How to construct a very small but efficient Antenna with PVC Plumbing tube and discarded fruit cans. - Just the thing to fit in a small space such as the house attic

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By Lloyd Butler VK5BR

There has been some revolutionary thinking on how Electromagnet Waves can be generated. One outcome of that thinking in small efficient antennas is the tubular dipole which has been named the EH antenna. Here we describe a typical antenna assemblies made up for 20 and 40 metres.

40 Metre Dipole

(Figures redrawn for AR Journal by Bill Roper VK3BR)

Introduction

An excellent way to start on the EH Antenna would be to just read the material by Ted Hart (W5QJR) on web site http://www.eh-antenna.com. However not everybody has access to the Internet and I will give a very short precis of how Ted introduces his subject.

It is some 120 years since Heinrich Hertz discovered that radio waves were periodic. For the last century our concept of the basic antenna has been a resonant half wave with other antennas being subsets of the basic Hertzian antenna.

Also about 120 years ago John Henry Poynton discovered the components of radiation which are in brief:

(1) There is an Electric (E) field and a Magnetic (H) field which must occur in the same space, be at right

angles to each other and be in time phase.

(2) The relationship between the E field in volts/metre and the H field in amp-turns/metre is equal to 377 ohms, the impedance of space.

To enable radiation, the E and H fields must be developed which satisfy these requirements. We learn that the E field in a resonant Herzian half wave antenna is developed from the ends of the antenna where the voltage is greatest and the H field is developed essentially in the centre where the current is greatest. Apparently the correct relationships between the E and H fields don't occur until around a third of a wavelength distance from the antenna where the fields are becoming weaker. So perhaps there is a better way!

We have gone along with the basic Herzian antenna for a century. However in the 1980's, Scottish Professor Maurice Hately (GM3HAT) correctly concluded that we didn't need a large resonant antenna and radiation could be achieved by creating the fields in the correct relationship from correctly phased untuned field generating elements. As a result, Professor Hately, together with several associates, introduced (and in fact patented) various forms of the Crossed Field Antenna which were designed to generate the E and H fields at right angles, in phase and in the same (and comparatively small) space. Hence the name Crossed Field Antenna (CFA).

Some of us will remember Ted Hart (W5QJR) who developed comprehensive formulae for the design of the Magnetic Transmitting Loop. Ted eventually became involved with documentation for the X Field antenna and went on to develop what he has called (and patented) the EH antenna.

So, I had a go at assembling versions of this antenna, one each for 20 and 40 metres. The article is about how I assembled them and how they performed.

Constructing an EH Antenna

The antenna consists of two tubular (or conical) plates with natural capacity between them. You might consider them to be a fat dipole (or fat bi-cone). The E field is generated by voltage across the plates and the H field by the displacement current in the dielectric between the two elements. (The fields intersecting at right angles are shown in Figure 1).

What I have assembled is two samples of this antennas based on some construction ideas by Stefano (Steve) Galastri (IK5IIR) which can be found on the web site I have mentioned. Steve formed the dipole by wrapping sheets of copper around PVC plumbing tube. For my antenna, I selected plumbing tube which nicely fitted around recycled metal fruit containers which I had saved. So my tubular elements are on the inside of the tube instead of the outside.

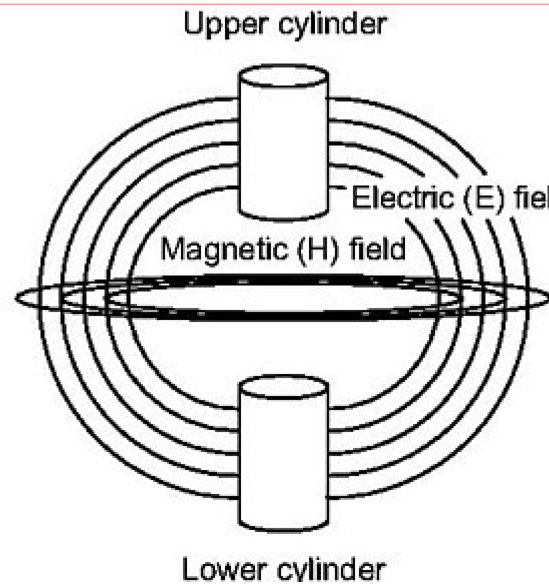

Figure 1

Fields generated between the two cylinders

For a standard EH design, the Radiation Resistance (RL) is given as equal to 2π x 377 = 2368 ohms. An external matching network is required to transformation from 50 ohms unbalanced line to the balanced input of the dipole with 2368 ohms radiation resistance. A balanced form of L network is used with two inductors and two capacitors. It is an easy matter to calculate the value of these components as each must have a reactance equal to the square root of (50 x RL) which equals 344 ohms. Adjustment of the network apparently also ensures that the displacement current is in phase with the voltage across the plates so that the E and H fields are in phase. From my experiments, the phase correction is that small that it is difficult to notice the deviation from the calculated values I have just quoted.

At this point I must draw attention to the fact that in Australia our standard measurement units are metric. However all the data I have referenced is in imperial units. To avoid any confusion, both to myself and others reading this article in conjunction with the web site, I have purposely kept to the imperial system.

The circuit diagram for my two units is shown in figure 2. I first assembled the 40 metre unit as shown in figure 3. For each cylinder (half dipole) I used two of our standard Australian fruit containers (fruit tins or fruit cans) which are 4 inches in diameter and 4.5 inches deep. The inside diameter of the PVC pipe I obtained was just a little over 4 inches, so the cans fitted in nicely. The cans were secured by self tapping screws which also doubled as connecting terminals where required. The can pairs were connected together by three straps on the outside of the tube.

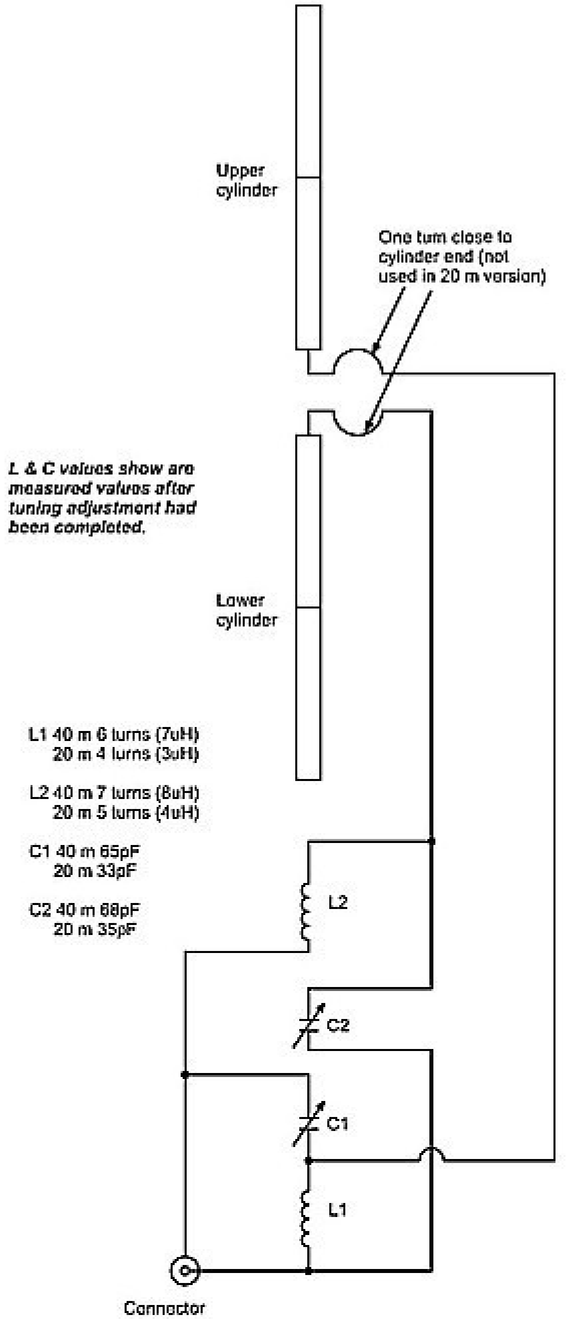

Figure 2 - Circuit Diagram.

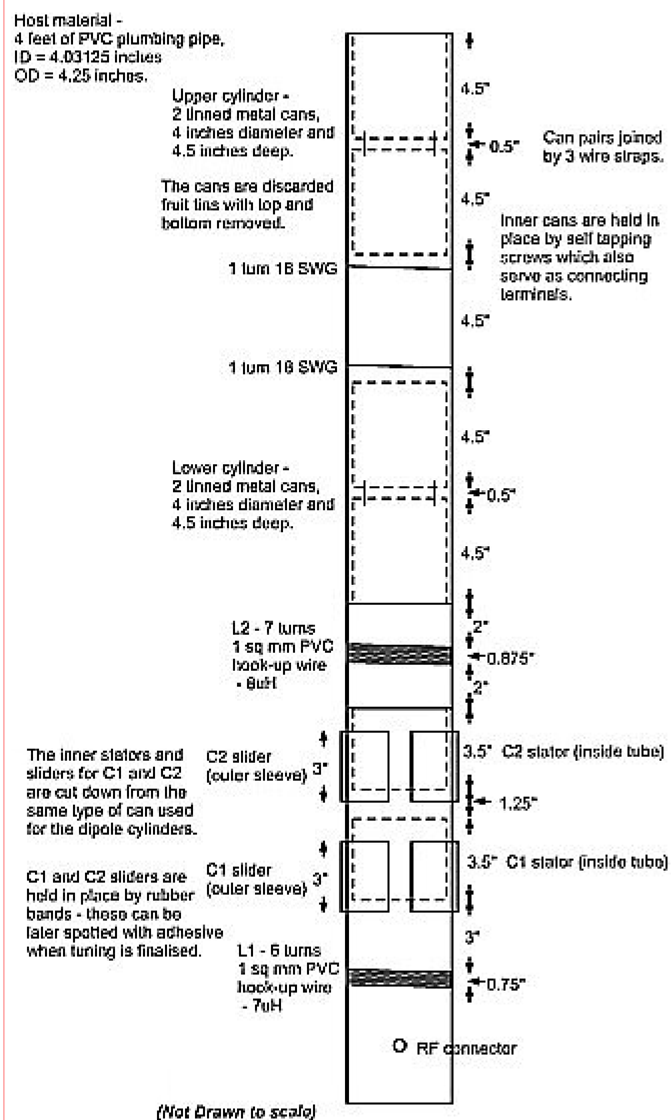

Figure 3 VK5BR 40 metre EH Dipole - Assembly

I followed closely Steve's arrangement for fitting a matching network. For the capacitor stators, I fitted cut down sections of more cans fitted inside the tube. For the adjustable sliders on the outside of the tube, I used further pieces of the tinned cans which are held in place by strong rubber bands. This allows them to be slid up and down to vary the capacitance made up by the two plates with the PVC tube as dielectric. If required, these can be glued in place later after adjustment is finalised.

The lower inductor L1 has one less turn than the upper inductor L2. On testing, I found this needed slightly less inductance which I reasoned was probably due to the extra inductance of the very long lead between L1 and the top cylinder.

Cylinder dimensions

According to the reference, cylinder diameter is not too important and my own tests seemed to confirm this. However, the ratio of cylinder length to diameter does control the radiation beam width. A low ratio gives a spread pattern more suitable for local contacts whereas, a higher ratio narrows the beam and gives a lower angle of radiation, more suitable for long distance (DX) communication. They say, typical ratios could vary from as low as 1.5 to an optimum figure of 3.14 for DX work.

My ratios are somewhat set by the can dimensions. For the 40 meter unit, the ratio is 2.4. Using this ratio, local reports consistently gave my signal as two S points below my half wave end fed inverted V antenna. At longer distances the difference was considerably greater. For the 20 meter unit, I tried to get the ratio a bit greater (again somewhat controlled by can sizes). For this unit the ratio is 2.85 and this works much better for distant stations.

For 20 meters, the reference suggested 2 inch diameter cylinders. I only had cans just under 3 inches diameter, so my cylinders for 20 meters are a little larger than suggested.

20 Metres

The assembly of the 20 metre unit is shown in figure 4. The arrangement is much the same as the 40 metre unit except that it is assembled with 3 inch diameter PVC plumbing tube which nicely takes another Australian standard fruit can which is just less than 3 inches in diameter. The can pairs are also a bit different. In the forty metre unit, I fixed each can in place separately and bonded them together. In the 20 metre unit I lapped ends of a pair, soldered them together and used only one set of screws to secure the pair in place.

Once again with the 20 metre unit, I found the matching balanced better with slightly less inductance in L1.

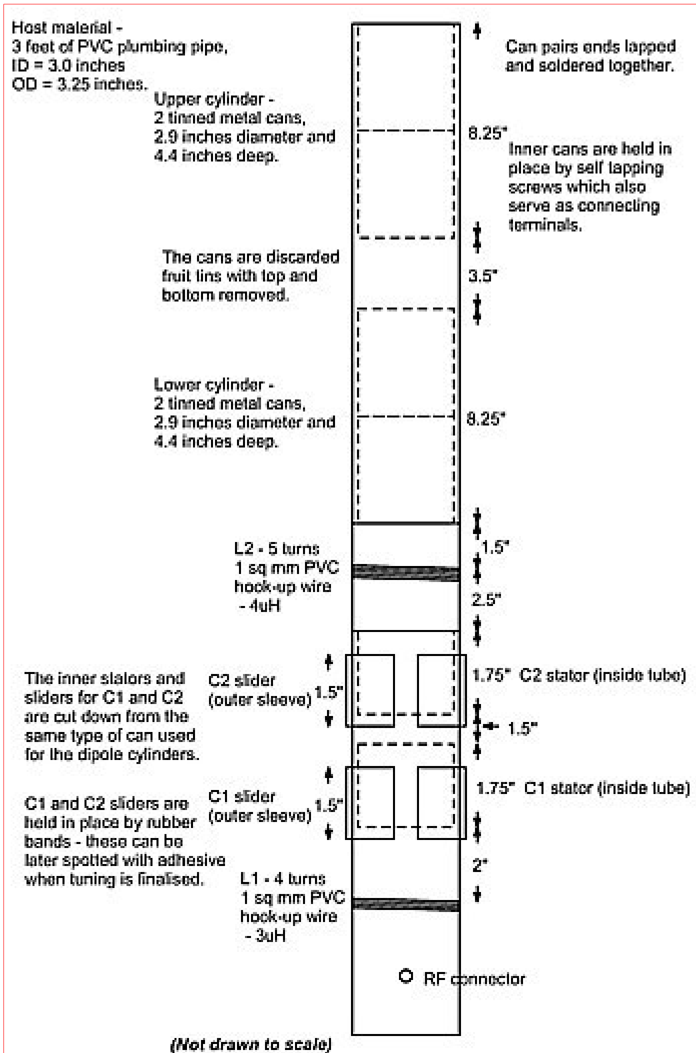

Figure 4

VK5BR 20 metre EH Dipole

Isolation Coils

Not mentioned previously are two coils of a single turn shown on the 40 metre unit, one mounted just below the top cylinder and one mounted just above the bottom cylinder. According to the web references, this introduces a small amount of phase shift which reduces radiation from the connecting wires inside the tube and actually increases the radiation from the cylinders. Steve says that spacing between the winding and the cylinder edge is critical but I don't know why. Anyway I have spaced my coils at 0.25 inch from the edge.

I have not included these isolation coils in the 20 metre unit but I might later add them to see if I can notice any change in performance.

Matching adjustment

The setting of L and C in the matching section is quite critical. Set the transmitter up on the centre frequency of the band with the transmitter set for about 10 watts output and look for low SWR. With the inductors, I put on more turns than I had calculated using Wheeler's formula and took off a turn at a time adjusting to the extremities of C1 and C2 each time. I close wound the coils but inductance can be reduced by pushing the turns apart. When the adjustment gets close, the reflected power will drop and SWR will run right down rather suddenly close to 1:1 when the right adjustment is found. When adjusted, I found I could light up a small BC fluorescent lamp from the field around the dipole with less than 15 watts. Low SWR also corresponds to maximum field strength as measured on a meter some distance away.

After alignment I disconnected leads from the inductors and capacitors and measured their values. The measured inductance and capacitance values are recorded on the circuit diagram (figure 2) and are very close to values calculated from reactance using the formula quoted earlier with the assumed radiation resistance of 2368 ohms.

Some Air Tests

To test the unit on the air, I made comparisons with an end fed Inverted V antenna which is a half wavelength long on 40 metres. On 20 metres it is a full wave long and operates, no doubt, with a rather complex arrangement of radiation lobes.

In general, on receiving with the antenna about a metre above the ground, both antennas produced signals several S points below the inverted V although I did find an occasional signal on 20 metres which appeared comparable with the inverted V. The receive level of the 20 metre antenna improved considerably when I raised the antenna to around 3 metres above the ground.

On transmitting on 40 metres to stations in the local Adelaide metropolitan area, reports gave the signal down around two S points on the inverted V. It was down a bit further on distant stations. On the other hand, it seemed to work better than a random length of wire strung up to the nearest tree and tuned up with a Z Match.

On transmitting on 20 metres some 1500 Km to the east coast of Australia, the EH dipole was just barely below the inverted V. This is quite impressive considering the dipole element is just 20 inches (half a metre) long and a fraction of the length of the 20 metre full wave inverted V.

Weather Proofing

My antennas, constructed as experimental units, are not made to withstand the elements without some form of protection or weather proofing. Without protection, the tin plate on the fruit cans would soon deteriorate and the cans would corrode. I could also envisage the many birds we have finding the hollow tube great to build a nest. The hollow tube would also be a great haven for spiders. Imagine having cooked spider as part of the dielectric between the two cylinders. However, the antenna would be fine if fitted under the tiles in the roof cavity or some other protected area..

Conclusions and Comments

The concept of the basic antenna has certainly changed. The fact that long distance communication can be carried out with such a small sized antenna is quite revolutionary. However if you have the space for a full sized antenna and you have one installed, I wouldn't dismantle it. From my tests, the full sized dipole (and complements of it) still works better. However if you live in a housing unit with limited yard space, one of these could be the way to go.

Of course it could be that my assembled example of the EH antenna might not be an optimum design. For example, for the radiating cylinders, I have made use of discarded fruit cans which are tin plated steel. More expensive copper sheet or copper tube would have lower surface resistivity although with such a high radiation resistance I wonder if this would make much difference. However there is one thing that I wondered about. The steel is a ferro-magnetic material and I wondered if its magnetic properties might in some way distort the desired magnetic field and alter the properties of the antenna.

Comparison of performance with the magnetic transmitting loop have been made. I felt I had better signal reports on 20 metres from my one metre square magnetic loop. However the magnetic loop has has extremely high Q and it has to be continuously retuned to traverse the frequency band. The EH antenna can be tuned up at the centre of the band and operated across the band without retuning. I found that it is possible to tune up with close to 1:1 SWR in the centre of the band and hold within 1.5:1 over the whole band.

Another point of comparison is the physical size. It's not so apparent for the smaller magnetic loop on 20 metres but an efficient magnetic loop on 40 metres might need 10 metres (or around 33 ft) of copper pipe in the loop circumference. Compare this to the dimension of the radiating element of the 40 metre EH dipole described.

A further feature of the EH antenna is its small capture area for noise pick-up. It is a very quiet antenna for pick-up of noise.

The hertzian concept for antennas has been with us for a long time. But now we are introduced to a new exiting concept and a new avenue for experimentation, all based on electromagnetic wave theory discovered by John Henry Poynton 120 years ago.

References

1. The EH Antenna Book by Ted Hart W5QJR - http://www.eh-antenna.com
(There are also other relevant articles on the eh site)

2. Full Network 20 Metre Antenna - http://www.qsl.net/w0kph/fullnet.htm

3. How to build and tune your EH Ham Antenna byStefano Galastri IK5IIR http://www.eh-antenna.com

UPDATE APRIL 2003

The preceeding article as published in Amateur Radio in April 2003 was prepared in September 2002 and theory included was that as known at that date. A lot of water has passed under the bridge since that time and a lot of controversy has since taken place concerning how it actually works.

For a start, I had observed an anomaly in the original theory of how the H field was developed from the E field displacement current. I have placed an article on the internet describing a new theory on how I believe this is developed, **refer http://www.qsl.net/vk5br/EHAntennaTheory.htm.** In brief, I believe that whilst the E Field is developed in a differential mode across the cylinders, the H field is developed from the displacement current of a secondary E field in a longitudinal or common mode between the cylinders and reference coax shield common..

More recently it has been observed **that there is a field around the outside of the coax cable** running a distance down the coax. This seems to be **due to current running down the outer shield.** Here is the source of the controversy. Some think that much of the radiation from the EH dipole is due to this current. Others believe it does not need the coax to work well. It is an interesting on going saga.

Radiation Precaution

In experimenting with these antennas, one should not forget that close proximity to the fields or radiation from any antenna could subject the body to higher than accepted safety levels. As far as the EH antenna is concerned, these fields have quite a high concentration within the vicinity of the two small dipole cylinders and the matching network. Care should be taken when the body is close to these, particularly when using high power. As mentioned in the previous paragraph, some field has been detected around the coax cable feeding the dipole unit. At this stage it is not known whether this might also reach a hazardous level and could possibly be of particular concern where the cable is run within the radio shack occupied by its operator.

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