Welcome to the wonderful world of EH Antennas

This text is designed to be read while reviewing the slides. This is a speech prepared for the National Association of Broadcasters in Las Vegas in April 2004. We hope it will help your understanding of the EH Antenna.

First slide – Title

Introduction

Slide 2 – Revolutionary Concept

The EH Antenna is a revolutionary concept because it does not fit classical theory and because all the parameters are what you would desire in an antenna. One patent has been issued and 2 more patents are pending.

Slide 3 – Photograph of AM broadcast antennas

This photograph displays our test antenna. By locating it close to a standard ¼ wavelength AM Broadcast tower (in the background) direct comparisons could be made. This eliminated ground conductivity and other variable site parameters.

We wanted you to see the real antenna but it was too large to carry, so we brought a scale model. (This antenna is shown in a later picture). The antenna was set on stage during the speech.

Slide 4 – The defining Parameters of the EH Antenna – Small Size

The following lists the antenna parameters and briefly defines them. More detail will follow. We begin with small size. Let me say that the EH Antenna has the same physical configuration as a fat vertical dipole. However, rather than being ½ wavelength long, the EH Antenna may be smaller than 1% of a wavelength. This scale antenna is 1% of a wavelength at 1100 KHz.

Slide 5 –The defining Parameters of the EH Antenna – Low Height

The center of the EH Antenna does not have to be ¼ wavelength high to equal radiation from a "standard" AM broadcast antenna.

Slide 6 – The defining Parameters of the EH Antenna –No Radials Required

Because the EH Antenna functions as a dipole, there is no need for ground radials.

Slide 7 -10 KW EH Antenna relative size

This scale drawing compares the 10KW EH Antenna to a standard tower. Note that no radials are required. The actual EH Antenna sets on top a tower.

Slide 8 – 1 KW EH Antenna relative size

This drawing compares the 1 KW EH Antenna to a standard tower. Note the free standing tower.

Slide 9 – The defining Parameters of the EH Antenna – Broad band width

The bandwidth of the EH Antenna is a function of the capacity between the cylinders. That means that even a small fat cylinder can provide more bandwidth than a tall tower.

Slide 10 – The defining Parameters of the EH Antenna – High Efficiency

Because there is high capacity, the tuning coil may be small, thus enhancing the antenna efficiency. It is important to note that there is no measurable loss in the antenna elements, which are large diameter short conductors.

Slide 11 –The defining Parameters of the EH Antenna – Low EMI

A unique feature of the EH Antenna is that the E and H fields exist only at the antenna because radiation is formed at the antenna, not at the far field. Because the fields are contained, Electromagnetic Interference (EMI) is typically more than 30 dB below the EMI of a Hertz antenna.

Slide 12 –The defining Parameters of the EH Antenna – High Economic value

When these features are summed up, the net result is high economic value for the Broadcaster. Because no radials are required, no land is required other than to support the base of the tower and guy wire tie points. This allows the antenna to be located any where, including the center of population areas where the cost of ground would be prohibitive if radials were required. Because EMI is low, this antenna would not cause interference to other electronic equipment. Therefore, the antenna could be on top a building.

Slide 13 – Does it work?

Sound too good to be true? Here is the proof of performance. Testing in accordance with FCC procedures by Stu Graham, a Broadcast Consultant, produced this graph showing that the radiation along the ground was 0.84 dB less than a standard broadcast tower, and the height was only 0.1 wavelengths above ground. If the height were increased, the

EH Antenna would produce more radiation than the standard tower.

Here is a question that has never been asked before - what if the antenna was lowered and the transmitter power increased? You would have a good very low profile system, but unfortunately the FCC says that is outside their standard box, therefore they will not consider it. The EH Antenna is the first to be able to raise this issue.

By the way, high angle radiation is slightly less than a standard tower, allowing the EH Antenna to be a good night time antenna.

The shape of the graph was determined from scale measurements and validated using a NEC model.

Slide 14 – Evolution of the EH Star Antenna – Resonant Circuit

Now that we know it works very well, we will address how it works. The best way to explain it is to examine the various parts of the antenna. We begin with the basic schematic consisting of two cylinders and a tuning coil.

The capacity between cylinders and the coil inductance allows the antenna to be resonant at the desired frequency. By the way, the antenna size is not related to wavelength, therefore a set of cylinders may operate over a wide frequency range, primarily dictated by the necessary bandwidth.

Slide 15 – Evolution of the EH Star Antenna –Phasing Coil

Now we add a phasing coil. The purpose is to place a phase shift between the tuning coil and the upper cylinder. For this design we find that a phase shift of 3 degrees is equivalent to a VSWR variation of 2:1. Therefore 6 degrees was chosen to prevent radiation from the line inside the lower cylinder and radiation from the top of the tuning coil.

Slide 16 – Evolution of the EH Star Antenna – Tapped coil

The next step is to tap the tuning coil for the proper impedance for the feed line. Remember, this antenna is high above the ground and a good impedance match is necessary to minimize transmission line loss. Note that the tuning coil is now grounded.

Slide 17 – Plot of Impedance Parameters

This plot displays the impedance components of the EH Antenna looking into the tap on the tuning coil. Note that maximum resistance does not occur at zero reactance. This causes the VSWR plot to be unbalanced.

Slide 18 – Evolution of the EH Star Antenna – Source coil

If we add a source coil, the inductance of that coil will cancel the capacity reactance and allow maximum resistance to occur at the same frequency as zero reactance. The amount of reactance is readily obtained from the graph. Adding that reactance allows the input impedance to the antenna to be R+j0 ohms at the desired frequency.

Slide 19 – Evolution of the EH Star Antenna – Antenna Input impedance

This plot is the corrected impedance after adding the source coil. There is also a plot of calculated VSWR (multiplied x 10. Note where the VSWR is 2:1 is plotted as a value of 20.

Slide 20 – Photograph of the small AM Broadcast antenna.

The small antenna is 4.5 times smaller than the large antenna. However, you also need to know that this small antenna is an AM Broadcast antenna, specifically designed for the high end of the band. We use different feed lines on the two antennas.

Slide 21 – Evolution of the EH Star Antenna –Transmission line

To determine the best value of R to tap the tuning coil, we must select the impedance of the transmission line. In the case of the big antenna we use open wire feed line composed of ½ inch copper pipes spaced to give an impedance of 338 ohms. This line runs down the center of the tower. For the small antenna we use two 50-ohm coax in parallel for an impedance of 25 ohms. These parallel coax lines also run inside the tower.

Slide 22 – Evolution of the EH Star Antenna – L network

For both antennas we provide an L network at the base of the tower to transform the transmission line impedance to exactly match the 50-ohm coax from the transmitter. This was done for two reasons, the first because it is easier to make a final trim adjustment standing on the ground to give 50+j0 than to spend a lot of time high on the tower, and to increase the efficiency of the transmission line. For convenience we even provide a platform to stand on while tuning the big antenna. The small antenna is tuned at the factory and shipped as a complete unit. Just attach the coax and it is ready to operate on the assigned frequency.

Slide 23 – Formation of Radiation – Primary E Field

Now that the schematic diagram has been explained, we need to look at what causes the EH Antenna to develop radiation at the antenna. To appreciate what you are about to see, you need to understand that Hertz antennas operate based on current flowing on the antenna. That current causes the development of a magnetic field surrounding the antenna. A changing magnetic field causes the development of an electric field. Therefore, the electric (E) field is 90 degrees phase shifted from the magnetic field. The two fields travel at different speeds and become in phase at about 1/3 wavelength from the antenna. This is commonly known as the beginning of the far field. Now, with the E and H fields in phase the Poynting Vector is created resulting in electromagnetic radiation.

On the slide you see the primary E field of the EH Antenna developed between the cylinders due to the antenna being resonant. Remember, the cylinders are the primary capacitor in our tuned circuit, thus there is a high voltage proportional to the transmitter power.

Slide 24 – Evolution of the EH Star Antenna – Secondary E field

Now we see a secondary E field developed between the source voltage and the cylinders. It is very important to note that there is a 90 degree phase difference between the source voltage and the primary E field. This is due to the 90 degree phase lag across the tuning coil. This secondary E field causes current to flow in the natural capacity between the source and the cylinders. This current is called Displacement current and develops a magnetic field.

Slide 25 – Evolution of the EH Star Antenna – H field

Note that the magnetic field surrounds the primary electric field. Remember the 90 degree phase delay between the source and primary E field? When a current passes thru a capacitor it will be advanced in phase by 90 degrees. Thus, the E and H fields are in phase and radiation occurs at the antenna. This effectively moves the far field to the EH antenna.

We no longer need large E and H fields to combine at the far field distance, because they are contained within the antenna sphere. This is why EMI is very low from an EH Antenna.

Because the E and H fields are efficiently integrated, the radiation resistance is high, thus the antenna efficiency is high.

Slide 26 – Web Site - and a picture of a small Ham antenna.

Many of you are Hams and will appreciate using an EH Antenna for communications. When used as a receive antenna it has two important characteristics; it produces slightly larger signal levels on your S meter on the receiver, in spite of it's very small size. More importantly, the EH Antenna only responds to radiation – it will not respond to either E or H fields, which are local noise. This is the inverse of low EMI. Therefore, the signal to noise ratio when the EH antenna is in a noisy environment is very high. You can get clear copy on signals that are buried in the noise on a Hertz antenna. The picture is a 20 meter antenna. The COKE can allows size comparison. The old timers will remember the beer can verticals.

We have shown that the EH Antenna works very well (both on receive and transmit). Now I want to go to the next level of detail to complete your education in the world of EH Antennas. To do this we will examine a computer program we wrote to define all of the details of the antenna. It is an EXCEL spread sheet.

Slide 27 – Antenna Analysis Program – Inputs

The program begins by filling in values marked by X in the left column. For example, what frequency do you desire, how much power, what is the size of the antenna? For our example we will use the values for the small antenna here on stage. Note that the cylinders are 8 inch diameter and each has a length to diameter ratio of 6. The bandwidth of the antenna is a function of the diameter while the pattern is a function of the length to diameter ratio. We have found by experiment that a ratio of 6 essentially matches the ideal ¼ wave broadcast tower pattern with a little less high angle radiation and a little more along the ground.

Slide 28 – Antenna Analysis Program – Bandwidth

I do want to digress for a moment to bring you up to date. On our web site we reported narrow bandwidth on the test antenna. It was much lower than we expected, but we could not quantify the value it should be. Recently we were finally able to develop an equation for the capacity between the two cylinders. Believe me, that equation is like many things associated with this antenna – it is not in the text books. That equation was the key that unlocked the ability to write a program to define the details of the antenna. The program told us that the bandwidth was reduced by a factor of more than 5.

Unfortunately, it did not tell us why. Through other activities we learned that there is a very large magnetic field inside the cylinders – and they are supported on iron tower sections. It does not take much imagination to know that is bad. We built a small antenna with 1 foot diameter cylinders. The bandwidth matched the calculated bandwidth, so that proved the program. We crammed a piece of iron stove pipe up the lower element and sure enough, the bandwidth dropped like a rock.

Think about that for a minute – from the equation for bandwidth note that the radiation resistance of the antenna must be drastically reduced if the bandwidth is reduced. It should be in direct proportion to the difference in bandwidth. If the radiation resistance increases dramatically, then the antenna efficiency should also increase. That says our test antenna will produce more radiation than previously measured, if the iron tower sections are replaced with aluminum. However, a large change in Radiation resistance will have only a small effect on efficiency.

We are waiting on the FCC to grant a permit for station KYET in Arizona. After installation, tests on that antenna will tell us the true performance of the large EH Antenna.

Slide 29 – Antenna Analysis Program – Inputs - Return to same program

Our program begins by asking for the frequency, transmitter power, and antenna size. It also asks for a guess at radiation resistance, which is corrected by measurement after the antenna is complete. In that sense the program is interactive.

Note that the radiation resistance is very high when you consider how small the antenna is. This is due to the high efficiency of the integration of the E and H fields. The effective resistance is a measured value of the total resistance – the Radiation resistance is the measured resistance less the internal loss resistance.

Slide 30 – Antenna Analysis Program – Results

The results of the calculation show the 3 dB bandwidth and the effective Q of the antenna. Compare the displayed value of Q to a typical value of 30 for a ¼ wave tower. The calculated bandwidth is a direct result of the capacity, which is the capacity of the cylinders and the stray capacity due to the tuning coil and antenna wiring.

This small antenna was designed for stations running 1000 watts or less, thus relatively low voltage between the cylinders.

Slide 31 – Antenna Analysis Program – Phasing coil details

As we said previously, we use a length of wire equal to 6 degrees for the phasing coil. Note the amount of heat loss due to this coil. The program calculates the heat loss for each item and then summarizes the total loss of the antenna.

Slide 32 – Rendering of the phasing coil

This is what the phasing coil looks like inside the fiberglass between the two cylinders.

Slide 33 - Antenna Analysis Program – Tuning coil design

The tuning coil was interesting to design. We wanted low loss but relatively small wires. We compromised on the flat wire with an effective diameter of almost ¼ inch and a coil diameter of 15.5 inches.

Slide 34 – Rendering of the tuning coil

This coil is covered by a fiberglass shield.

Slide 35 – Antenna Analysis Program – Source coil details

The source coil impedance is a measured value. After it is measured then the loss can be determined after the length of wire in the coil is calculated.

Slide 36 – Rendering of the Source coil

The source coil is located below the tuning coil inside a piece of fiberglass.

Slide 37 – Antenna Analysis Program – Transmission line

The loss in parallel coax lines is very small at these frequencies. They are less than 100 feet long. We wanted some value of transmission line impedance other than 50 ohms and the parallel coax seemed a good solution. We use open wire line on the big antenna.

Slide 38 – Antenna Analysis Program – L network

At the base of the tower we use an L network to convert the impedance of the parallel coax to match the 50-ohm coax from the tower. The program tells us what components to use in the L network. Note that due to high current in the coil the loss in the L network is almost equal to the loss in the tuning coil.

Slide 39 - Picture of the L Network box

Those parts are in an aluminum enclosure. It was too much effort to bring it to this convention.

Slide 40 – Antenna Analysis Program – Summary

This brings us to the summary of the program where the total of all losses gives an overall efficiency of greater than 98%, or less than 1/10th of a dB loss. This is another indicator of the revolutionary nature of the EH Antenna.

Slide 41 – Antenna Economic analysis

As Engineers we enjoy the technical aspects, but to keep us employed the station owner must be able to afford new technology. Again, the EH Antenna offers unprecedented economics due to its revolutionary capabilities. This slide presents an economic view. We have included both the small and large EH Antennas.

Slide 42 – Antenna Economics - examples

You can add costs in various ways, but the answer is always the same – if the land costs more than an EH Antenna you can not afford to use the old standard ¼ wave tower. The examples give more detail, but it does not change the over all concept.

A more interesting comparison is to consider the value of the land your antenna is now on. Can you sell that land, buy an EH Antenna and install it in the center of population where it should be, and pocket the difference? Chances are that if you have owned the land more than a few years the answer is YES. Are your lease costs too high?

Slide 43 – Bandwidth vs. Frequency

There has been a lot of discussion about antenna requirements for digital communications. This slide shows what the EH Antenna offers – more bandwidth than any other antenna. The two curves are for the 10 KW and 1 KW antennas.

Now we can take questions. First, I want to thank you for your time and hope that you now have an undistorted view of the EH Antenna and what it can do for you. If you have questions we are only a few key strokes away on the internet, and I always carry my cell phone.

First Question? I will answer that one – Yes, the EH Antennas are ideal for use in phased arrays.

Next question?