DEMONSTRATION 4

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This is the fourth in a series of demonstrations to allow the reader to build a very simple and very inexpensive EH Antenna, and experience the excellent performance parameters of this new and revolutionary concept in antenna theory.

This document was prepared to present the detailed design of the *STAR* version of the EH Antenna, as well as assistance in construction and tuning. Previous demonstrations used a 40-meter antenna as an example. We will detail a 20-meter version in this demonstration, and include some information relative to 80 meters.

We have not yet prepared additional Demonstrations, but will if we deem the subject matter important to you. Under consideration is more technical information primarily at the engineering level. Check the web site periodically.

DEMONSTRATION 4: The detailed information is presented in the following table, followed by appropriate comments. We have included information relative to the 40-meter antenna for reference.

HAM BAND				
METERS		40	20	
MHz		7	14	
FORM DIAMETER				
INCHES		3.25	2.625	
CM		8.255	6.6675	
CYLINDER LENGTH				
INCHES		4.5	4.875	
CM		11.43	12.3825	
CYLINDER SPACING				
INCHES		3.25	2.625	
CM		8.255	6.6675	
CYLINDER TO COIL				
INCHES		3.25	2.625	
CM		8.255	6.6675	
# TURNS ON PHASING COIL		2	0	
# TURNS ON TUNING COIL		20	12 - 2.5” diameter	
TAP AT# TURNS		1.25	1.5	
# TURNS ON FEED COIL		12	8 - ½”diameter	
APPROXIMATE TOTAL LENGTH				
INCHES		16	19	
CM		40.64	48.26	
BANDWIDTH - KHZ				
2:1 VSWR		160	650	
.+/- 3 dB		360	1330	

PHYSICAL: The antenna diameter is not critical, but it does have a direct effect on antenna bandwidth due to capacity between the cylinders. Unfortunately, we have not yet developed an equation to define the capacity as a function of diameter and length. From experience, for a 2.375-inch diameter antenna on 80 meters we get a 2:1 VSWR of 67 KHz. For one on the same frequency but 4 inches in diameter we get 160 KHz.

If spacing between the cylinders is equal to their diameter, internal radiation is held to a minimum. Therefore, best results depend on this spacing. Note that the spacing between the lower cylinder and the tuning coil is also the same as the diameter. Also the feed coil should be spaced about ½ diameters below the tuning coil.

Generally, the length of each cylinder need only be 1.5 to 3 times the diameter. The longer cylinders will reduce the beam width, thus increase the antenna pattern gain. Please note, as the beam width is reduced; the take off angle is modified and reduces communications at higher takeoff angles.

BANDWIDTH: For the antennas described in the table, the 40-meter antenna has sufficient 2:1 VSWR bandwidth to cover the entire phone or CW band. The bandwidth can be further extended by using an antenna tuner, but only within the 3 dB bandwidth of the antenna. Typically, the +/-3 dB bandwidth is approximately twice the 2:1 VSWR bandwidth. Therefore, the 40-meter antenna detailed above can cover all of 40 meters by using an antenna tuner. It is only the lower bands where the bandwidth is an issue. This is because even very large diameter cylinders have low capacity. Larger is better, but even for a small diameter there will be adequate bandwidth to cover the part of the band you use most of the time. If you like to work over the entire band and the 3 dB bandwidth is less than desired, you need to construct a means to remotely tune the antenna. One method is to use an electric screwdriver to move a copper or aluminum slug in and out of the coil. These non-ferrous slugs will increase the frequency because they effectively reduce the inductance, and have negligible effect on efficiency. The slug can be a short piece of pipe.

The bandwidth of the 20-meter antenna in the table is unusually wide because of the large diameter relative to the operating frequency. Normally, we use a ¾ in diameter antenna for 20 meters, but we wanted to show what could be done. Note that the Q of an antenna is equal to the operating frequency divided by the 3 dB bandwidth. For the Coke can antenna the Q = 14/1.33 = 10.5. For the typical Hertz antenna; either a ¼ wavelength vertical or a ½ wavelength dipole, the Q is about 30. In other words, the bandwidth of the Coke can antenna is about 3 times the bandwidth of a 16-foot vertical or a 32-foot dipole.

PHASING COIL: The purpose of the phasing coil located between the cylinders and connected between the top cylinder and the tuning coil is to provide a few degrees of phase shift. The EH Antenna concept is based on proper phasing between the E and H fields. If the voltage on the wire is not the same phase as the voltage on the cylinders, there will be no radiation from the wire or the top of the tuning coil. We found that a phase shift of about 3 degrees was equivalent to a 2:1 VSWR, so a shift of 6 degrees or more is typically used. We recommend you calculate a length of wire equal to 6 degrees (6/360 = 0.016 wavelengths), and then wind the coil with that.

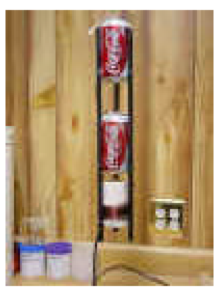
TUNING COIL: The purpose of this coil (inductance) is to series resonant the capacity of the cylinders at the desired operating frequency. The loss resistance of this coil is the only loss in the antenna. There is one potential loss that can be reduced, and that is due to the current in the coil resulting from circulating current in the shunt capacity of the coil. For each of the antennas we have described, we used close wound coils. By spacing the turns the self-capacity is reduced, thus reducing the circulating current, and therefore reducing the loss in the coil. Even with close winding, the loss is relatively small and only the perfectionist will complain about it. How you wind your coil is your choice. #14 wire has been found to be entirely satisfactory for 100 watts, but larger wire is recommended for higher power and spaced turns.

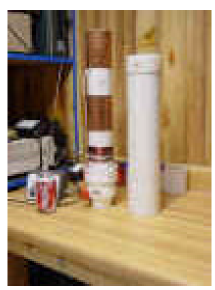
FEED COIL: With reference to the schematic diagram, note the coil in series with the coax center conductor. We call this the feed coil, for lack of a more appropriate name. The *STAR* version of the EH Antenna will have minimum VSWR at a frequency other than where the reactance is zero. Inserting this coil will correct that and, more importantly, allows minimum VSWR to coincide with maximum radiation. We prefer this coil to be located below the tuning coil a sufficient distance to eliminate most of the mutual coupling.

A BEER CAN VERTICAL: In the old days, a beer can vertical was most Ham's dream, and a few were actually constructed. For a ¼ wavelength vertical, that is a lot of beer cans. This one only requires two. Since I prefer coke, those cans are 2 5/8 inches in diameter and 4 7/8 inches long, thus the length to diameter is a little less than two. We had some fiberglass rod in the junk box, so we used that for mounting. The plan was to hang the antenna from a tree, so no special mount was designed. The string is tied to the flip thing that opens the can. I might add that this antenna will withstand the weather if the spacer material will. If the spacers are made of wood strips (or small dowels from Wally world or any craft store), a good coat of varnish will allow operation in the weather for a year or more. This version of the EH Antenna does not use any variable capacitors or other items subject to weather. Be sure to put a drain hole in the bottom of each can. Note: we normally use cylinders – the coke cans have tops and bottoms. The capacity between cylinders has the effect of a shunt capacity across the coil, but we disregarded it for this unique antenna.

The picture of the Coke Can Vertical shows the tuning coil and the tap. There was no good place to put the small phasing coil below the top cylinder, so we left it out. The feed coil is air wound and located inside the main coil and mounted at right angle to minimize coupling. Sheet metal screws are used to make the electrical connections to the cans.

The picture of the 40-meter antenna includes a coke can beside it to illustrate size. The large flange at the base of the antenna is a mechanical arrangement George dreamed up to allow the use of a thin PVC weather cover over the antenna. That cover is in the background.





Click to enlarge

Note that the 20-meter antenna is longer than the 40-meter antenna in the table above. If the diameter of the 20-meter antenna were reduced to ½ inch, it would be much smaller. I point this out to exhibit the broad range of construction possible. Although I have not tried it, I believe you could build a very good 75-meter mobile antenna using a diameter as small as 1 inch and still outperform the best of the commercial mobile antennas. For the experimenter, please be aware that the smaller the antenna the larger the coil needed for resonance. That means that both the efficiency and the bandwidth will be reduced as the diameter is reduced.

THE GOOD THE BAD AND THE BEAUTIFUL: George and I have tried to point out in these demonstrations the capability and the shortcomings of the *STAR* version of the EH Antenna. The list below presents the pros and cons of the EH Antenna compared to a conventional Hertz antenna.

		STAR	HERTZ
EFFICIENCY		VERY HIGH	VERY LOW FOR SMALL ANTENNAS
BANDWIDTH		VERY HIGH	VERY LOW ON LOW BANDS,
SIZE		VERY SMALL	VERY LARGE ON LOW FREQUENCIES,
EMI		VERY SMALL	VERY LARGE ON LOW FREQUENCIES,
RECEIVING		VERY QUIET	VERY NOISY

The following comments put these comparisons in perspective:

- **Efficiency**: A 75-meter mobile antenna will have an efficiency of less than 3%. Efficiency of an EH antenna is limited only by the loss in the coil, typically only a few percentage is lost in heat, because the radiation resistance is high.
- **Bandwidth**: The instantaneous bandwidth of the EH Antenna is typically greater than a full size Hertz antenna. Both the Hertz mobile antenna and the loop antenna are noted for their narrow bandwidth. The 2 inch diameter *STAR* antenna mentioned previously had a 2:1 VSWR bandwidth of 67 KHz at 3.9 MHz. If we assume the 3 dB bandwidth is twice that, then the Q of the antenna is 30, the same as any full size Hertz antenna. A larger diameter allows greater bandwidth.
- **Size**: A Hertz vertical antenna should be ¼ wavelength with ¼ wavelength radials. A Hertz dipole is ½ wavelength long. The EH Antenna is a dipole and needs no radials – the physical dimensions of the *STAR* antenna are measured in inches, rather than wave length.
- **EMI**: For an EH Antenna it is virtually non-existent, and is typically greater than 30 dB below the EMI created by a Hertz antenna.
- **Receiving**: You have to experience this one to appreciate it – very quiet - - a superior signal to noise ratio with equal received signal level.

What else could you desire from an antenna? The beauty of the EH Antenna is unequaled in the eyes of any one that appreciates antennas.

It is our hope and expectation that you will experiment with the *STAR* version of the EH Antenna. We have shown that the antenna physical characteristics are not critical; so do not hesitate to play. You do need a simple diode field strength meter. If you don't have one, they are simple to build. A signal generator is a big help in getting the antenna tuned close to frequency. A grid dip meter will also serve that purpose. Any of the new antenna analyzers are a big help.

COAX FEED: The EH Antenna is an excellent antenna, but it is only useful if the radio can communicate with the antenna. Unfortunately, because the antenna is located a distance from the radio, some form of transmission line is required, typically coax. It is my opinion that the E field of the antenna couples to the coax, even though the E field is primarily contained very close to the antenna. This causes current on the coax, which in turn develops an E field that interacts with the E field of the antenna. If the coax is changed (moved, rolled up) then the interaction is changed and the result can be measured as a change in VSWR of the antenna. Because the antenna is so small, any metallic object near the antenna will have this effect. However, that object must be very close compared to the same effect on a Hertz antenna at a much greater distance. If it is inconvenient to tune and match the antenna in the operating location, set the match and tuning close to the desired frequency and use an antenna tuner to make the radio happy.

Ten STEPS TO SUCCESS: George and I want to walk you through the construction and tuning of an EH Antenna. We are not trying to tell you how to drill holes or other simple mechanical activities. What we do want to tell you are those things unique to the EH Antenna that can be gained only from experience or from this demonstration. If you do not have the necessary test equipment to perform one of the following steps, beg borrow or steal from your Ham friend, or have him help you:

Step 1 Select the form and construct the cylinders.

Step 2 Measure the capacity between the cylinders.

Step 3 Calculate the length of wire for the phasing coil, and then install it.

Step 4 Calculate the inductance of the tuning coil (to make it series resonant with the capacity of the cylinders), and then install it with a couple of extra turns.

Step 5 Connect the top of the coil to the top cylinder. Space the wire ½ inch or more away from the lower cylinder to minimize capacity coupling. We prefer running this wire down the center of the lower cylinder.

Step 6 Connect a wire to the lower cylinder. This will be “ground” for the antenna.

Step 7 Connect a short piece of coax to the lower end of the coil and the lower cylinder wire. Measure the resonant frequency and remove turns to set the frequency just below the desired frequency.

Step 8 Connect the lower cylinder wire (ground) to the bottom of the coil. Connect a short piece of coax to the “ground” of the antenna (you just created) and to a tap on the coil 2 turns above the bottom.

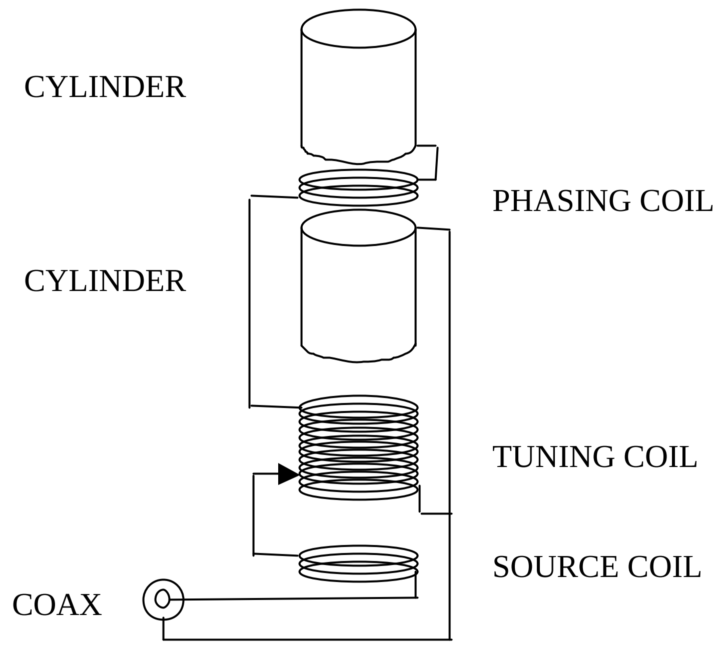
Step 9 Measure the value of X when R = 50 ohms. Calculate the value of a coil with that reactance and install it in series with the center lead of the coax. Alternately, experimentally determine the value of inductance that allows minimum VSWR to occur at the same frequency as maximum radiation.

Step 10 Adjust the tap on the coil to get perfect VSWR, then again adjust the top turns on the coil to place the antenna resonant frequency where desired. The impedance of the antenna can be adjusted by spreading turns on the low end of the coil. The operating frequency can be adjusted by spreading turns on the top of the coil. Be aware that changing the tap will also change the frequency, so start low with too many turns, correct the VSWR then set it on frequency. Hot glue will keep it there.

If you use a MFJ or other battery powered analyzer, connect a ground to it. Without the ground, the readings will be unstable and affected by touching the analyzer because any object in the approximately the antenna will cause a change in the antenna characteristics. The third wire power ground from the wall socket works great.

We saved the best parameter to present last. Hams are notorious for wanting something for nothing. The *STAR* is as close as you will get. One can be built for very very little cost in time or money and there are no critical parts. What else can we say?

We hope you have found the Demonstration documents helpful. You are now well informed about the *STAR* version of the EH Antenna, what it’s capabilities and limitations are, and you are also aware that this is the most important development in antenna concepts in more than 120 years.



SCHEMATIC DIAGRAM OF THE EH *STAR* ANTENNA