INTRODUCTION TO EH ANTENNAS

By Ted Hart CEO
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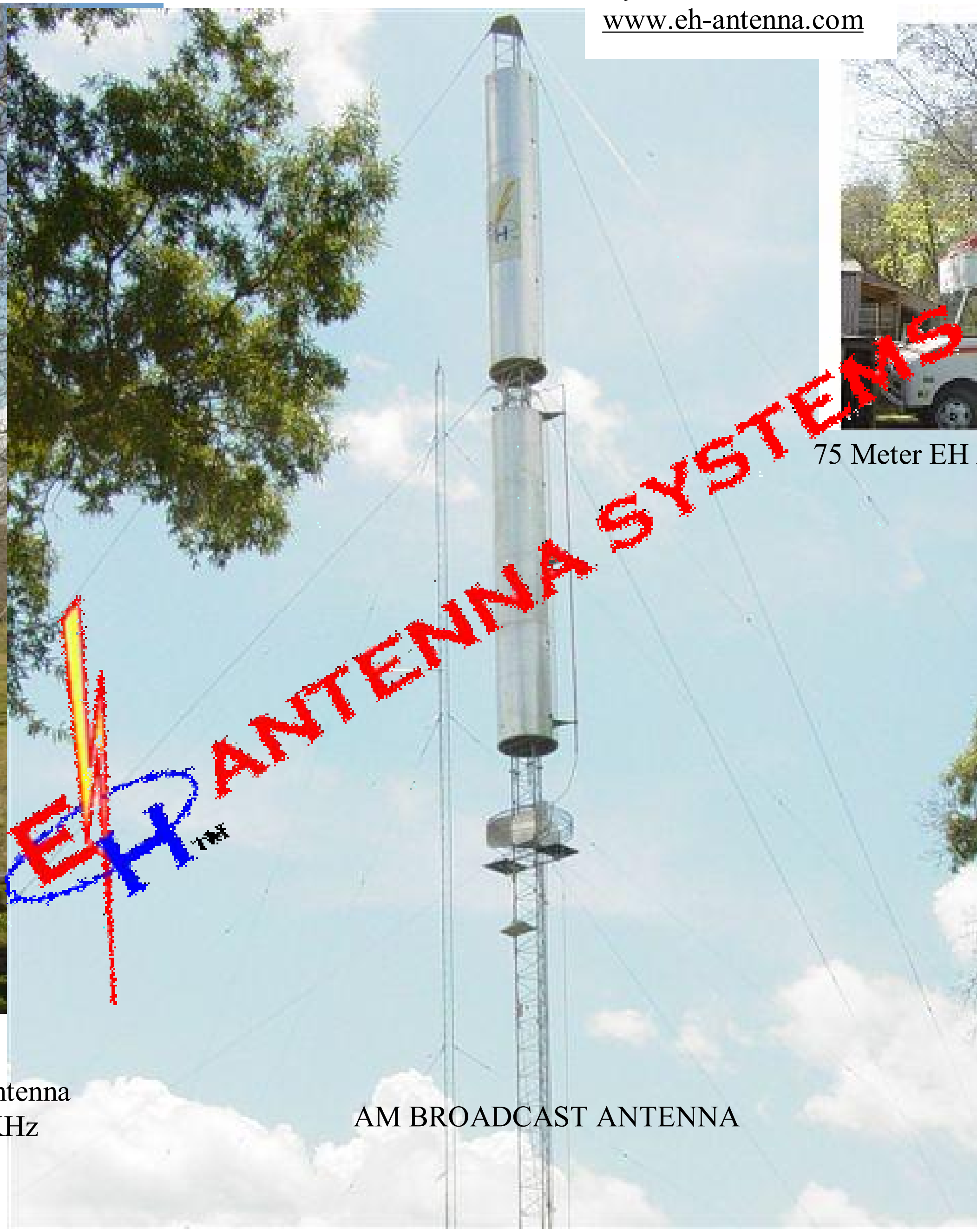
AM Broadcast Antenna
1200 to 1700 KHz



AM BROADCAST ANTENNA

75 Meter EH Antenna on an Emergency Van

20 Meter Ham Antenna

ABOUT THE AUTHOR

The Author - Ted Hart got his license (W5QJR) in 1948 and has been continuously active. Because of an early interest in Ham Radio, Ted had a very long and enjoyable career as an Electronics Engineer before retiring in 1996. Incidentally, other items Ted developed for Ham Radio include the Antenna Noise Bridge, the Small Loop Antenna, and many other items and concepts printed in Ham and Professional Magazine articles.

INTRODUCTION

This book takes the reader through the basic EH-Antenna concept and guides the reader through the detailed design and construction of a working Ham EH-Antenna, and provides the tools to design an EH Antenna for any specific application.

The EH-Antenna provides a unique combination of improved efficiency and real estate conserving features to make the antenna attractive to old and new Hams alike. It is one of the only alternatives for the space stricken Hams in the urban areas. EH Antennas have repeatedly given good and consistent results when built, tuned, and used the way they are designed. As the aerial is very small and inexpensive to build with commonly found materials, it's an aerial I warmly recommend for confined spaces or stealth applications even in the developing countries. As an added feature, the EH-Antenna is easily hidden and very stealthy compared to a dipole or any vertical aerial. I have a couple of homebrew EH-Antennas in my attic and I have no complaints from my neighbors.

Although the EH-Antenna was conceived a few years ago (1996), it has not yet gained wide acceptance. New ideas sometimes take time to grow, but there has been a great deal of confusion about this technology as a result of new principles that must be incorporated. The purpose of this book is to clarify the theory and to provide information to the public that will allow any ham to build an EH antenna to suit his own specifications (frequency, bandwidth, etc.) and correctly employ it. It is through this knowledge and use of the aerial that the reader (and user) can discover for themselves the many features the EH-Antenna has over conventional aerials.

The EH-Antenna concept is covered by three patents (6,486,846, 6,864,849 and the third is approved but not yet issued). Because it does not conform to classic theory as printed in the textbooks, the scientific community has also been slow to embrace the material.

Controversy isn't always a bad thing, especially if it leads to mature and responsible debate. Furthermore, this book will provide the technical and application data to dispel all of the negative comments. It is my hope that all individuals, especially critics, will take the time to simply build the device and see for themselves that sometimes new ideas actually DO work!!!

This aerial concept is proven in various applications including AM Broadcast, Ham, and commercial systems. Two companies, one in Europe and one in Japan, manufacture and sell EH-Antennas for Hams under license of the patents. To date there is no company in the USA manufacturing Ham aerials. A company in Italy uses EH-Antennas to communicate with miniature transponders that are the new method of reading bar codes at a distance, known as RF Identification (RFID). The EH-Antenna provides a large improvement over other types of aerials in this application.

The target audience of this book is the Radio Amateur, but the information will be an eye opener for the practicing Aerial Engineer. To ensure an understanding, concepts and theory are presented in an overly simplified manner so that ideas are easy to follow. The less experienced Ham may choose to gloss over some technical information, but he will gain a sufficient understanding of the EH-Antenna to build and use one. For those who want more detailed technical information, it is available at the web site, including documents and references to other web sites. There is also a discussion group on the Internet for the EH-Antenna.

Because the book is written for Hams, I feel it is important to make it open and free to every one. Send a copy to a friend and tell others in your Ham club about it. It will be a great item for discussion on the air. The gift of a great aerial will be appreciated by any Ham, especially those apartment dwellers that have gone silent because they could not install a large aerial. For those who wish to make a presentation to their Ham club, there is a Power Point presentation on the web site that includes both the video and text to be read along with the video for a complete presentation. That presentation is out of date as are others on the web site. This book should be considered the updated version for all EH Antenna concepts and implementation.

Health and Safety

The EH-Antenna is, when in use, emitting a very strong RF field, often very much stronger than with a conventional aerial. Besides, when did you have a full size dipole for the 80m band inside your shack for test? I want to remind you all about the information about RF safety rules you once had to learn before you were first granted your Radio Amateur Certificate! Use low power when you are testing and tuning the aerial inside your shack or if anyone is in close vicinity to the active aerial. Remember the symptoms of excessive RF radiation!!!!! It's almost like getting sunstroke and it is dangerous with excessive RF exposure! **Do not touch any parts**

<u>of the aerial while transmitting</u>!!! Any resulting nerve damage could take time to manifest symptoms and they are **<u>not</u>** reversible! The most common cause of RF radiation accidents are generated by the Ham testing and tuning in the shack. If unsure about RF radiation, take time to freshen up your knowledge by reading the ARRL Handbook's chapter on the subject!

Most of the RF outdoor accidents end with a fall. Never work alone, especially if you use a harness to prevent you from a fall. Many falls where a harness was used resulted in fatal injuries unless discovered and taken care of within 8 to 15 minutes after the fall! Again, never work alone. **All RF accidents are avoidable! And unnecessary!**

The introduction and health warning was written by Dan Andersson of England.

EH ANTENNA SYSTEMS

To My Dearest Helen
You are my inspiration and my rock. Without your patience and encouragement, I don't think I would have had the strength to complete this document.
Ted

FORWARD

This is an unusual book that discloses unusual characteristics of an unusual and new concept in antenna theory. Therefore, I am taking liberty with conventional book formats and also want to present a preview of coming distractions. The following list covers the major differences in performance parameters between EH and conventional (Hertz) Antennas. The name of this new concept, and the logo, implies that the E and H fields are in phase and efficiently integrated at the source, thus bringing the far field to the antenna. A total of 16 unique parameters associated with the EH Antenna are pointed out. Therefore, prior knowledge of antennas and antenna theory must not be allowed to override these new concepts in the readers mind if the reader desires an understanding of the EH Antenna. For reference, the new parameters are listed below. Corresponding parameters for a Hertz antenna are included for comparison.

PARAMETERS OF AN EH ANTENNA	***PARAMETERS OF A HERTZ ANTENNA***
Maximum radiation is a function of proper phasing, not resonance	*Radiation Resistance is almost constant over a wide range*
The E and H fields are in phase at the antenna.	*Radiation begins when the fields are in phase <u>at the far field</u>*
Size of an EH Antenna is typically less than 2% of a wavelength.	*Hertz antennas are 50% of a wavelength or loaded for resonance*
EH Antennas are typically vertical dipoles – no land required for radials	*AM Broadcast verticals require 120 ¼ wavelength radials*
Length-to-diameter ratio of EH Antenna cylinders set the radiation pattern.	*Multiple elements are used to control the radiation pattern*
Bandwidth is a function of the capacity between cylinders.	*The bandwidth is a fixed entity of Hertz antennas*
Radiation Resistance is a constant 120 ohms.	*Radiation Resistance is a function of antenna size*
Efficiency of the EH Antenna approaches 100%.	*Efficiency is a function of size*
For receiving, it produces the same signal level as a full-size Hertz antenna.	*Received signal level is a function of size*
Signal to noise ratio is significantly better than a Hertz antenna.	*Hertz antennas respond to independent E or H fields*
Electromagnetic interference (EMI) is virtually eliminated.	*Large E and H fields cause EMI*
Harmonic radiation is virtually eliminated.	*Hertz antennas are resonant and have related harmonic resonance*
Bi-cone and disc-cone shapes can be used to enhance the radiation pattern.	*Single element wire antennas have fixed patterns*
Radiation pattern of a small loop EH Antenna is flipped orthogonal.	*Radiation is in the plane of the small loop*
An active array can have close-spaced elements with limited interaction.	*Coupling between elements causes very difficult matching problems*
The EH antenna produces both conventional and Kor radiation.	*Hertz antennas produce conventional radiation.*

The EH Antenna concept is the most significant change in antenna theory in more than 120 years.

CHAPTER 1- BASIC CONCEPT

THEORY: As with any new concept, a fundamental understanding of the EH Antenna is necessary to appreciate what it is and what it can do. To boil all of the theory down to its most simple terms, the EH Antenna (and the basic patent) is based on the simple concept that a -90 degree phase shift (not a phase delay) network between the two halves of the antenna will cause the electric (E) and magnetic (H) fields to be in phase at the antenna. This allows radiation to occur at the antenna rather than at the far field distance as is the case for conventional Hertz antennas. It can be said that the EH Antenna brings the far field to the antenna. Hertz antennas produce E and H fields that are 90 degrees out of time phase and the resultant fields do not begin to come into phase until they have propagated away from the antenna about 1/3 of a wavelength. When they become in phase, electromagnetic radiation is created. This is worth repeating: ***If we consider the fact that the relative phase of the E and H fields is directly related to the phase of the applied voltage and current, then an application of current that is 90 degrees phase delayed relative to the applied voltage will cause the E and H fields to be in phase at the antenna***. *(*This is a revolutionary concept and the first unique parameter of the EH Antenna presented in this book*)* This simple concept can be applied to any antenna with very significant benefits. By providing this combination of E and H phasing at the Antenna, it is possible for miniature antennas to have performance that can equal large Hertz antennas!!!!!

In subsequent paragraphs we will delve into how this new antenna concept is implemented.

RESULTS: To use an example, let us assume a standard 75 meter mobile antenna. When we add a -90 degree phase shift network, the bandwidth increases and the efficiency (radiation) typically more than doubles (>3 dB). How can this be? The network has caused the E and H fields to be efficiently integrated at the antenna (not at the far field) to produce radiation at the antenna. This causes the radiation resistance to increase which improves efficiency. Consider that a standard Hertz antenna has lower radiation resistance and also develops very large E and H fields that will interact with ground and ferrous objects. For the Hertz antenna, this will reduce radiation resistance and ultimately lower the efficiency.

Throughout this book, the reader will encounter performance characteristics that are new, because they are unique to the EH Antenna. The first we will consider is radiation resistance. The value of radiation resistance of a Hertz antenna is a function of size and proximity to other objects. The radiation resistance of a EH Antenna is a constant value of approximately 120 ohms at the frequency where the phasing is correct (This is the second of many unique parameters).

Tests on an AM Broadcast antenna indicate that the EH Antenna (with out radials) will exceed the radiation of a conventional broadcast tower (with 120 ground radials) by almost 4 dB if the EH Antenna is ¼ wavelength above ground.

Because the EH Antenna constrains the E and H fields to the local vicinity of the antenna, electromagnetic interference (EMI) is virtually eliminated compared to large E and H fields of Hertz antennas out to 1/3 wavelength. (This is the third unique parameter). In addition, for AM Broadcast stations, the E and H fields as well as the radiation are created at the cylinders high above ground. Therefore, there is no effect on persons on the ground or in offices below the antenna. This allows an AM Broadcast station to be located in the center of population. Further, because no radials are required, it is now feasible to locate an AM Broadcast station in the center of population.

As a receiving antenna, even though it is very small, it produces the same signal level into the receiver as a full size antenna. (This is the fourth unique parameter). However, because the antenna only responds to radiation and rejects independent E or H field noise, the signal to noise ratio is significantly better, particularly on the low bands where the noise is greater. (This is the fifth unique parameter). This is because noise sources such as motors or other sources of sparking (including lightning) create large independent E and H fields but only small amounts of radiation. The relative magnitude and orientation of the E and H fields may not be correct to produce radiation. Conventional antennas convert the independent E and H fields from these extraneous noise sources into power applied to the receiver, as well as radiation, thus creating greater noise in the receiver.

It is important to note that there were two issues above that have been hard for the purist to swallow. First, they believe an antenna is a very simple series network comprised of inductance, capacitance and resistance. Therefore, it is very difficult for them to accept a new concept that implies the antenna characteristics change when a -90 degree phase shift network is applied, thus allowing the E and H fields to be in phase. As a result, a small antenna can produce more radiation than a large antenna. Second is the concept that a very small antenna is able to provide equal or greater signal level into the receiver compared to a full size conventional antenna. The fact that EMI is drastically reduced and signal to noise ratio is greatly improved are a little easier to grasp.

Antenna Size: When large diameter cylinders are used for antenna elements rather than wires, the capacity between the two halves of the dipole antenna can be large, thus causing the bandwidth to be high, even when the cylinders are short. This allows the EH Antenna to be very small, typically much less than 2% of a wavelength rather than 50% of a wavelength like a standard dipole or a ¼ wavelength vertical that must have ground radials. (This is the sixth unique parameter). Conventional antennas are a problem for Hams and an economic problem for commercial AM Broadcast stations due to the large amount of land required.

Radiation Pattern: Even though the total length of an EH Antenna is measured in inches rather than many feet of wire, the length to diameter ratio of the EH Antenna controls the radiation pattern. (This is the seventh unique parameter). For example, for an EH Antenna in the low bands (40, 80, and 160 meters) to make use of near vertical incidence radiation for local contacts, the recommended length to diameter ratio of each cylinder is 12 or greater. For the bands above 40 meters, Mother Nature limits communications via the ionosphere to low angles. To maximize radiation at low angles, a length to diameter ratio of 6 or less is recommended. A value less than 6 has been chosen for AM broadcast antennas to maximize radiation along the ground and reduce high angle radiation that causes interference at night when the ionosphere allows high angle radiation at those low frequencies.

CHAPTER 2 –THE CONCEPT IN DETAIL

APPLICATION OF THE CONCEPT: To gain an understanding of how the EH Antenna works, we will discuss Figure 1 in detail. Assume there is a feed line that connects a source to the two cylinders, with the connection being shown. The source causes a high voltage to be applied resulting in a large E field between the two cylinders. The voltage is very high at the feed ends of the cylinders and is reduced to a very low value at the open ends of the cylinders. This creates a large differential voltage across each cylinder. The surface resistance of the cylinders is low, thus the differential voltage across each cylinder causes high current to flow vertically on the cylinders. In turn, this current creates a large magnetic field surrounding the cylinders. We now have E and H fields in the proper relative physical orientations to allow them to interact. If the source has the proper time phase relationship between the applied voltage and current, thus causing the E and H fields to be properly phased, radiation will be created. This is why a -90 degree phase delay is needed in the source.

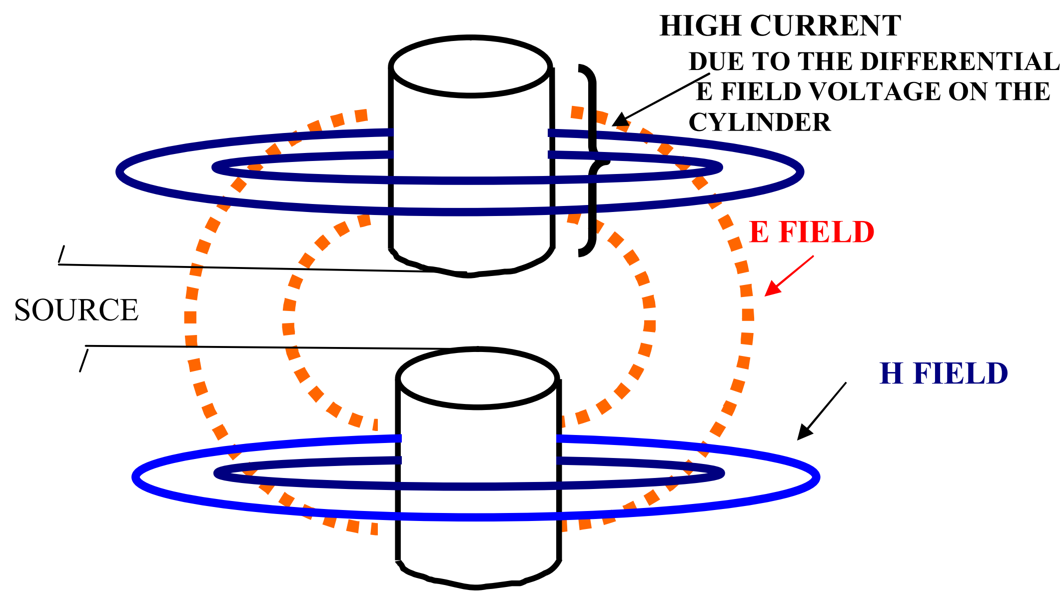


FIGURE 1 CREATION OF E AND H FIELDS

It is important to note that a very strong magnetic field also exists inside the antenna. To reduce loss due to eddy currents, the cylinders must be made of non-ferrous material such as copper of aluminum. Unless either of those materials is used, the antenna performance will be degraded **below** acceptable levels. Also, there can be **no** ferrous material inside the cylinders. Eddy currents on that ferrous material will cause the material to be heated, thus absorbing power that subtracts from the radiation.

The Phase Delay Network: During the development phase of the EH Antenna three different network configurations were designed to create the proper -90 degree phase shift between the two cylinders. The networks are depicted in Figure 2 thru 4 below.

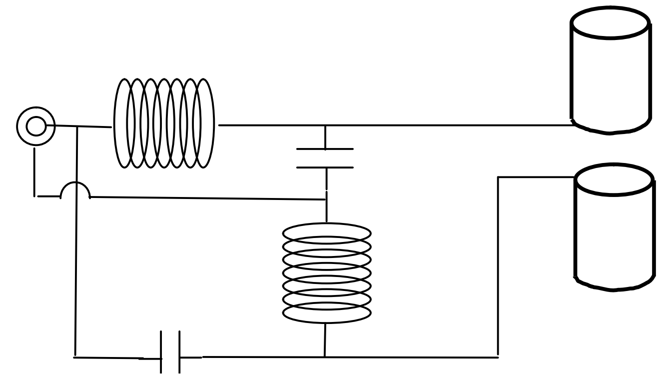


FIGURE 2 – L+L NETWORK

A. L+L Network: The first configuration was known as the L+L network and is shown in Figure 2. One L network provided a -45 degree phase shift and one provided + 45 degree phase shift. The L/C ratio is chosen to provide an impedance match to the coax. This arrangement works very well. However, even though the value of the two capacitors is very low, the capacitors must be able to withstand very high RF voltage.

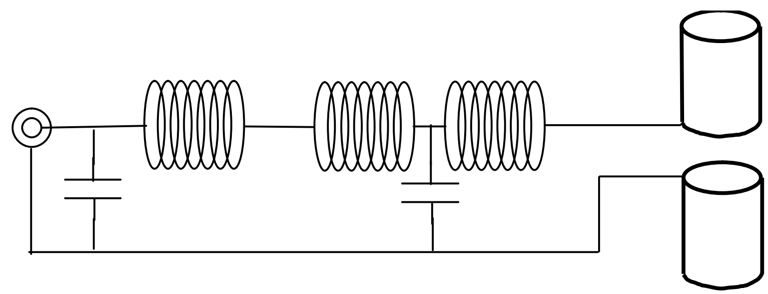


FIGURE 3 – L+T NETWORK

B. L+T Network: The second iteration used an L+T network as depicted in Figure 3. Typically, the L network transforms from 50 to 25 ohms with an associated -45 degree phase shift. The T network then transformed from 25 ohms to match the impedance of the antenna and provides an additional -45 degree phase shift. In this network the capacitors may be low voltage but must have high RF current capability. This network is very sensitive to phase shift in the transmitter because it is essentially a series network where phase is concerned.

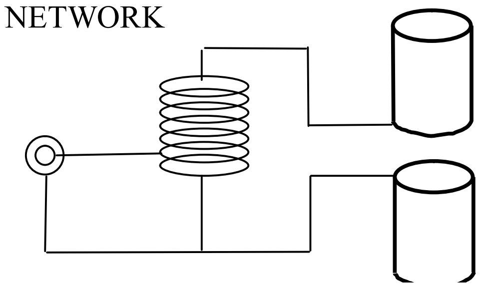
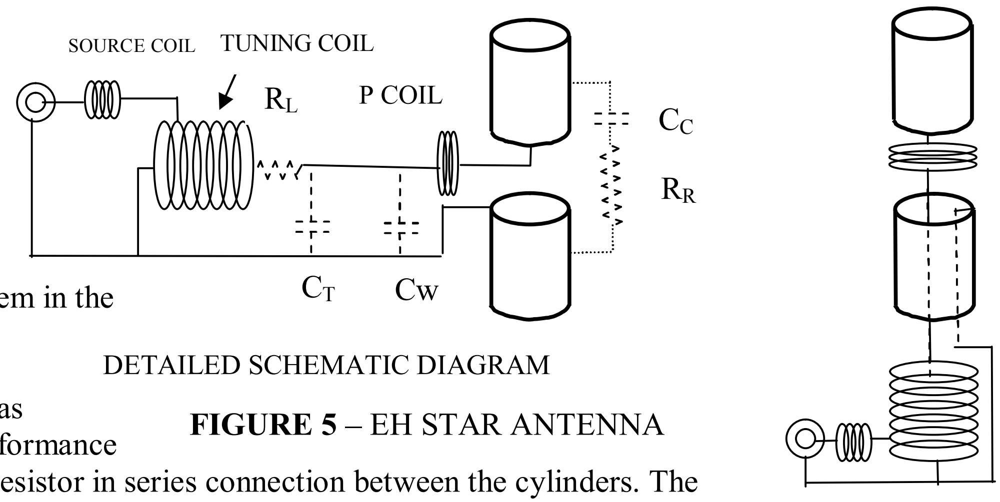


FIGURE 4 – EH STAR ANTENNA

C. STAR Network: The third and preferred configuration is shown in Figure 4. Note that the tuning coil is tapped for 50 ohms and the low side is connected to the coax shield. There

is a nominal -90 degree phase shift across the tuning coil. Because this configuration is simple and has a minimum of components, it has been given the name “EH STAR Antenna”.
Although the performance is the same for any of the three configurations, only the “STAR” version will be detailed in this book due to the simplicity and economics for Hams. Because there is a minimum of components, thus greater long term reliability, the STAR version is used for AM Broadcast.

Schematic Diagram: The diagram above provided a simple view of the major physical components. A complete schematic diagram and physical implementation is shown in Figure 5 for the STAR version. The physical configuration is shown on the right. The schematic diagram includes virtual components (using dashed lines) as well as physical components. The following paragraphs describe each item in the schematic diagram.



DETAILED SCHEMATIC DIAGRAM

FIGURE 5 – EH STAR ANTENNA

Cylinder Capacity (C_C): The cylinders are referred to as the radiating elements of the antenna. A measure of performance of the antenna is indicated by the virtual capacitor and resistor in series connection between the cylinders. The value of the capacitor is a function of the size of the cylinders, and can be calculated by the following equation: C=0.546 L + 2.06 D. C is measured in pFd when L (length of one cylinder) and D (diameter of a cylinder) are measured in inches. **This equation can not be found in the text books.** It was developed through the use of a very complex electrostatic program in Germany specifically for the development of the EH Antenna.

Radiation Resistance (R_R): The virtual Resistance shown on the diagram is called the Radiation Resistance. It can not be measured directly, but exists as a function of performance of the EH Antenna. ***This resistance occurs only at the frequency where the proper phasing of the network occurs. This may not be the same frequency where resonance occurs.*** (This is the eighth unique parameter). This fact separates the EH Antenna from conventional Hertz antennas because the EH system does not conform to conventional theory. A misunderstanding of this important fact is the primary reason for degraded performance due to mistuning of the EH Antenna.

Although the effective Radiation Resistance can not be measured directly, it can be accurately determined by measuring the radiation bandwidth of the antenna then computing the value as R_R=BW*Xc/F where BW is the +/- 3 dB bandwidth as measured by a field strength meter, Xc is the capacitive reactance calculated or measured for the cylinder capacity, and F is the operating frequency. Note that the bandwidth is a function of the capacity between cylinders, thus the antenna size dictates the bandwidth. (This is the ninth unique parameter).

We have found that all STAR EH Antennas (using cylinders) have a radiation resistance of approximately 120 ohms. This is another departure from conventional theory where the radiation resistance of Hertz antennas varies as a function of the length versus frequency and other parameters including proximity to ground and other objects. Items removed more than two antenna lengths from an EH Antenna have no effect. On the other hand, items up to ½ wavelength have a large effect on the radiation resistance of a Hertz antenna. This is one indication of the relative size of the E and H fields of the two antenna types.

Phasing Coil (P Coil): A small inductance is located below the top cylinder. Its purpose is to provide a small phase shift (nominally 6 degrees) in the feed wire to the top cylinder to prevent radiation from the wire as it passes through the lower cylinder, and also to prevent radiation from the tuning coil. To calculate the length of wire in this inductor, use the following equation: L=984/F*6/360*12 where L is measured in inches and F is the operating frequency in MHz. This equation calculates the wavelength in feet, converts it to 6 degrees phase delay, and then converts it to inches. For convenience the equation can be reduced to approximately L=200/F with sufficient accuracy.

Wire Capacity (C_W): The capacity of the wire running through the lower cylinder is surprisingly high compared to the capacity between cylinders. Therefore, it must be included in any precise model of the EH Antenna. The equation for the capacity is Cw=0.614/log(C/W)*L in pFd, where C is the diameter of the cylinder and W is the diameter of the wire and L is the length of the cylinder in inches.

Coil Capacity (C_T): The self capacity of the tuning coil may have a significant effect when calculating the inductance needed to tune the antenna. Consult a handbook for the capacity of the coil you need for your antenna, or just experimentally adjust the tuning coil to compensate for it. For most applications use a value of ½ the cylinder capacity with sufficient accuracy, then trim to fit. .

Other capacity: There is an additional capacity that is very difficult to calculate. It is the capacity between the lower cylinder and the tuning coil. It will be necessary to build the antenna and trim the tuning coil to achieve the center of the desired operational frequency.

Loss Resistance (R_L): The wire comprising the tuning coil will have some amount of RF Resistance, depending on the amount of wire in the coil, the wire size, and the operating frequency. The efficiency of the antenna is related to the amount of heat loss in this wire compared to the Radiation Resistance. The power loss can be determined by calculating the current in the tuning coil and the resistance, then the lost power $P=I^{\wedge 2}R$. For power levels of 100 watts or less, use #14 enamel covered wire. For higher power use #8 wires up to full legal power.

Efficiency: The efficiency of the antenna is the output power divided by the input power which can be expressed as $\eta=R_R/(R_L+R_R)$ for conventional antennas. There are capacitor currents that shunt the tuning coil current in the EH Antenna that prevent that equation from being accurate. However, because the radiation resistance is very large (120 ohms) compared to the loss resistance in the wire (a fraction of an ohm) that comprises the tuning coil, the EH Antenna efficiency approaches 100% unless very small wire is used to make the tuning coil. (This is the tenth unique parameter).

Tuning Coil: The amount of inductance in the tuning coil is determined by adding the values of the three (3) capacitors and using that value to calculate the value of inductance $L=1/((2\pi F)^2(Cc+C_W+C_T))$. With the calculated value of inductance and the physical size of the coil, a handbook can be used to find the number of turns of that coil and the self capacity. We will present an equation to calculate the number of turns in a later chapter.

Source Coil: As previously noted, the frequency at which maximum radiation occurs may not be the same as the resonant frequency. Maximum radiation occurs when the phasing is correct. Minimum VSWR occurs when the system has minimum reactance as seen by the transmitter. This is a major deviation from conventional Hertz antennas. Unless the resonant frequency and maximum radiation frequency are the same, a transmitter will prefer the frequency where the lowest VSWR occurs. This will be close to the resonant frequency but may be far away from the frequency where the phasing dictates maximum radiation, thus the radiation will be low. This becomes very apparent when the tuning coil gets hot while transmitting even though the VSWR meter on the transmitter is happy – until the antenna melts!!!

If the antenna were a simple tuned circuit with the tuning coil and cylinder capacity and the Radiation Resistance in series, then maximum radiation would occur at the resonant frequency, as in a conventional antenna. The manner of connecting the coax to the tuning coil (feed close to one cylinder) provides a -90 degree phase shift inside the antenna. However, because the parallel capacity of $C_W + C_T$ is across the tuning coil but the Radiation Resistance is only in series with Cc, there is a frequency shift between resonance and maximum radiation. It may be small and can be compensated by adding a series reactance in the feed line. If the values of C_W and C_T are small, than a source capacitor is needed to correct the input impedance to be R+j0 at the same frequency as maximum radiation.

On the other hand, if the self capacity of the tuning coil or the capacity between the coil and lower cylinder is large, then a source inductance is necessary to correct the input impedance. This is the typical case for Ham antennas because of close wound coils and locating the tuning coil about one diameter below the lower cylinder.

CHAPTER 3 – IMPLEMENTATION

PHYSICAL DETAILS: Following an introduction to the various components (both real and imaginary) of the EH Antenna, it is now appropriate to look at the physical construction. With reference to Figure 3, there is a sketch showing the configuration of the "STAR" version.

Radiation Pattern: As with any antenna design, it is appropriate to begin by choosing the desired radiation pattern. The pattern is controlled by the cylinder length to diameter ratio. For low angle radiation as normal for AM Broadcast stations and Ham bands above 7 MHz, or for chasing DX on the low bands, the L/D ratio is typically chosen to be 6:1 or less. For typical Ham antennas below 10 MHz that use high angle radiation for close communications, an L/D ratio of 12 or greater is chosen.

To put the radiation pattern of a EH Antenna in proper perspective, please see Figure 6 on the following page. The patterns of standard antennas were derived using a MININEC computer program. The layout may not be familiar to the reader, but it clearly shows the relevant information. Begin by looking at the pattern for a dipole ¼ wavelength high. The radiation at 90 degrees (straight up) is very good, and falls off at lower take off angles. Dipoles at ½ wavelength high do not perform well at high angles, but give increased radiation at lower angles. As the dipole is raised higher, nulls in the pattern begin to appear. The shape of these patterns (peaks and nulls) apply to horizontal beams; their horizontal beamwidth is narrowed by a factor of the antenna gain. The pattern of a ¼ wave vertical is also presented. These are ideal patterns, not necessarily what you would expect form your backyard antenna. In particular, if there are buildings blocking the desired direction, the calculated pattern can not be realized in practice. Patterns for the horizontal dipoles are broadside to the dipole. There is a null off the end, making the dipole pattern directional in the horizontal plane. Also, the pattern assumes 120 radials surrounding the vertical.

There is another plot – called the ideal antenna. We calculated the pattern of a hypothetical antenna that would give equal signal level at all distances. For example, at a takeoff angle of 90 degrees, the ionosphere is 185 miles high (typically). On 75 meters, when the band is open, a 100 watt transmitter with a antenna gain of -10 dBi would communicate to a dipole a signal level of about S9+8 dB.

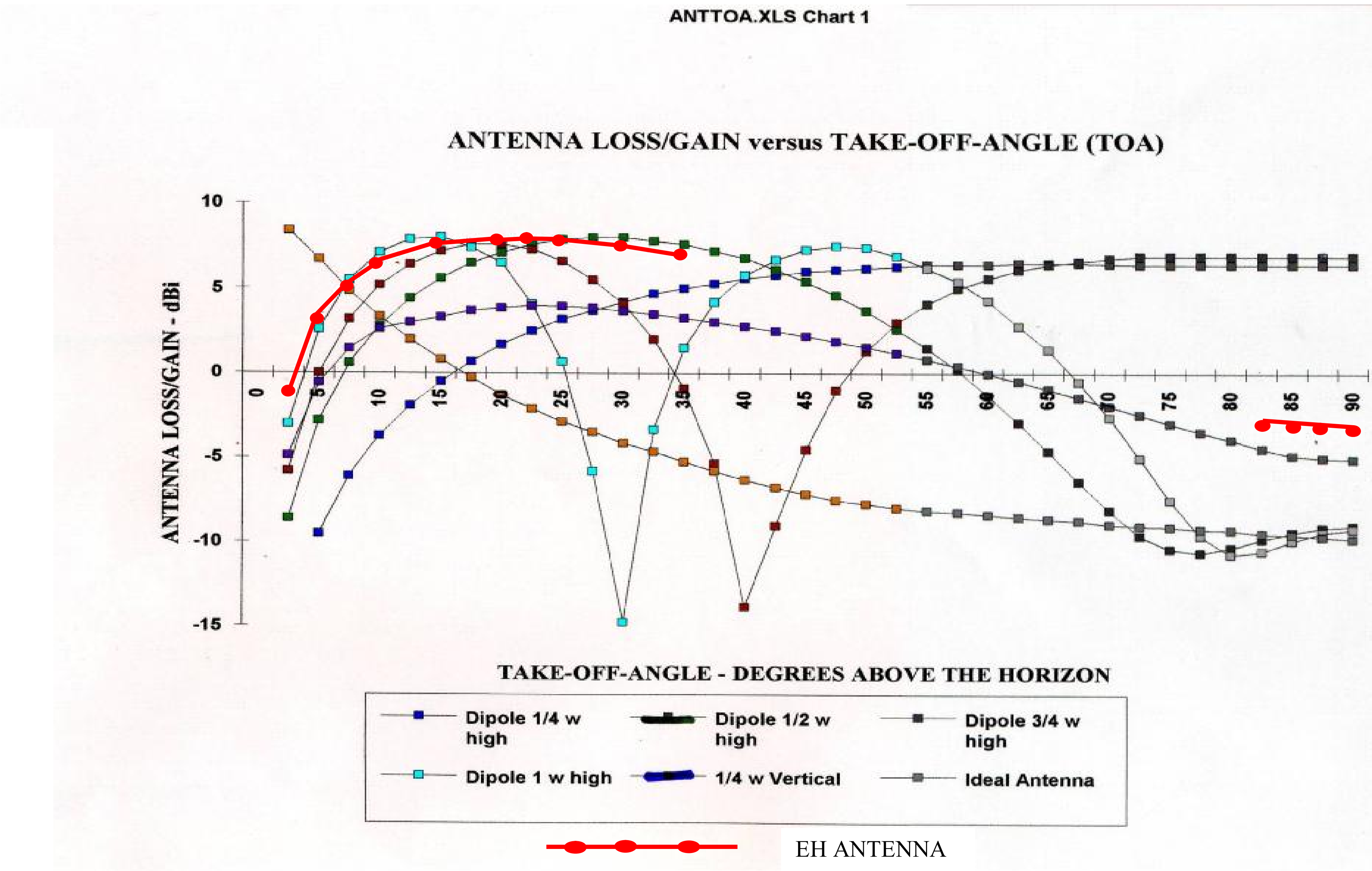


FIGURE 6 – RADIATION PATTERNS OF VARIOUS ANTENNAS

At 1500 miles, the ¼ wavelength high dipoles would give a received signal level of about S8+5dB. The ideal antenna would have a gain of +4 dBi at a take off angle of 8 degrees. The ideal antenna would sacrifice signal level at close range for more signal at long range.

Where does the EH Antenna fit into this picture? For a 12:1 Length/diameter ratio the EH Antenna (at very high angles) has a gain of about -8 dB to -10 dB compared to a ½ wave dipole ¼ wavelength above ground, when it is mounted vertically. For an L/D ratio of 3, at low angles the EH Antenna is about 4 dB over a ¼ wave vertical. We have drawn relative performance curves for the two EH Antenna configurations using red circles and red lines on the plot of Figure 6. It is an excellent antenna for low angle (DX) radiation. The plot assumes a height of ¼ wavelength for the DX antenna. However, at a height of 0.1 wavelengths the gain would only be reduced about 4 dB, essentially making it equal to a ¼ wavelength vertical with 120 radials.

The gain over a vertical was determined by measurement. An EH Antenna was compared to a standard AM Broadcast antenna. Also, a 40 meter EH Antenna was compared to a ½ wavelength vertical antenna. Although the EH Antenna was better at low angles, the vertical was better at high angles. There have been other tests on other frequencies, with consistent results.

On the cover of this book is an Emergency Van developed by the local radio club. The 75 meter antenna is for use in an emergency to cover the state, including communications with the ARES center about 80 miles distant. It is interesting to note that there are also 40 and 20 meter antennas made on similar plastic pipes. They are stored in the van when not in use. The 40 and 20 meter antennas are frequently used when the van is being demonstrated during the day with great success.

This will help you decide which antenna you prefer for your particular mode of operation. It should be pointed out that the best low angle performance for the EH Antenna is when it is ¼ wavelength above ground. On 40 meters that is only 30 feet. That puts it above most local buildings giving it an even greater advantage over the vertical with buried radials, because the radiation is from the cylinders high above ground. At high angles a vertically mounted EH Antenna can never beat the old standard dipole. However, if you are short on space and want to get on 160, 80, or 40 meters with an almost invisible antenna, then the EH Antenna will be the choice. At high angles the performance does not degrade rapidly as the antenna is lowered, so even at low heights down to 0.1 wavelengths (but still above roof level) the EH Antenna will be very good.

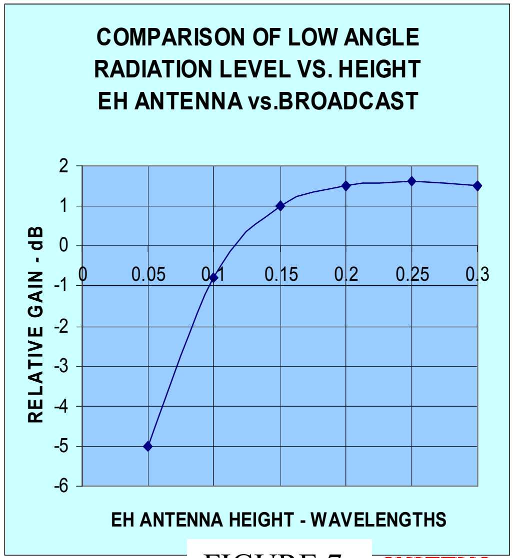


FIGURE 7

Be aware that the EH Antenna is typically a vertical dipole, therefore it can not perform well close to ground. On the other hand it does not require radials. This is a major economic factor for AM Broadcast, especially above 1200 KHz where the small antenna can be mounted on a non-guyed tower, thus the only real estate required is only that sufficient for the tower base. At a height of about 0.1 wavelengths above ground the EH Antenna will equal the radiation from a standard AM Broadcast tower, with an increase in radiation along the ground up to a height of ¼ wavelength, then the low angle radiation begins to decrease with a minimum at ½ wavelength, then a maximum at ¾ wavelengths. Even on 160 meters for DX the EH Antenna will be outstanding at a height of only 16 meters, about 52 feet. Even at 30 feet above the ground, it is an excellent DX antenna. For this reason the EH Antenna should be the antenna of choice for DXpeditions.

To detail the radiation level along the ground (or very low DX angles), the plot of Figure 7 is presented. The shape of the curve was first developed by experiment using a 20 meter EH Antenna and a distant source. Then, an EH AM Broadcast antenna was installed and tested in comparison to a standard ¼ wavelength tower that has 120 radials and exhibits performance in accordance with FCC standards. (see the large photograph on the front cover).The testing was performed by a Broadcast Consultant and submitted to the FCC in a report required as part of the experimental license. The plot shows that an EH Antenna mounted at a height of 0.1 wavelengths above ground was 0.84 dB below a standard AM Broadcast antenna. If the EH were moved higher to1/4 wavelength the level would increase to almost 3 dB more than a standard tower. It gets more interesting. This was during the development phase of the program. It was later learned that the steel support tower inside the cylinders caused the bandwidth to be 40 KHz rather than the calculated value of 279 KHz. It was not until much later that we learned how to accurately calculate bandwidth. The reduction in bandwidth can be correlated to a reduction in radiation resistance from 120 ohms to 17 ohms. It would seem that a loading that causes the bandwidth to change by a factor of 7 would have a large effect on the antenna efficiency. However, our calculations show that the difference would be only a fraction of a dB. That brings the difference between a standard AM Broadcast antenna and a EH Antenna to more than 3 dB, a little less than 4 dB observed in other measurements. However, we have since learned that a L/D ratio of 3 would enhance the low angle radiation compared to the 6:1 ratio used for the test, thus 4 dB is a conservative number. The major point of this plot is to show that at 0.1 wavelength above ground, the performance of an EH Antenna will essentially equal a ¼ wavelength tower with 120 buried radials. As previously noted, the radiation is from the cylinders, not close to ground level. Thus, for Hams, the radiation is not blocked by buildings as it would be from a standard vertical, and <u>no radials are required</u>.

FIGURE 8A - 40 METER BICONE

FIGURE 8 B DISC-CONE

For some applications it is desirable to have greater control over the radiation pattern than offered by the cylinder length to diameter ratio. This can be achieved by the use of bi-cone shapes. (This is the eleventh unique parameter). Although these antennas radiate 360 degrees in the azimuth plane, they can offer very narrow elevation beam widths and additional gain. The radiation from a disc cone as shown in Figure 8B is a narrow beam centered at a take off angle equal to ½ the angle between the disc and the cone. The example shown was an experiment tested on the AM Broadcast band. The bi-cone as shown in Figure 8A creates a narrow beam that is parallel to the ground, when the bi-cone is oriented as shown. Unfortunately, we do not have an exact value of gain at this time, but it is significant.

One other EH Antenna configuration should be considered here; a phased array using EH Antennas. We have shown that each antenna in the array can be very small, even on 160 meters. Because of the constrained E and H fields, an active array (all elements are actively fed- no parasitic elements) can have close spaced elements because the interaction is very limited. (This is the twelfth unique parameter).

Bandwidth: After the desired radiation pattern has been selected, the next step in the design process is to select the desired bandwidth. By using the equation for capacity between cylinders and assuming that the Radiation Resistance has a value of 120 ohms, the diameter can be readily chosen. To assist in this process the chart in Figure 9 specifies the cylinder capacity as a function of the cylinder diameter. Two (2) curves are included. The upper curve is for an L/D ratio of 12 while the lower curve is for an L/D ratio of 6.

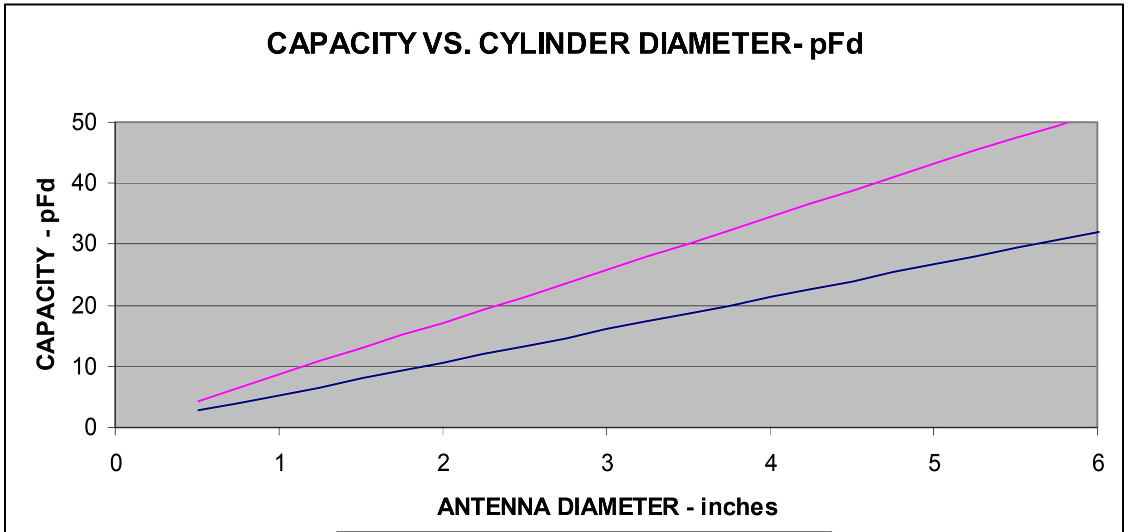


FIGURE 9 - CAPACITY VS

Figure 10 is a plot of capacity required for a given bandwidth for the major Ham bands. The blue curve is for 160 meters, the purple is 80 meters, next is the yellow for 40 meters then 20 meters and finally the bottom curve is 10 meters. Note that only a very small capacity is required for a large bandwidth at the higher frequencies. On the other hand a large capacity is required for the lower bands, thus large cylinders. For example, the cylinders for the large AM

Broadcast antenna are 36 inches in diameter and 18 feet in length. However, for the small AM Broadcast antenna for use above 1200 KHz, the cylinders are only 9 inches in diameter and 54 inches in length while providing the necessary bandwidth at the high end of the broadcast band. (A photograph of that antenna is on the front cover of this book). It is interesting that the AM Broadcast band covers a frequency range of 1700/540=3.15. That is a wider range than 80 thru 30 meters or 30 through 10 meters. Please note that the EH Antenna is not frequency sensitive; the size just dictates the bandwidth at the frequency to which it is tuned.

In theory, the EH Antenna could be constructed for use at any frequency. However, they get very small even on 2 meters. Much above that would not be practical.

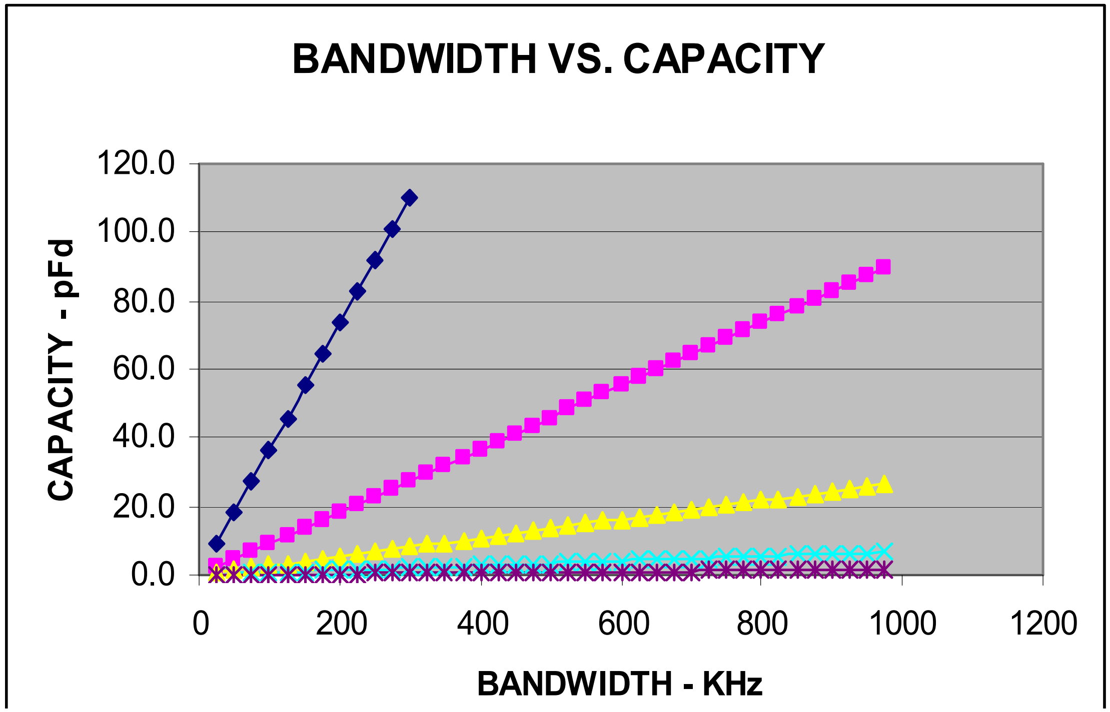


FIGURE 10- +/- 3 dB BANDWIDTH AS A FUNCTION OF CYLINDER CAPACITY

In the following paragraphs we will use examples to explain the technical details. To use the two plots, assume a desired bandwidth of 300 KHz on 40 meters. By the way, we have made the calculations based on a +/- 3 dB bandwidth. The 2:1 VSWR bandwidth will be approximately ½ the 3 dB bandwidth. It should also be noted that an antenna tuner will allow good performance over the 3 dB bandwidth by converting the antenna impedance to very low VSWR to make the transmitter happy. Do not use an antenna tuner to transmit outside the 3 dB bandwidth even if low VSWR is attainable. The reason is that the tuner may change the reactance without changing the phasing which will cause a significant difference between the resonant frequency and frequency of maximum radiation. At the resonant frequency (typically the lowest VSWR frequency) the effective Radiation Resistance may drop dramatically. In this case a large amount of the transmitter power will be applied to the loss resistance. Now the transmitter is heating the tuning coil rather than developing radiation with the disastrous effect that the antenna will get very hot – resulting in a drooping antenna that looks like charcoal. Words of advice – make or buy a simple diode field strength meter to use in the shack while operating. You will also need one to properly tune the antenna.

Now, on with the example: For a 600 KHz 3 dB bandwidth (300 KHz 2:1 VSWR bandwidth) on 40 meters the plot indicates a need for about 16 pFd of cylinder capacity. The first plot, for a L/D ratio of 12 indicates the need for a 2 inch diameter cylinder. This will be a great general purpose Ham antenna. On the other hand, if a very good DX antenna is desired with a 2:1 VSWR bandwidth of 600 KHz on 40 meters, then a 3 inch diameter cylinder would be required. This is a large antenna by EH Antenna standards even though the length is measured in inches rather than a large number of feet (468/7=67 feet at 7 MHz) as required for ½ wavelength dipoles or 34 feet for a ¼ wavelength vertical plus a lot of 34 foot radials. .

If the reader considers a 3 inch diameter antenna having a length of 6.25 feet to be too large for 40 meters, there are alternatives. Reduce the bandwidth to only that range for your normal operations or use an electric screw driver to turn a screw to move a slug in the tuning coil to remotely tune the antenna, or use a ¾ wavelength feed line. More on this later.

The plots above are based on an assumption that the effective Radiation Resistance is 120 ohm. Your antenna may vary a small amount. However, when your antenna is complete and the final tests do not nominally agree with the calculated bandwidth, the cause should be determined before using the antenna.

It should be noted that a very small antenna can be constructed on 40 meters that will outperform a very large antenna. It is also interesting to note that the only means to increase the bandwidth of a conventional wire antenna is to use a folded dipole. The bandwidth increased, but the size stayed the same – ½ wavelength. It is also interesting to note that an antenna tuner may be used to tune a dipole over a wide frequency range. This is because the radiation resistance of a conventional Hertz antenna is almost constant, but slowly increases with frequency. Compare this to an EH antenna where there is a peak in radiation resistance only at the frequency where the phasing is correct. At other frequencies the radiation resistance is almost zero. For this reason, harmonic radiation is virtually eliminated. (This is the thirteenth unique parameter).

For those who prefer to calculate the bandwidth, the equations can be set on an excel spread sheet. Simply input the parameters and you will instantly see the resultant capacity, the bandwidth, the antenna Q and the total length of the antenna. This allows the reader to experiment before construction begins. Note: in the bandwidth equation use a value of 120 ohms for R. A complete program that calculates all design requirements for an EH Antenna will be found in on the web site. I created the spread sheet and others volunteered to convert the equations to other program formats to make it easy for Hams.

Specify the Frequency, Diameter (D) in inches and the L/D ratio in the space below

Frequency =	1.9	MHz		
Diameter =	2.25	Inches		
L/D ratio =	12			
C =	19.4	pFd	C(pFd)=	.0.546*L+2.06*D
BW =	52.7	KHz	BW(KHz)=	R*C*6.28*F^2/1000
Q =	36.0		Q =	F/BW
Total Length =	4.7	Feet	Length =	D+2*D*L/D

Before we leave this subject, there is another important consideration that needs to be followed in the construction process. To prevent internal fields from corrupting the performance, **the spacing between the cylinders must be equal to the diameter.** This is the reason one (1) diameter is included in the total length.

Now, take a look at the 40 meter antenna you just designed. The diameter was 2.25 inches and the length of each cylinder was 12*2.25 = 27 inches. Therefore, the total length of the antenna is only 27+2.25+27 = 56.25 inches. We have an antenna on 40 meters that is only a little more than 2 inches in diameter and less than 5 feet tall. Look at this antenna another way. This antenna has a length of 56.25/((984/7)*12)= 0.033 = 3% of a wavelength. That is a small antenna. However, if you are willing to trade bandwidth for size, the antenna could be very much smaller. Note the example in the calculation above for a 160 meter antenna. Most Hams on 160 stay close to a single frequency, but even so a small 160 meter EH Antenna can offer a 3 dB bandwidth of 50 KHz, about equivalent to a 120 foot dipole.

A very useful trick is to use an electric screw driver to drive a screw that moves an aluminum or copper slug inside the tuning coil as a means of changing the operating frequency. This reduces the need for an antenna with wide instantaneous bandwidth, thus it can be smaller. To make the point, in Japan FR Radio Lab manufactures an EH antenna that has 1 inch diameter cylinders and a L/D of 12 for a total length of 25 inches (0.8% of a wavelength) on 80 meters. A small motor moves the slug and allows coverage from 3.5 to 4 MHz. Because the slug changes both the phasing and resonance, low VSWR can be maintained over a large frequency range.

By now I am sure that you, the reader, have realized that this is not a conventional antenna, therefore the size is chosen for the desired bandwidth and radiation pattern. Regardless of the size, all of the desirable parameters still hold with the possible exception of efficiency. On the low bands when the amount of wire needed in the tuning coil is large if small cylinders are used, the efficiency will be slightly degraded, but only a small amount. For example, assume the loss resistance in the tuning coil is 0.5 ohms. The antenna efficiency is then 120/(120+0.5) = 99.6%. If the loss doubles the efficiency is reduced to 120/(120+1) = 99.2%.

In subsequent paragraphs we will present the necessary implementation details. As before, we will use examples to clarify the concepts.

CHAPTER 4– BUILD A 40 METER ANTENNA

Preparation: With the concept of the EH Antennas fully defined, we can now proceed to build one and measure its capability. This will answer the nagging question – does it really work, or were the naysayers right? You can prove it to your self.

We want a very simple low cost antenna that can be constructed in a very short time. Remember, it is a demonstration, not a Mona Lisa to be hung in the Louvre. After you have experimented with your first antenna and find that it really does work, then you can specify the best antenna to suit your specific operational scenario. The second one you build may not be a real thing of beauty either, but there is a saying – a Mother always loves her babies.

Why 40 meters? The antenna is small enough to allow construction and test inside the Ham shack, yet it is a low enough frequency that makes it less critical to build and adjust. Further, 40 meters is almost always open, which allows you to get on the air immediately after you complete the antenna. Please, do not transmit with full power until you are sure that the antenna has been properly adjusted and tested. Personally, I find it amusing to learn that an antenna melted because it was not adjusted properly, but you may not feel the same while watching your creation go up in smoke. The antenna we are going to build will be limited to 100 watts. You will understand why as we proceed.

Required Items: There are three (3) things you must have before beginning the project:

1) You must have a Field Strength Meter. You can build a simple one with a diode and meter from information in a handbook, or buy one in a flea market. A lot of them have shown up that were combined VSWR and Field Strength Meters made for use on the Citizens band. The field strength meter is not frequency sensitive.

2) You will need a form to construct the antenna on. We recommend the use of a 2 inch diameter plastic pipe from the hardware store. The diameter is specified as the internal diameter (ID) because it is designed for water flow, not antenna construction. The outside diameter (OD) will be about 2.25 inches. Only use white or clear plastic. If the pipe is colored, the color is a result of included carbon particles and they get very active in the presence of RF. The result is heat, and that is not a good thing for the health of plastic pipe, and does not enhance antenna performance. Even the white pipe contains particles to help protect for ultra violet radiation. This is not good, but tolerable. Normally the plastic pipe comes in 10 foot sections for a very low price.

3) You will need some #14 copper wire with enamel (varnish) insulation. For the game we are playing do not use any other type of insulation. This wire is available at any shop that rewinds motors and generators.

It is highly desirable to have an Impedance Meter such as the AEA Bravo (about $2200) and a signal generator, but not absolutely necessary. You can trade time for the lack of equipment.

Construction: Even though we discussed one size for 40 meters, it seems too large for a beginner project. Therefore let us consider only a DX antenna for 40 meters with a 3:1 length to diameter ratio. Most of the material for this one is readily available. Consider a 2.25 inch plastic pipe. The capacity will be 8.3 pFd and the 3 dB bandwidth will be 307 KHz, or about 150 KHz 2:1 VSWR bandwidth. The antenna will have 2.25x3=6.75 inch cylinders and a total length of 2.25+2x6.75=15.8 inches. This is more reasonable for the first one. Unfortunately, as you proceed through the design process you will find that you need about 27 turns of wire because the cylinder capacity is so small.

Lets consider a 3 inch diameter pipe (3.25 OD) and a DX antenna (3:1 L/D). This will have a capacity of 11 pFd with a +/- 3 dB bandwidth of 444 KHz, or a 2:1 VSWR bandwidth of about 222 KHz. Because the pipe diameter is larger and the capacity is larger, the coil will be more reasonable with only 15 turns. Now, the cylinders will be 3*3.25=9.75 inches. This is much more compatible with the aluminum foil you will steal from your wife's kitchen to make the cylinders. The total length of the antenna will be

3.25+2*9.75=22.8, just less than 2 feet. The tuning coil will add additional length of about 1 inch plus spacing of about 3 inches for a total of 22.8+4=27 inches.

Next, calculate the capacity of the wire through the lower cylinder; Cw=0.614/log(C/W)*6.75 = 0.614/log (3.25/0.064)*9.75 =0.614/1.71*9.75 = 3.51 pFd. Now you can see that this is not a negligible value compared to the cylinder capacity.

Next we need the capacity from the tuning coil. Now, we have a chicken and egg problem: how do we calculate the capacity if we do not know the inductance, and how do we know the inductance if we do not know the capacity? The answer is – guess, then iterate the process until you get an exact value. On the other hand, why bother to iterate when there are other capacitor values that we can not calculate, including the capacity between the lower cylinder and the tuning coil. If we assume that the coil capacity is about ½ the cylinder capacity, we have about 6 pFd. We need a coil of L=1/((2πF)^2C)=1/((2π7e6)^2*(12+3.5+6)e-12)=24 uHy. This is interesting, but what we really want to know is how many turns of #14 wire are needed! Try this, n=(L*(18D+10B)/((D/2))^2)^.5 where L is the inductance in uHy, D is the coil diameter in inches, and B is the coil length in inches. Now we have another chicken and egg problem – we need to know the coil length before we can calculate the number of turns. Using #14 wire and a close wound coil, we can use a value of 0.064 for the wire diameter. This gives 1/.064=15.6 turns/inch – assuming perfect winding. Remember, we are not exactly sure about the capacity, so our inductance is suspect, and now we have introduced another variable. The point I want to make is – make your best guess with your best tools, then add a few extra turns then trim to fit.

I have modified the equation above to give a unique solution by including the length as a function of the wire spacing. That equation is: N=(10LS+((10LS)^2+4.5D^3L)^.5/(D^2/2) where N=number of turns, L is the inductance in uHy, D is the coil diameter, S is spacing in inches between turns (0.064 for #14). Although the text books will show optimum length to diameter ratios for the coil to enhance the coil Q, it has little effect for an EH Antenna. This is because the loss resistance is a function of the coil Q, and because the loss resistance of the coil is very small compared to the radiation resistance, a change in coil Q has a negligible effect on efficiency.

Solving the equation we find that we need 15 turns. Add a couple of extra because it is easier to remove turns that to add them. How long will the coil be? Simply multiply the number of turns by the spacing, and the answer is 15*0.064=about 0.96 inches.

Wind the coil beginning one diameter below the lower cylinder. Next run a wire inside the lower cylinder spacing the wire near the center of the pipe and between a screw terminal just above the top of the tuning coil and to the center between the cylinders. This terminal is intended to be a holding point for a jumper wire to the coil to be used during the tuning process. Add a phasing coil between this wire and the top cylinder. Next, add a wire just inside the lower cylinder wall between the lower cylinder and to the bottom of the tuning coil. Use a clip to serve as the connection to the coil with a short wire from the screw terminal. Scrape the insulation from the wire at each of the bumps.

You have just built an EH Antenna for 40 meters. It is not an antenna until the feed line is connected. Use a short piece of coax (about 3 feet long) from the test equipment to the antenna. The shield connects to the bottom of the tuning coil; the center conductor connects to a tap on the low end of the coil. Start about 1 turn up.

COMPUTER PROGRAM: You have been lead through a process that explains the various details of the EH Antenna. You are not expected to go through the laborious activity to sort through all of the details to design an EH Antenna, so a computer program has been developed to do that for you. You will find that program on the web site. It is presented below in Excel spread sheet format. Jack has converted the program to Visual basic. It will be very easy for any Ham to use with out confusion. If the program was only presented in Excel, there are many ways to create problems and get confused unless you are an experienced user. For the 40 meter antenna discussed above, here are the details:

FOLLOWING IS A DESIGN PROGRAM FOR AN EH ANTENNA

written by
Ted Hart CEO, EH Antenna Systems, LLC

SPECIFY THE PARAMETERS IN THE BLUE CELLS.

Frequency =	**7**	MHz		
Cylinder Diameter =	**3.25**	Inches		
L/D ratio =	**3**			
C =	12.0	pFd	C(pFd)=	.0.546*L+2.06*D
Xc=	1892.7	ohms		
.+/- 3 dB Bandwidth =	**443.8**	KHz	BW(KHz)=	R*C*6.28*F^2/1000
Q =	15.8		Q =	F/BW
Total Length =	22.8	inches	Length =	D+2*D*L/D
Total Length =	1.9	feet		

INSERT THE MEASURED BANDWIDTH OF THE COMPLETED ANTENNA

Measured BW=	**440**	KHz	
RR=	119.0	ohms	
Measured vs. calculated =	-0.9	% Variance	

CALCULATE THE TUNING COIL PARAMETERS

Wire diameter =	**0.064**	inches	use 0.064 for #14
Spacing=	**0.064**	inches	
Turns per inch=	15.6		
Coil Diameter=	**3.25**	inches	
Cylinder wire C=	3.5	pFd	
Estimate Coil C=	6.0	pFd	This is only an estimate
Coil Inductance =	24.0	uHy	
Number of turns=	**15**		(10LS+/-((10LS)^2+4.5D^3L)^.5/(D^2/2)
Coil Length=	0.9	inches	
Length of wire =	48.1	inches	4.0 Feet

Note - the value of inductance is based on estimates of capacity for the coil and includes an estimate of 1/2 the cylinder capacity for the capacity between the coil and cylinder. This may result in a small change in the number of turns on the coil.

CALCULATE ANTENNA EFFICIENCY

RF Resistance in coil=	0.17	ohms	
Antenna Efficiency =	**99.86**	%	only approximate
Antenna Efficiency =	**-0.006**	dB	only approximate

Note: In the EH Antenna there is more current in the coil than in the Radiation resistance due to the currents in the capacitors that shunt the coil. Therefore, the true efficiency must consider this, but the calculation above does not. However, even if the loss is much greater, the efficiency remains very high because the loss in the coil is very small in. comparison to a Radiation Resistance of 120 ohms. The efficiency is based on the measured bandwidth, not calculated bandwidth.

CALCULATE THE LENGTH OF WIRE FOR THE PHASING COIL

Wire length =	28.1	inches
Wire length =	2.3	feet
Turns =	2.8	

TUNING AN EH ANTENNA: You have constructed something you would like to call an antenna. However, unless you tune the antenna correctly, you will have nothing but a pile of worthless stuff. So, to transform this thing to some thing of real beauty (in the eye of the beholder), please read and understand the following information, then apply it correctly. If you do you will have a very good antenna. If you decide to tune this antenna the way you would a conventional Hertz antenna, then all of your previous effort has been wasted and you will never have a useful antenna. There are many of these on the scrap pile and many Hams condemn the EH Antenna because they just would not try to understand the concept and properly tune the antenna.

I will suggest that you have two major items of test equipment; a signal generator and a Field Strength Meter. If you have enough patience you can use your transmitter for the signal generator, but it will be very difficult and cause a 5 minute task to drag on for a long frustrating period.

. **You can not continue this effort without a Field Strength Meter.**

Drill a hole in the top of the antenna and use a string to support the antenna from a hook in the ceiling. The height should be comfortable while you adjust the taps on the coil.

To prevent the antenna from being touchy while tuning it, connect a wire from the ground side of the antenna to ground. Inside the shack use a wire to the ground terminal on a power outlet if you have no other ground for your rig.

Frequency of Proper Phasing: The first step in the tuning process is to find the frequency where the phasing is correct. Yes, I said phasing, not resonance. All you need to do is to watch the Field Strength Meter (FSM) and tune the signal generator over the range you expect the antenna to be tuned to. A maximum reading on the FSM will tell you where the antenna creates maximum radiation. That is also the frequency where the phasing is correct (-90 degrees between the cylinders). Using the clip lead on top the tuning coil, move the tap until maximum radiation occurs at about mid-band on 40 meters.

If you do not have a signal generator, set the transmitter power to minimum and the frequency to mid band. Adjust the tap on top the coil to give maximum reading on the FSM.

Impedance Matching: This will be an iterative process, so be prepared to spend a little time on this one. The goal is to adjust the antenna to provide an impedance of 50+j0 (correct match and resonance) to the transmitter at the same frequency where maximum radiation occurs. Because the process is iterative, do not spend a lot of time trying to be perfect with each adjustment, just get close. If you do not have an impedance meter, then use a transmitter for the adjustment. Most transmitters do not give accurate VSWR readings at low power, so set the power to about 10 watts for this test, or the minimum power compatible with accurate VSWR readings.

Adjusting the Source Impedance: The first step, while keeping the frequency of the transmitter at the maximum radiation frequency is to observe the VSWR and adjust the feed tap for minimum VSWR. We want a 50 ohm match, but the rub here is that proper phasing and resonance will not be the same. To note the difference, tune the transmitter for minimum VSWR – note the frequency – then tune to maximum radiation and note the frequency. If there is a difference between the two frequencies this must be corrected.

As previously stated, a source reactance can be inserted in the feed line. Begin a couple of inches below the tuning coil and wind about 5 turns of wire around the pipe. Connect this coil as a series element between the coax center conductor and the feed tap on the tuning coil. Check again and determine if the two frequencies converged or moved further apart. If they converged (or moved toward convergence) then adjust the size of the coil to cause convergence. If the coil caused the frequencies to move apart, then a capacitor is needed. Without an impedance meter it is really not possible to determine the correct value of reactance needed, except by experiment. Add a capacitor with about 10 ohms reactance for a first test. $C=1/(2\pi FXc)$. On 40 meters this will be about 470 pFd. Again, adjust the value for convergence.

If a capacitor is used, then the current through that capacitor must be considered when selecting the proper capacitor. Assume that you use 100 watts and the feed line is 50 ohms. Therefore the current is $I=(P/R)^{.5} = (100/50)^{.5}= 1.4$ amps. This is much more than a small capacitor can handle. This is readily verified by applying 100 watts and watching to determine just how long it will be before you hear an explosion and the room is covered in stuff that does not have a pleasant smell. Figures 11 and 12 will help explain what is meant about the resonant and phasing frequencies not being the same. These are actual plots from a 75 meter antenna. In Figure 10 note that minimum VSWR occurs at a much lower frequency than the maximum radiation frequency as depicted by the maximum resistance (Blue line). Even though the reactance (Red line) goes through zero twice in the plot, minimum VSWR occurs when the reactance is close to zero and the resistance is close to 50 ohms, thus minimum VSWR. In Figure 11, after the proper amount of reactance is added to the feed line to shift the resonant frequency to be the same as the correct phasing frequency, and setting the tap for a 50 ohm match, we see zero reactance at the frequency of maximum resistance, almost. A little more reactance is needed, I just quit too soon. Note that minimum VSWR continues to occur where the reactance is zero (resonance) in preference to maximum radiation. These plots illustrate the complex nature of the EH Antenna and the major reason that many Hams have not successfully tuned the antenna correctly, thus they have not achieved maximum performance. These plots are exactly what you would see on a very expensive network analyzer. Because you do not have one is no reason not to achieve the maximum performance from your EH Antenna. Just work with it until maximum radiation (on the Field Strength Meter) is the same frequency as minimum VSWR, and VSWR is close to perfect. Without a network analyzer it will take a little more time, but the end result can be the same.

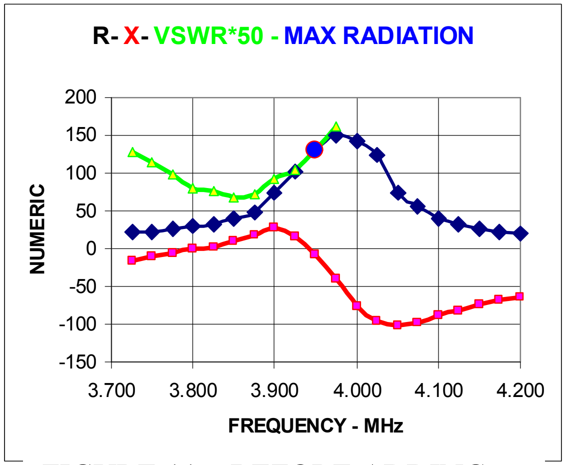


FIGURE 11 – BEFORE ADDING THE SOURCE COIL

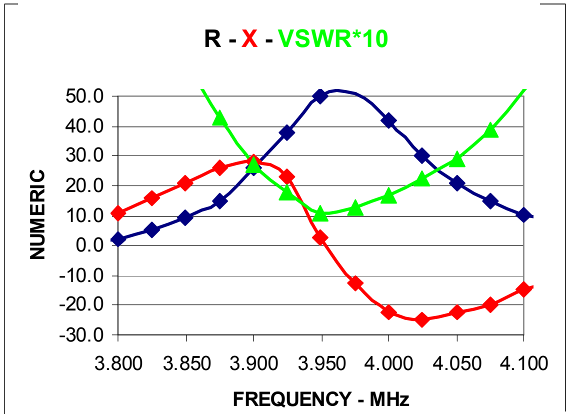


FIGURE 12 – IMPEDANCE AFTER ADJUSTING THE SOURCE COIL

Final Adjustment: With convergence of phasing and resonance, all that is needed is to adjust the feed tap on the tuning coil for 50 ohms (low VSWR). If you are careful, the VSWR can be very low. In fact, so low that it is virtually perfect. It Is important to note that the tap on the feed coil can be selected for any desired feed line impedance. For the large broadcast antenna we use open wire feed line down the tower, then an L network at the base of the tower to convert to the impedance to match the transmitter coax line.

Measure the bandwidth: Now, to prove that you have a EH Antenna, measure the +/- 3 dB bandwidth. This is done by setting the transmitter power to ½ power, setting the FSM to give close to a full scale reading, then setting the transmitter to full power. Next, adjust the transmitter frequency + and –until the meter indicates the same value as ½ power. Record the two frequencies and subtract the difference. This is the +/- 3 dB bandwidth. Unfortunately, you really can not do this – because the transmitter will see a very high VSWR before the +/- 3 dB bandwidth is achieved which will cause the power to fold back. A signal generator would come in very handy for this measurement. The alternative is to measure the 2:1 VSWR bandwidth (the difference between the two frequencies where the VSWR is 2:1) and double that value to approximate the +/- 3 dB bandwidth. It should compare favorably with the calculated bandwidth. You may have to adjust the transmitter power to less than full output to run this test.

Calculate the performance: One performance parameter of an antenna is the Q. This is a dimensionless value that simply compares the operating frequency to the bandwidth. Q=F/BW. A low value of Q indicates wide bandwidth. Typical values of Q for wire dipoles are about 30. Compare your antenna to a typical dipole. The calculated value is 7/0.443=15.8, about twice the bandwidth of a dipole.

There are several useful relationships that apply to antennas. These include Q=F/BW=Xc/R. A little algebra manipulation produces R=Xc*BW/F. To determine the effective radiation resistance we need the value of the cylinder capacity converted to reactance at the operating frequency, the measured bandwidth, and the operating frequency. To simplify the equation, $R= BW/(2\pi F^2C)$. For your antenna the value of R should be about 120 ohms. If it is, you have a great EH Antenna.

FEED LINE: We saved the bad news for last. You really did not expect to get something for nothing, did you? You have a great antenna with low VSWR, so you would expect to locate the antenna outside with a long feed line and communicate very happily for ever after. You could if you eliminated the feed line. We need to review the concept where we learned that the E and H fields are contained at the antenna. Unfortunately, they still exist to relatively high levels out to a distance more than twice the length of the antenna. The E and H fields remain strong enough to cause current to flow on wires that are in that area. Unfortunately, this includes the coax. When current flows on the coax disastrous consequences result. The frequency of the antenna appears to change as does the impedance if the position of the coax is changed. This is not good and makes the EH Antenna appear as if it is virtually useless. This is not unique to the EH Antenna. Coax currents occur on any antenna. There will also be RF on the transmitter, some times enough to burn you.

What to do? The only choice we have is to tame this beast. The only way to do this is to eliminate the feed line. It must be there to convey the transmitter power to the antenna (and receive signals from the antenna), so it can not be eliminated. It is time to apply RF techniques to allow us to have our cake and eat it too. By placing a RF trap in the feed line, we can solve the problem. We want to eliminate the current on the external shield of the coax while preserving the internal function of the coax. There are two (2) choices for the trap.

RF Choke: A more conventional approach is the use of an RF choke in the feed line composed of winding a length of the coax to form a coil. The desired RF continues to flow through the coax, but externally the RF Choke is effective in blocking the RF current on the outside of the coax shield. A high impedance in the feed line (on the external shield) will prevent current flow. The impedance of the choke is proportional to the size. If the length of coax is ¼ wavelength the impedance will be maximum. Also, if less than ¼ wavelength of coax is used and a capacitor is used across the coiled coax, the capacitor can cause the coil to be resonant at the operating frequency thus producing a very high impedance. It has also been found that covering the choke with aluminum foil and using a jumper wire to the coax shield below the choke will enhance the isolation.

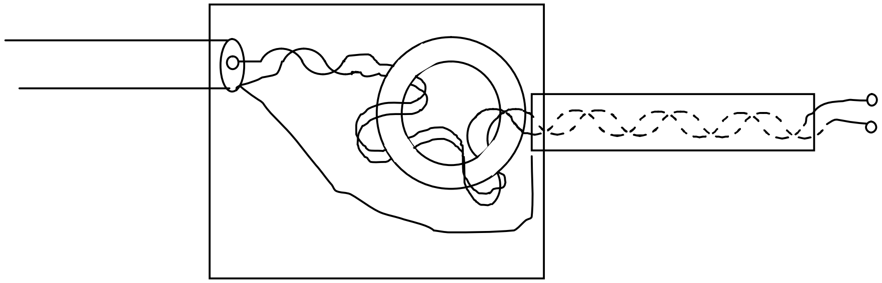


FIGURE 13 – CURRENT BALUN

Current Balun: Another method is to use a balanced line where the undesired current on the feed line is the same on both feed wires, thus it effectively cancels. However, it is desirable to be able to use coax to feed the antenna. We can have our cake and eat it too, if we build a simple current balun to convert from a coax line to a balanced line, then use a short section of the balanced line between the balun and the antenna. A sketch of the balun is shown in Figure 13. The balanced line is comprised of #14 wire (enamel insulation) with a few turns twist per foot. The length should be at least three (3) times the length of the antenna. The twisted line is covered by a shield (stripped from coax). That shield is connected to the coax and the box containing the balun, but the other end near the antenna is left to float. The balun is comprised of a few turns of wire that was first twisted then wrapped thru the toroid core. This is mounted in a box for shielding and weather protection. For the best toroid consult the handbook.

It is your choice as to which type of choke you prefer. In extreme cases (very high power) you may want to use a coax choke below the current balun.

Now, adding a choke was not too big a price to pay to calm down the beast, was it? Why didn't you add a choke to your ½ wavelength dipole? The E and H fields are so large they extend beyond the Ham shack, so it is a useless gesture to add a choke. I want to close this book on a good note after advising you of the bad news above.

Odd length feed line: Want more bandwidth? Maybe build a smaller antenna and achieve the same bandwidth? If you use an odd quarter wavelength coax, it will effectively increase the bandwidth. This is because as the impedance of the antenna changes, an odd quarter length of feed line will show the inverse, thus the transmitter sees an increase in resistance, thus effectively increasing the bandwidth of the antenna by keeping the VSWR low. You can do the same with an antenna tuner. This is like having an automatic antenna tuner. When computing the length, include the velocity factor of the coax. If you calculate the radiation resistance after applying the line you will be able to compare the increase compared to 120 ohms.

How much affect can this have? About double the bandwidth for a ¾ wavelength of coax. However, even though the transmitter stays happy over a wider bandwidth, at the extreme edges of that bandwidth the antenna may decide to melt because the power is now being applied to heat the coil, rather than being radiated. It does not pay to try to fool Mother Nature. Watch your field strength meter.

After you finish the antenna you will note that the frequency changed a small amount when you put on the cover. You may want an easy way to change the frequency for other reasons. This is easily done by using a copper (or aluminum) ring around the tuning coil on the outside of the cover. This will increase the frequency of the tuning coil. The amount depends on where it is placed, allowing adjustment of the frequency by sliding the ring. Make the ring about ½ inch high.

High Power: We have described a EH Antenna for 100 watts or less. Even at this power the RF voltage will be very high between the cylinders. Use construction techniques to prevent arching. This should include another larger plastic pipe to cover the antenna from the weather. For higher power you need to use better insulation, such as fiber glass, for the support and cover. Also, the wire should be at least #8.

CHAPTER 5 – SMALL LOOP ANTENNA

It was previously stated that the EH Antenna concept can be applied to any antenna. What happens when you add a -90 degree phase shift to a small loop antenna? Here is one example – a loop was constructed above the bed of my pick up truck using 1 inch copper pipe. The details from a spread sheet are included in the table below.

Note the change in values after the loop was converted to an EH Antenna. The efficiency increased by a factor of 4.7 from 17.5% to 81.9%. The bandwidth increased by the same factor, and the voltage and currents were reduced due to an increase in the Radiation Resistance. What is even more interesting, but not shown on the spread sheet, is that the radiation pattern changed from being in the plane of the loop to 90 degrees from the plane of the loop. (This is the fourteenth unique parameter) In other words, a small horizontal loop now radiates vertically with high efficiency. This feature allows EH Loop antennas for RFID to be used under shelves in stores to communicate with transponders affixed to items on the shelves.

CHAPTER 7
KOR RADIATION

This chapter addresses a new concept in radiation that has been named Kor radiation. It is only included here to indicate that the EH antenna produces both conventional and Kor radiation. (This is the fifteenth unique parameter of the EH Antenna presented in this book). Rather than a lengthy discussion on this new physics concept, please see our web site for more detail. In concept it is a new discovery by Vladimir, a Russian Physicist, which proves that there are two forms of radiation, not just one as has been the accepted physics theory. The new radiation is a magnetic vector without the associated E field. This allows Kor radiation to have the fundamental properties of a magnetic field, yet it is actually radiation. Therefore, it has several important properties. Kor radiation has excellent penetrating properties through water, earth and other media that absorbs conventional radiation (due to the E field component) and, as a magnetic field, it travels at infinite speed. Our web site reveals this new physics concept. We could not patent a new physics concept, but a patent is pending on Hz antennas that allow use of the radiation.

Conventional antennas can communicate with each other. Hz antennas can communicate with each other. EH Antennas can communicate with both conventional antennas and Hz antennas. Conventional antennas can not communicate with Hz antennas. If you read that carefully you will recognize the fact that Kor radiation is a new media that allows non-interfering communications with conventional antennas. In other words, KOR radiation has

Calculations for a small loop antenna		
Frequency	3.95	MHz
loop circumference	24	Feet
Area	35	Feet Squared
conductor diameter	1	inches
Transmitter Power	20	watts
Radiation Resistance	0.010	Ohms
Loss Resistance	0.048	Ohms
Efficiency	17.5	%
Efficiency	-7.6	- dB
Inductance	3.34	uHy
Capacitor	486.1	pFd
Q	720	.-
Bandwidth	5.49	KHz
Capacitor Voltage	3060	Volts P/P
Loop Current	18.6	Amps
The following applies after converting a small loop to an EH Antenna		
Input Measured Data		
Bandwidth	25.0	KHz
Q	158.0	.-
Total R	0.262	Ohms
Radiation Resistance	0.215	Ohms
Efficiency	81.9	%
Efficiency	-0.9	- dB
Ratio of increase	4.7	% Efficiency
Capacitor Voltage	1433	Volts P/P
Loop Current	8.7	Amps

doubled the available frequency spectrum. More food for thought!

THE END

Yes, this is the end of the book, but the beginning of a great future for the reader. We hope you enjoy the EH antenna on the Ham band of your choice. If you are a military or commercial user, we would be pleased to discuss a license agreement for your application. I can be reached at ted@eh-antenna.com. Please only contact me for business related issues. I can not find time to answer all Ham questions. For help with questions about the book or the EH antenna please go to our discussion forum on yahoo.

www.eh-antenna@yahoogroups.com

NOTE: Any person may build and use an EH Antenna for their personal use if there is no commercial gain. For commercial or military applications a license of the patents is required from EH Antenna Systems, LLC to allow manufacturing and sales of the antenna. To date two patents have been granted and the third will be issued late in 2005.

APPENDIX

It would seem appropriate to name all of those that have been significant contributors to the development of the EH Antenna. Although there have been many and the list spans the globe, I have chosen to only name those few that contributed the most, and want to thank them with my deepest heartfelt thanks.

Dan Anderson– England
Jack Arnold – Colorado, USA
Lloyd Butler– Australia
Marco – ARNO Elettronica – Italy
Masa – FR Radio Lab- Japan
Stefano – Italy

LINKS:

www.eh-antenna.com
www.eheuroantenna.com
www.fr-radio.com
http://www.qsl.net/km5kg/ Note: this site contains an excellent design program

Korobejnikov Vladimir Ivanovich- Russia

Answers to Questions Raised

There have been a number of Hams that have, for their own personal reason, diligently tried to condemn the EH Antenna concept. They have written articles trying to convince others that this new concept is a hoax, or worse. It is difficult to fathom the reason for their behavior, but then it takes all kinds. The following is some of the things **they say**, and a response to each one:

1) It is the coax that radiates, not the EH Antenna. Response: That is a blatant lie. Perhaps that is too strong a response. If that person does not know better, then he is not lying, he has chosen not to understand and chooses to remain ignorant. The fact is that the coax can not radiate if there is a choke in the coax only a short distance from the antenna, or the coax is very short.

2) The antenna must have a coax lead to be able to radiate. Response: More ignorance. A small hand held network analyzer like the AEA Bravo allows a complete look at the antenna characteristics when the coax lead is only long enough (a few inches) to allow the connection. Further, a very small source connected to the antenna will allow full performance – with out any coax.

3) The EH Antenna can not work because it does not comply with Maxwell's equations. Response: We have simply found a way to bring the far field to the antenna. This does not violate Maxwell or Poynting or any other conventional theory. It does establish a new theory that can not be found in the text books. Because it is new, we have obtained three patents.

4) The EH Antenna can not work because the computer programs used to analyze antennas prove that it will not work. Response: It is unfortunate that those programs (most of them are derived from the NEC program) do not allow analysis of this new concept in antenna theory. That does not prove that the EH Antenna will not work, it simply proves that the computer program is not capable of an analysis of the EH Antenna.

5) I built an EH Antenna and it does not work, therefore the EH Antenna theory is not valid. Response: This makes you wonder about some people. Did they build the antenna correctly? Did they tune it correctly? It could be said that these people would abandon a car because it quit. Did it occur to them that they must put gas in the tank to make the car go? Probably not!

6) There is one classic that a lot of the naysayers hang their hat on. One Ham, with a very expensive Network Analyzer tested a EH Antenna we sent to him and determined that it was a good antenna. Then he proceeded to feed it with a small source to test the radiation in comparison to a standard vertical. The radiation was dismal, thus he declared in a fancy report that the EH Antenna was no good. This then became evidence that the EH Antenna does not work. Response: Unfortunately, that Ham disregarded the information sent to him that explained that any phase shift in a network between the collector of the transistor and the antenna will prevent the antenna from achieving maximum performance. This is especially true of the L+T network. He (and others) could not accept the fact that the phasing is critical to the operation of the EH Antenna, because that is a departure from conventional theory.

There are many other put downs, but I think you get the idea that there are some people that just want to complain rather than learn about a new concept. If you have read this far in the book you are not one of those. Now you know part of the reason that the EH Antenna has not been well received among the Ham community. It is my hope that this book will provide the necessary information to reveal the true aspects of the EH Antenna concept. I do not believe that all of the naysayers will ever apologize or even go away. As I said, it takes all kinds of people. If you build and properly tune your EH Antenna you will learn the truth.

The EH Antenna concept is the most significant change in antenna theory in more than 120 years.

EH ANTENNA SYSTEMS