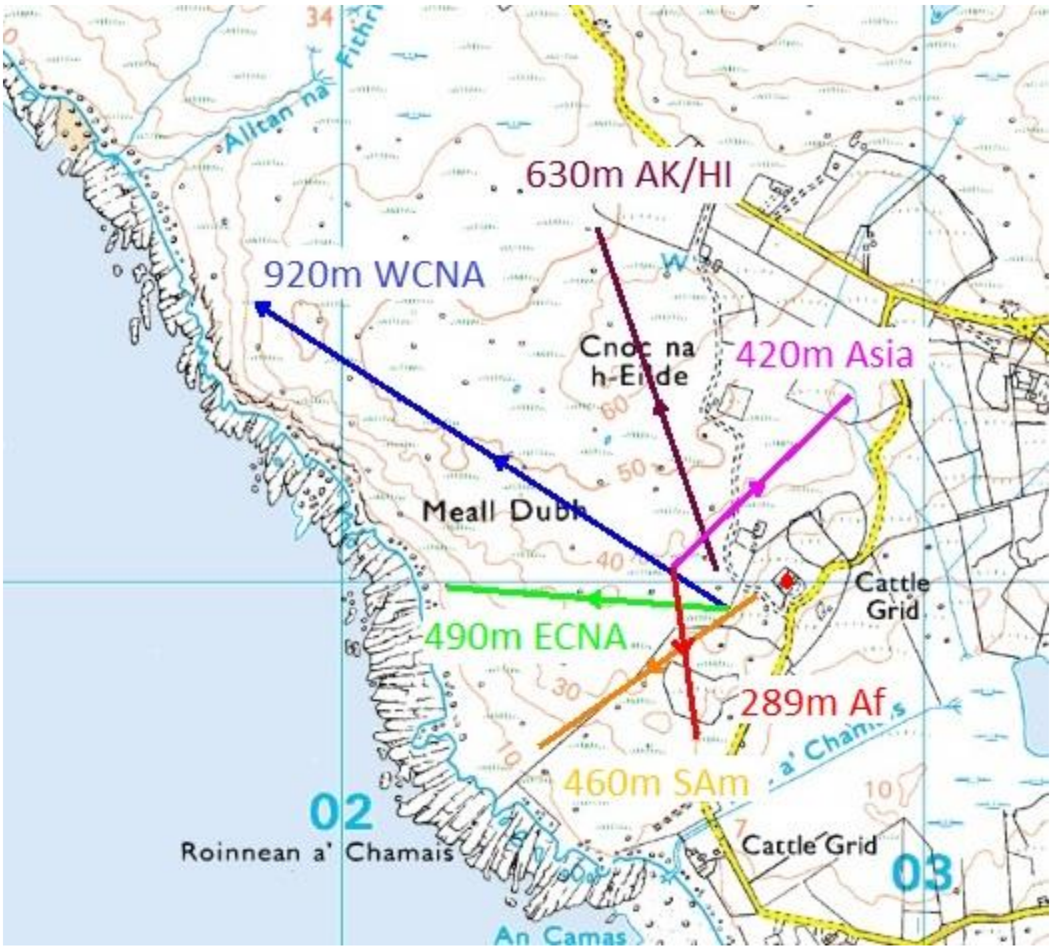

Fig 3: Map of Clashmore Antennas

Note the terrain profile from the contours. The ground is undulating, and slopes down to the sea towards the ends of the antennas for improved low-angle pickup and enhanced sea gain. This season was the first time I've erected a beverage as long as 920m following the example of MW DX enthusiasts in Scandinavia and e-mail dialogue with Bjarne Mjelde. It's on a very exposed position on a low ridge – when the wind blows from the south-west it accelerates up the slope to hit the antenna broadside-on. Figure 4 shows a photo looking towards the end of this antenna.

Fig 4: View of the last 100m of the 920m Beverage

This antenna has proved particularly useful for receiving low power MW stations from the east coast and from Ohio and surrounding states during the winter of 2020-2021.

BEVERAGE COMPONENTS and CONSTRUCTION

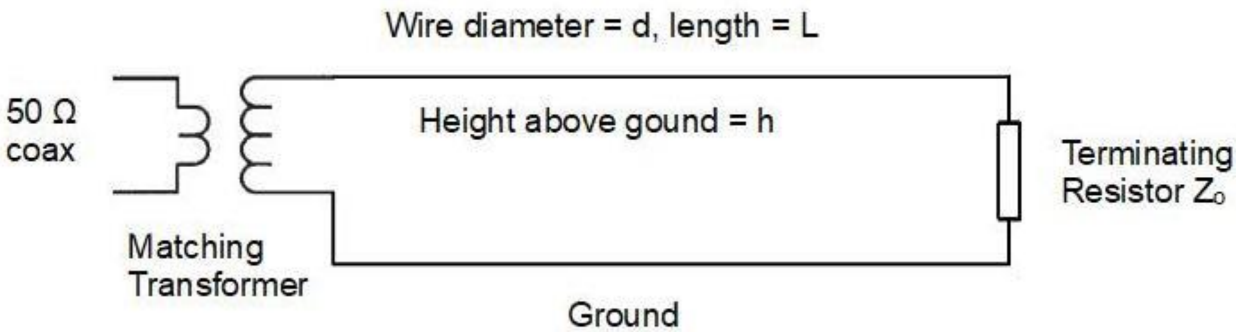

Fig 5: The Important Aspects of a Beverage

Figure 5 is a diagrammatic representation of the beverage. Z_0 is the characteristic impedance of the transmission line formed between the wire and ground, which becomes the value of the terminating resistor and of the primary of the transformer that matches the antenna to a 50 ohm feed line.

In the remainder of this article, we'll consider each in turn, first with simple theory, and then with the practical implications, starting with the wire.

<u>Choice of Wire</u>

The requirements are quite simple – the wire must have low resistance and be strong enough to withstand the environment. It should be available in continuous lengths of at least 500m and be supplied on a reel.

There are multiple choices, and everyone has their own preferences based on cost and the environment the antennas must withstand. Pros and cons for a few examples below:

PVC coated copper equipment wire – 7/0.2 mm

Pros: Readily available, low cost (500m for ~£38), lightweight

Cons: Stretches, sheath stronger than wire, weak

The preferred option for DXpeditions in the UK. The main disadvantage is that the wire can break without the PVC sheath breaking and making it very difficult to find out where this might have occurred so that it can be repaired.

PVC coated copper equipment wire – 16/0.2 mm

Pros: Readily available, low cost (500m for ~£77), wire stronger than sheath

Cons: Stretches, adequate strength for permanent installations

This is what I use for my permanent installations. If the wire breaks, so does the sheath, so it's easy to discover where a repair is needed. The main disadvantage is that the wire stretches during strong winds and therefore requires regular maintenance. I'm happy to do this since it keeps me fit; some people walk their dogs; I walk my antennas!

The fact that the wire has some give in it makes it less of a safety hazard than the stronger wires shown next, which use steel for strength and to avoid stretching. The next two options were suggested to me by Bjarne Mjelde as alternative options, used by some Scandinavian DXers for beverages in Western and Arctic Norway and Sweden. I have no experience of using them myself.

PE coated wire – 19 strands Cu clad Fe

Pros: Strong, minimal stretch, low maintenance, permanent

Cons: Sourced from USA ("The Wireman" type 531 AWG 13), very expensive (500m for ~$500 + $120 shipping to Europe)

Plastic coated wire – 18/0.4 mm Fe, 1/0.5mm Cu

Pros: Extraordinarily strong, minimal stretch, low maintenance, permanent

Cons: Sourced from Europe ("Hofi Fe-Litze RS 0101-183"), supply issues, very expensive (similar to above), heavy, stiff.

All the wires mentioned suffer from weakening due to corrosion when the sheaths are damaged and there is water ingress between the sheath and the wire, and none will last more than approximately 3 years in a demanding environment.

<u>Tools for Wire Handling</u>

It's important that wire is handled correctly to facilitate running it out and bringing it in without introducing kinks, twists and tangles. Figure 6 shows some of the tools I use – old cable drums and electric fence reels. Note the use of a piece of aluminium tube through the centre of a reel so wire can be paid out without twisting.

Fig 6: A Selection of Reels

Support and Height of Wire

Beverage-on-Ground (BOG)

Pros: Easy to put up, good front/back ratio

Cons: Animal damage, less gain than elevated antenna

It's normal to put up the supports before the wire is reeled out, but in the case of the BOG, supports aren't needed, the wire is just laid on the ground. Suitable if the ground is rocky or no supports are available, just reel the wire out and use on a temporary basis.

Beverage on a hedge or strung between tree branches etc

Pros: Easy to put up, good gain and directivity

Cons: Variable height, difficult to tension

Possibly a good solution in woodland or along hedgerows. An alternative is to simply connect to a farmer's fence wire along a field boundary, although performance is unpredictable – try it and see!

Beverage on Bamboo Canes etc

Pros: Good gain and directivity, reduced animal damage

Cons: Additional cost of canes (Qty 100 2.1m canes, delivered for <£100)

This is my preferred option for both temporary and permanent beverages. As shown in Figure 7.1a I use bamboo canes with a saw cut in the top to hold the wire, with PVC tape around the cane below the slot to stop the cane splitting. 2.1m is a good height for the canes to raise the wire above sheep, cattle, and deer to avoid damage; people can easily duck under the wire. If none of these are a problem, then a height of 1m is probably a good option.

Fig 7a: Bamboo every 5-10m

Fig 7b: Intermediate 40mm x 40mm

Fig 7c: Ends 75mm x 75mm

During gales the wire is intended to come out of the saw-cut and fall to the ground where it will suffer less damage. In a temporary or DXpedition setting the whole length of the wire can be supported by bamboo canes, although in my permanent set-ups I use 75mm square fence posts at each end with an electric fence insulator to hold the wire tight (Fig 7c). In addition, I use intermediate posts (40mm square or 50mm round tree stakes) at approximately 100-150m intervals or changes in gradient, also with electric fence insulators for tensioning. Keeping the wire under tension reduces the probability of it breaking or coming off the canes in moderately strong winds.

Characteristic Impedance

Having decided on the type of wire and the height above ground, we are now able to work out the characteristic impedance of the antenna. With reference back to Figure 5 the characteristic impedance can be calculated using the formula:

$$Z_o = Y \times 138 \log(4h/d)$$

where Y = correction factor for ground conditions

Since I use 16/0.2 wire and 2.1m canes d = 1.0mm and h=2.0m, hence:

for good ground Y=1.12, therefore Z_o = 603Ω and for average ground Y = 1.2, therefore Z_o = 646Ω.

All well and good, but how do we know what our ground conductivity is? The ITU-R World Atlas of Ground Conductivities (https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.832-2-199907-S!!PDF-E.pdf) indicates that for my area it is generally poor - my ground is a mix of peat bog and stony glacial deposits which is typical for poor conductivity. Further reading on the topic may also be found at https://hamwaves.com/ground/en/ .

Some DXers use a variable resistor as the termination, tuning it for best rejection off the back of the antenna. This is OK for DXpeditions and narrow-band installations, but since the depth of the null varies with the weather, frequency and arrival angle of the unwanted signal it's not particularly helpful for either broadband reception or a permanent installation. I use a fixed resistance, as described next, and it provides adequate front to back rejection for my purposes.

Terminating Resistor

In this case 680Ω made up from 4 x 3-watt 680Ω resistors in series/parallel.

Fig 8a: Internal View

Fig 8b: Mounted on Terminating Post

Ground

Fig 8c: Ground Rod

Normally any static build-up on the wire due to rain, hail, or snow, is discharged through the primary of the matching transformer, but if the wire breaks during a storm it can discharge through the terminating resistance, and on occasion this is enough to burn out even the 12 watts of resistance used; the unit in Figure 8a is on the workbench after repair. Figure 8b shows how the resistance box is mounted on the terminating post and connected to the antenna wire and ground lead. The fixed earth wire goes to the ground rod – I use 22mm copper water pipe 2 or 3 feet (600-900mm) long with two brass screws bolted to the pipe and then soldered in. An eyelet on the end of the earth wire makes for a solid connection. For ease of earthing all my antennas terminate in boggy areas!

Note that the wire at the termination goes vertically to ground; it is also possible to use a sloping wire from the top of the end support to ground, but in my situation, this would make it vulnerable to damage from animals. Both are electrically equivalent, as a vector analysis will show.

Matching Transformer

There are many ways in which a matching transformer can be constructed, but I have chosen to follow the work of the late John Bryant, Bill Bowers, Nick Hall-Patch (VE7XDR) and Mark Connelly (WA1ION), whose papers have appeared in Medium Wave News (see References).

$N2/N1 = \sqrt{(R2/R1)}$, so to match 50Ω to 640Ω the turns ratio = $\sqrt{(640/50)} = 3.6:1$ (where N2/N1 is the turns ratio).

Using Type 75 (or J) ferrite has been shown to perform best for broadband transformers over LW, MW and SW frequencies below 5 MHz. The optimum is to use an overlapped winding on an FT114-75 toroid, with turns count of 39:11 for the above match.

Fig 9: Transformer Box Mounted on Post with Close-up Showing Construction Detail

The photos in Figure 9 show the construction in a rainproof plastic box with drain hole in the bottom. The transformer in this case is marked as 35:1, the turns being held in place with small tie-wraps, and the transformer mounted in the box using bathroom silicone sealant. Note that the transformer is constructed from the same wire as the antenna since it must discharge any static picked up on the wire, and transformers made with fine wire aren't robust enough to do this. The coaxial cable back to the shack (in this case 200m away) is buried 2-3 inches (50-75mm) deep to protect it from animal damage and minimise unwanted pickup of signals and noise. The same style of earthing is used as for the termination resistance.

Earthing Options

But what do we earth, and where? The paper by Bryant et al shows four earthing options as shown in Figure 10.

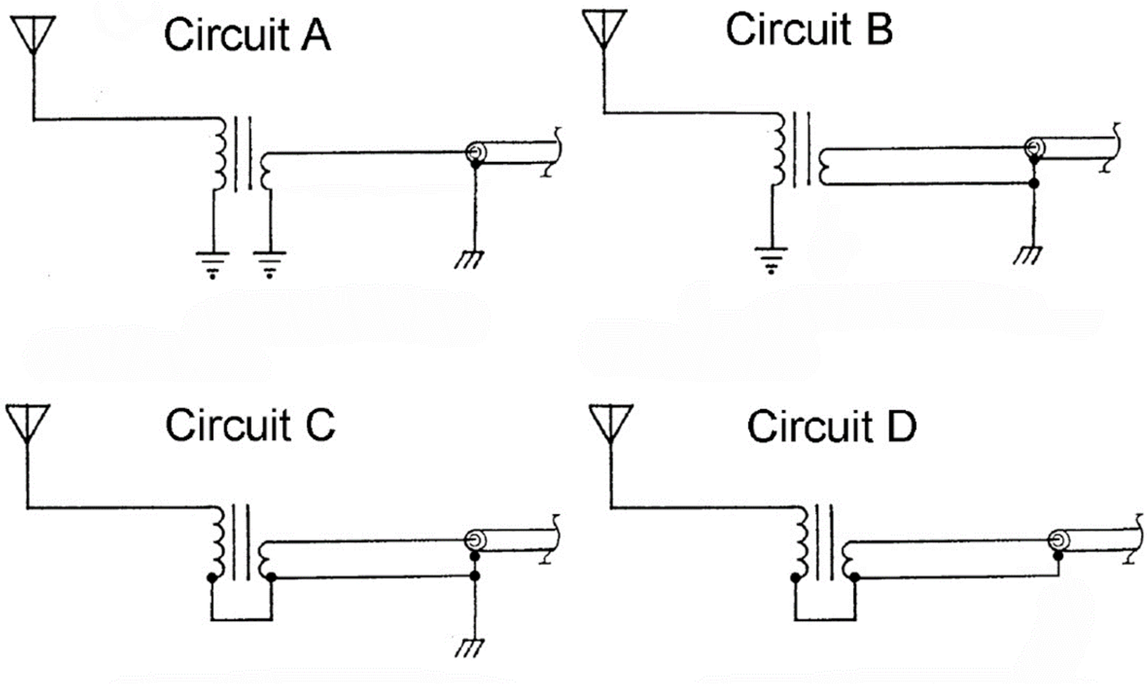

Fig 10: Earthing Options

The guidance given by the authors of the paper is to experiment and find what provides the least noise or unwanted pickup in your own circumstances. There may be special situations in which options C or D are appropriate, but my preference is for A or B, because static pickup is discharged directly at the end of the antenna wire. After some experimentation I use Option B, with the antenna earthed at the feed point, but the coaxial cable earthed as it enters the house. You can check the degree of pickup in your system – nothing should be heard at the receiver if you disconnect the end of the antenna wire. Never connect the end of a beverage directly to your receiver input to avoid rain/hail/snow static damaging the front end and giving you a jolt! Always use a transformer.

Antenna Length

The last parameter to be considered is the antenna length L; this will determine its radiation pattern and gain. If you do a search of the internet there are lots of radiation patterns available; an example from the late John Devoldere's (ON4UN) book Low Band DXing is shown in Figure 11 for a typical antenna 2m high at 1.83 MHz above average ground.

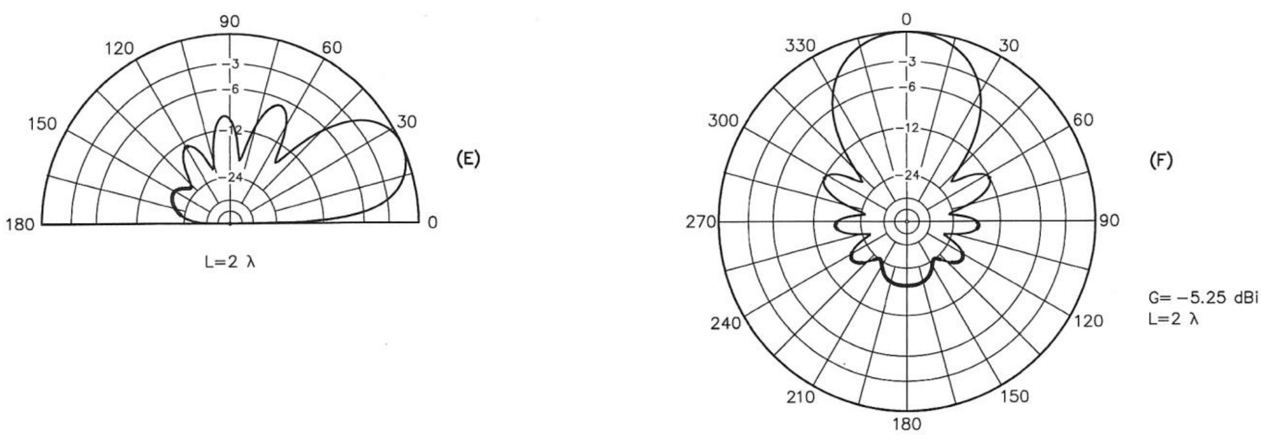

Fig 11a: L=2λ, gain = -5.25 dBi, azimuthal beamwidth = 56º, elevation angle = 24º

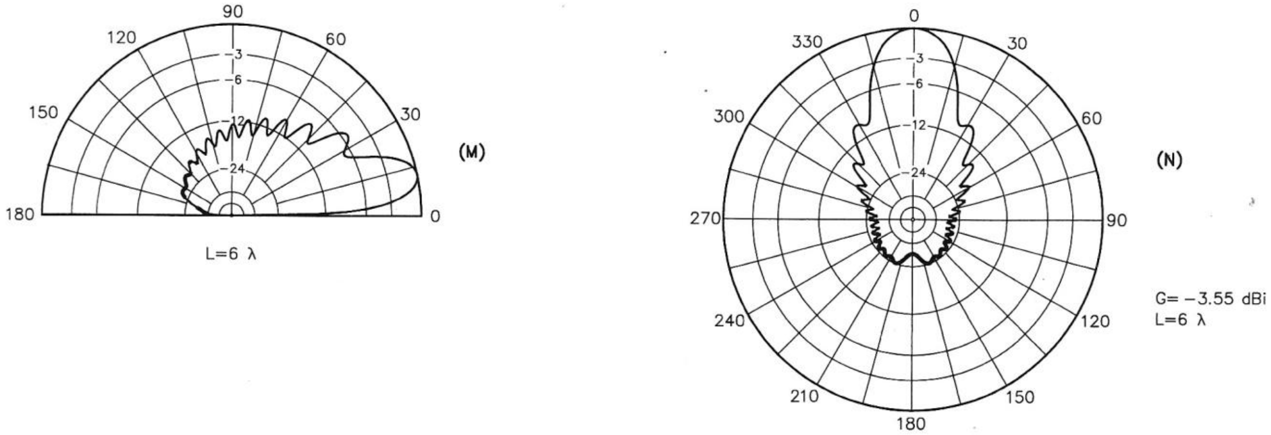

Fig 11b: L=6λ, gain = -3.55 dBi, azimuthal beamwidth = 30º, elevation angle = 12º

In simple terms, beamwidth narrows as length increases, and gain increases with length. I don't want to get bogged down in detail, merely to state that experience and theory show that the optimum length is approximately 6λ (electrical), which due to the Velocity Factor (VF) of the transmission line is 5λ (physical), although up to 8λ will provide good performance. The table in Figure 12 translates these wavelengths into physical antenna lengths for the various frequencies that are of interest to MW DXers and amateurs.

kHz	Band	Metres	Physical Length in metres			
			0.5λ	1λ	2λ	**5λ**
137		2188.27	1094	2188	4377	**10941**
475	600	631.34	316	631	1263	**3157**
1900	160	157.78	79	158	316	**789**
3650	80	82.14	41	82	164	**411**
5338	60	56.16	28	56	112	**281**
7100	40	42.22	21	42	84	**211**
530	MW Top	565.65	283	566	1131	**2828**
1710	MW Bottom	175.32	88	175	351	**877**

Fig 12: Table of Practical Antenna Lengths by Frequency

Ideally, all our antennas would be 5λ I length, although few of us can build or maintain beverage antennas longer than 1000m, and most will struggle to reach a few hundred metres. The shaded areas show the target lengths for different bands, and so for MW we should be aiming for a length of at least 500m and preferably 1000m. That does not mean to say that shorter beverages aren't worth constructing – they are, but their performance won't be so good as longer antennas, as the radiation pattern and gain models show. My experience of using a 920m beverage last season has confirmed what Scandinavian DXers have been saying for a while, which is that 1000m provides significantly improved performance over 500m on the MW band.

Antenna Profile

The gain and radiation pattern diagrams in Figure 11 assumes the ideal of the antenna being in a straight line in the vertical and horizontal planes, something not achievable in the real world. We can't do much about how level the ground over which we run the antenna is, as shown for my 920m beverage in Figure 13. However, what we can do is maintain as straight a line as possible in azimuth, then let the terrain determine the height above sea level and accept the performance.

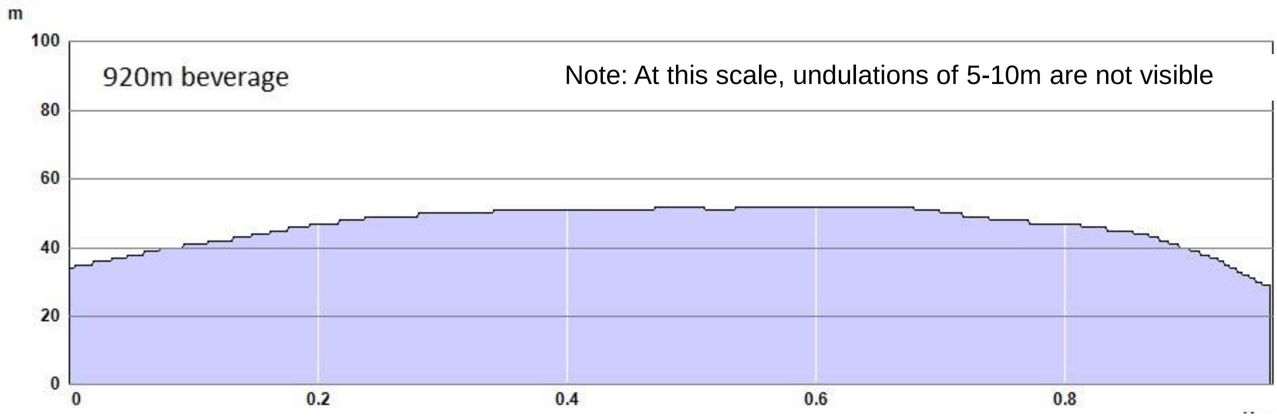

Fig 13: Height Profile of 920m Beverage

In practice beverages are very forgiving – nothing about their construction is unduly critical. If you haven't built one before, have a go and be amazed at the performance you achieve!

KEEPING the BEVERAGE OPERATIONAL

You can't just put up a beverage and forget about it, unless you live in a very benign environment. The issues you must deal with may differ from mine, so use my examples as a guide.

Sources of Damage

- Animal damage e.g., cattle knock down canes, deer antlers catch the wire
- Wind gusts 50-70 mph (80-115 km/h)
  - Wire comes off canes, stretches, breaks
- Wind gusts >70-90 mph (115-145 km/h) Note: Winds speeds locally have reached 129 mph.
  - Canes snap, wire comes off canes
  - Wire stretches, breaks in multiple places, sections of wire disappear
- Sheep nibble wire blown onto the ground, causing further damage

Maintenance and Repair

- Walk the antennas regularly to inspect and repair, especially after gales or if a drop in performance is noted
- Perform a continuity test (at either end) first
- Put fallen wire back on the canes and re-tension
- Reposition or replace damaged canes
- Make temporary repairs to breaks

Figure 15 shows a continuity test using a test box comprising a series 9v battery, LED, resistor, and push button to activate. The antenna wire is connected to the terminal and the wire to ground through either the termination resistor or matching transformer. If the antenna is intact the LED will light when the button is pressed. If not, there is a break somewhere, which must be found and repaired.

Figure 14 shows a temporary repair of a break. Any corroded wire is removed before making a knot in the two ends, stripping 10cm of sheath from each wire, twisting the bare ends together, and using a connection block to secure. The discontinuity is short compared with the wavelength and there is no impact on performance.

Fig 14

Fig 15: Continuity Test

Refurbishment of Wire

- Reel the wire in and take it back to your workshop at least once a year.
- To inspect and repair the wire use the set-up in Figure 16 and wind the wire from one reel to the next to check its integrity as you go.
- Replace the temporary repairs made in the field, since water gets underneath the sheath and creeps along the wire, and the copper starts to rot.
- When make a permanent repair cut back to shiny tinned copper, remake the joint, and solder, as in Figure 17. The solder melts the PVC sheath and seals the ends to water ingress.
- Do a continuity test after each repair (to do this make sure you bring the start of the wire out through a small hole near the centre of the reel).

Fig 16: Arrangement for Checking and Refurbishing the Wire

Fig 17: Permanent Repair

REFERENCES

There are many good references available on the web which will fill in some of the gaps in this article – just search on "Beverage Antennas". Try "W8WWV – The Benchmark Beverage" by Greg Ordy.

Recommended book:

- "Antennas and Techniques for Low Band DXing" – John Devoldere ON4UN (SK) (ARRL). A comprehensive book on all aspects of antennas for Low-band operation

Articles of relevance in previous issues of Medium Wave News, specifically:

- Antenna Impedance Transformers; John Bryant; MWN Vol 47#04 September 2001.
- Broadband Receiver Antenna Matching; Mark Connelly WA1ION 15-Jul-03; MWC Reprint T33, available for download from: https://www.qsl.net/wa1ion/bev/bb_antenna_matching.pdf
- Antenna Transformers; John Bryant, Bill Bowers, Nick Hall-Patch VE7XDR; MWN Vol 40#05 October 2003.
- Binocular Transformers; Dick van der Knaap PA4VHF; MWN Vol 67#01 Supplement April 2021 (I recommend the use of Teflon-sheathed wire for physically small beverage matching transformers to avoid damage caused by static discharge – mah).

If the characteristic impedance of your antenna is close to 450Ω you might consider the use of a 9:1 Ruthroff transformer to match the beverage to your 50Ω co-axial cable; also called transmission line transformers or broadband transformers. Here are a couple of references from the web from which you can learn more:

- The Design of Ruthroff Broadband Voltage Transformers – M Ehrenfried – G8JNJ: https://g8jnj.webs.com/Balun%20construction.pdf
- Transmission-Line Transformers, http://k5tra.net/TechFiles/Transformers.pdf