Feel Yourself a Student!

Dear friends, I would like to give to you an interesting and reliable antenna theory. Hours searching in the web gave me lots theoretical information about antennas. Really, at first I did not know what information to chose for ANTENTOP. Finally, I stopped on lectures “Modern Antennas in Wireless Telecommunications” written by Prof. Natalia K. Nikolova from McMaster University, Hamilton, Canada.

You ask me: Why?

Well, I have read many textbooks on Antennas, both, as in Russian as in English. So, I have the possibility to compare different textbook, and I think, that the lectures give knowledge in antenna field in great way. Here first lecture “Introduction into Antenna Study” is here. Next issues of ANTENTOP will contain some other lectures.

So, feel yourself a student! Go to Antenna Studies!

I.G.

McMaster University

Inspiring Innovation and Discovery

McMaster University Hall

Prof. Natalia K. Nikolova

LECTURE 1: Introduction into Antenna Studies

by Prof. Natalia K. Nikolova

Definition and circuit theory description. Brief historical notes. General review of antenna geometries and arrangements. Wireless vs. cable communication systems. The radio-frequency spectrum.

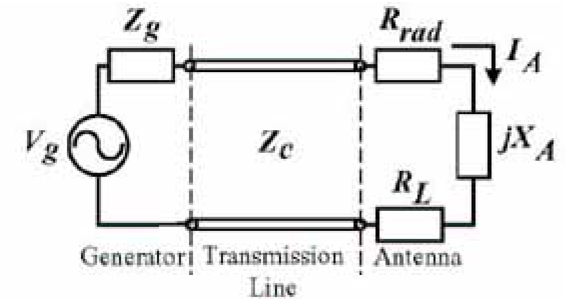
1. Definition and circuit theory description.

The antenna (aerial, EM radiator) is a device, which radiates or receives electromagnetic waves.

The antenna is the transition between a guiding device (transmission line, waveguide) and free space (or another usually unbounded medium).Its main purpose is *to convert the energy of a guided wave into the energy of a free-space wave (or vice versa) as efficiently as possible, while in the same time the radiated power has a certain desired pattern of distribution in space*.

a) transmission-line Thevenin equivalent circuit of a radiating (transmitting) system

V_g - voltage-source generator (transmitter);
Z_g - impedance of the generator (transmitter);



R_{rad} - radiation resistance (related to the radiated power)

$$P_{rad} = I_A^2 \cdot R_{rad}$$

R_L - loss resistance (related to conduction and dielectric losses);

jX_A - antenna reactance.

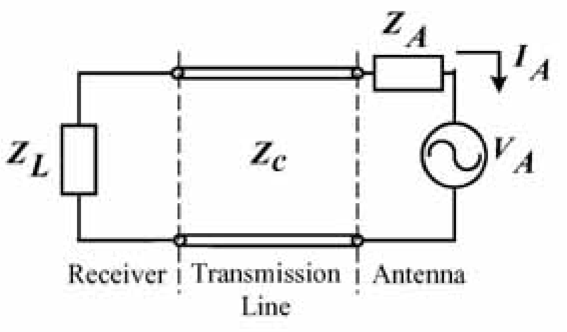
Antenna impedance:

$$Z_A = (R_{rad} + R_L) + jX_A$$

One of the most important issues in the design of high-power transmission systems is the matching of the antenna to the transmission line (TL) and the generator. Matching is specified most often in terms of VSWR. Standing waves are to be avoided because they can cause arching or discharge in the TL. The resistive/dielectric losses are undesirable, too. They decrease the efficiency factor of the antenna.

b) transmission-line Thevenin equivalent circuit of a receiving antenna system

The antenna is a critical component in a wireless communication system. A good design of the antenna can relax system requirements and improve its overall performance.



2. Brief historical notes.

James Clerk Maxwell formulates the mathematical model of electromagnetism (classical electrodynamics), “*A Treatise on Electricity and Magnetism*”, 1873. He shows that light is an electromagnetic (EM) wave, and that all EM waves (light included) propagate through space with the same speed, which depends on the dielectric and the magnetic properties of the medium.

James Clerk Maxwell

Heinrich Rudolph Hertz demonstrates in 1886 the first wireless EM wave system: a / 2 λ - dipole is excited with a spark; it radiates predominantly at about λ.8 m; a spark appears in the gap of a receiving loop. Hertz discovers the photoelectric effect and predicts that gravitation would also have a finite speed of propagation. In 1890, he publishes his memoirs on electrodynamics, simplifying the form of the electromagnetic equations, replacing all potentials by field strengths, and deducing Ohm's, Kirchhoff's and Coulomb's laws.

Heinrich Rudolph Hertz

May 7, 1895, the first wireless telegraph message is successfully transmitted, received, and deciphered. A brilliant Russian scientist, ***Alexander Popov*** (also spelled Popoff, Poppov), sends a message from a Russian Navy ship 30 miles out in sea, all the way to his lab in St. Petersburg, Russia. The Russian Navy declares Popov's historical accomplishment top secret. The title “Father of Radio” goes to G. Marconi.

Alexander Popov

Guglielmo Marconi (the Father of Radio) sends signals over large distances. In 1901, he performs the first transatlantic transmission from Poldhu in Cornwall, England, to Newfoundland, Canada. The receiving antenna in Newfoundland was a 200-meter wire pulled and supported by a kite. The transmitting antenna in England consisted of 50 wires, supported by two 60-meter wooden poles.

Guglielmo Marconi

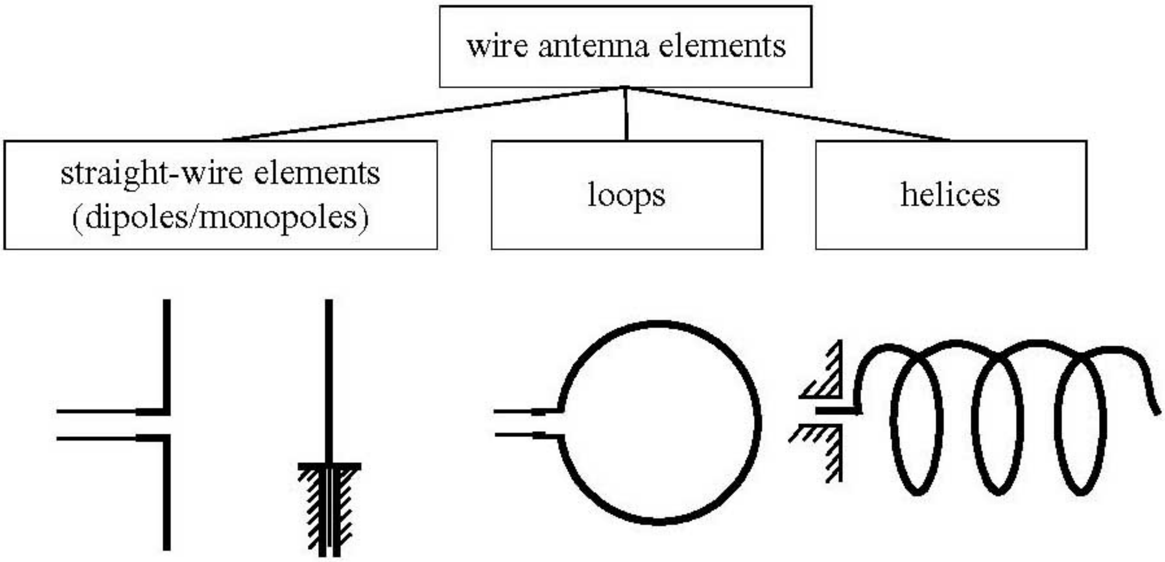
The beginning of 20th century (until WW2) marks the boom in wire antenna technology (dipoles and loops) and in wireless technology as a whole, which is largely due to the invention of the DeForest triode tube, used as radio-frequency generator. Radio links are possible up to UHF (about 500 MHz) and over thousands of kilometers.

WW2 marks a new era in wireless communications and antenna technology. The invention of new microwave generators (magnetron and klystron) leads to the development of the microwave antennas such as waveguide apertures, horns, reflectors, etc.

3. General review of antenna geometries and arrangements.

3.1. Single-element radiators.

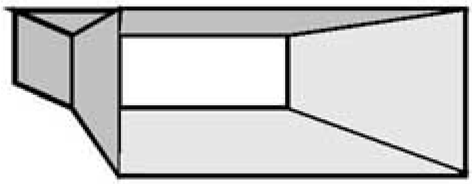
A. Wire radiators (single-element)



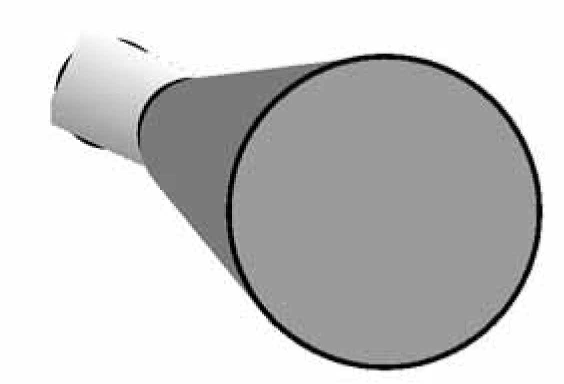
There is a variety of shapes corresponding to each group. For example, loops can be circular, square, rhombic, etc. Wire antennas are simple to make but their dimensions are commensurable with the wavelength. This limits the frequency range of their applicability (at most 1-2 GHz). At low frequencies, these antennas become increasingly large.

B. Aperture antennas (single element)

(a) Pyramidal horn



(b) Conical horn



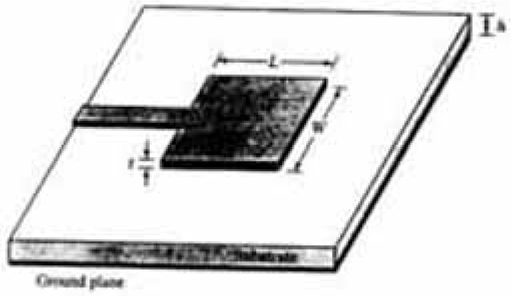
Aperture antennas were developed before and during the WW2 together with the emerging waveguide technology. Waveguide transmission lines were primarily developed to transfer high-power microwave EM signals (centimeter wavelengths), generated by powerful microwave sources such as magnetrons and klystrons. These types of antennas are preferable in the frequency range from 1 to 20 GHz.

C. Printed antennas

The patch antennas consist of a metallic patch etched on a dielectric substrate, which has a grounded metallic plane at the opposite side. They are developed in the beginning of 1970s. There is great variety of geometries and ways of excitation.

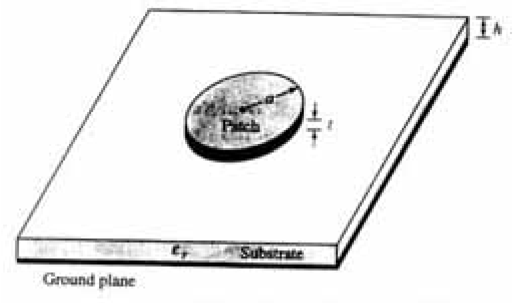
Printed Patch Radiators

(a) Rectangular patch



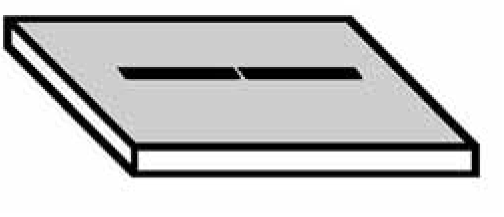
Printed Patch Radiators

(b) Circular patch

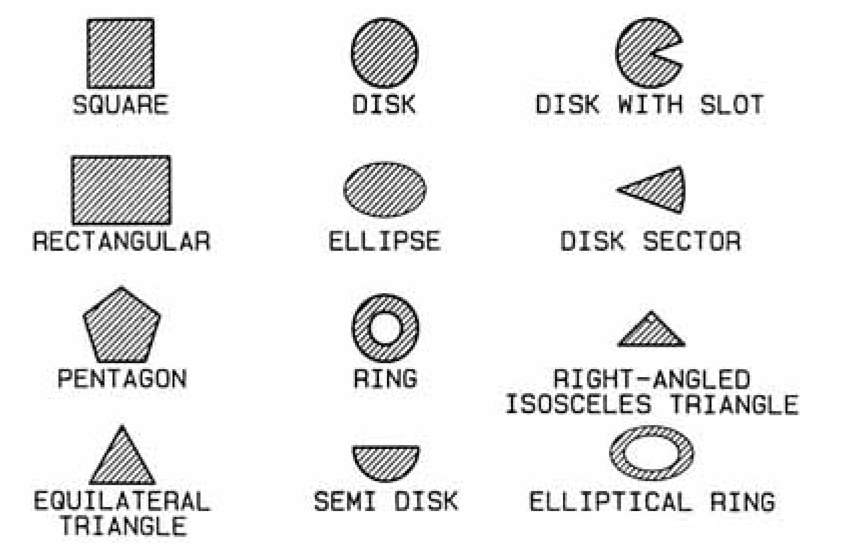


Printed Patch Radiators

(c) Printed dipole



Forms of Patches

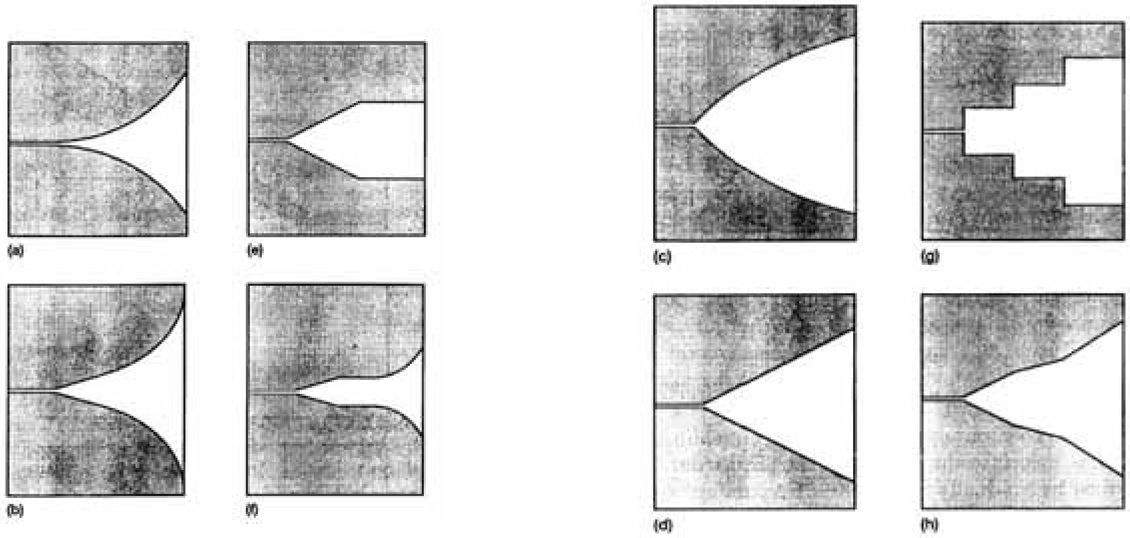


PRINTED SLOT RADIATORS

Slot antennas were developed in the 1980s and there is still intensive research related to new shapes and types of excitation. They are suited for integration with slot-line circuits, which are usually designed to operate at frequencies > 10 GHz.

Both patch and slot antennas share some common features. They are easy and cheap to fabricate. They are easy to mount; they are light and mechanically robust. They have low cross-polarization radiation. Their directivity is not very high. They have relatively high conducting and dielectric losses. These radiators are widely used in patch/slot arrays, which are esp. convenient for use in spacecraft, satellites, missiles, cars and other mobile applications.

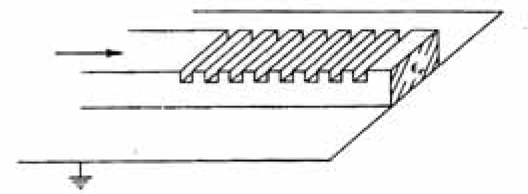
PRINTED SLOT RADIATORS

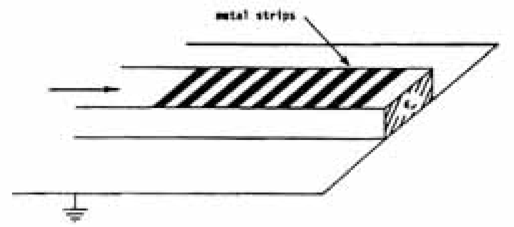


D. Leaky-wave antennas

These are antennas derived from millimeter-wave (mm-wave) guides, such as dielectric guides, microstrip lines, coplanar and slot lines. They are developed for applications at frequencies > 30 GHz, infrared frequencies included. Periodical discontinuities are introduced at the end of the guide that lead to substantial radiation leakage (radiation from the dielectric surface).

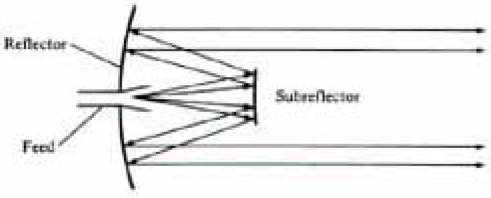
The antennas in the mm-wave band are of big variety and are still a subject of intensive study.





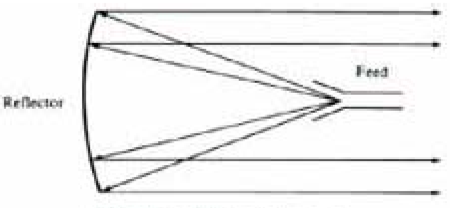
E. Reflector antennas

A reflector is used to concentrate the EM energy in a focal point where the receiver/feed is located. Optical astronomers have long known that a parabolic cylinder mirror transforms rays from a line source on its focal line into a bundle of parallel rays. Reflectors are usually parabolic (paraboloidal). Actually, the first use of a parabolic (cylinder) reflector was used for radio waves by Heinrich Hertz in 1888. Rarely, corner reflectors are used. Reflector antennas have very high gain and directivity. Typical applications: radio telescopes,

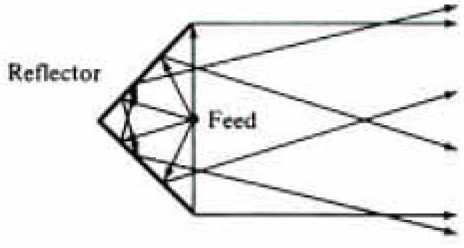


(b) Parabolic reflector with Cassegrain feed

Typical Rrflectors



(a) Parabolic reflector with front feed



(c) Corner reflector

satellite telecommunications. They are not easy to fabricate and, in their conventional technology, they are rather heavy. They are not mechanically robust.

The largest radio telescopes:

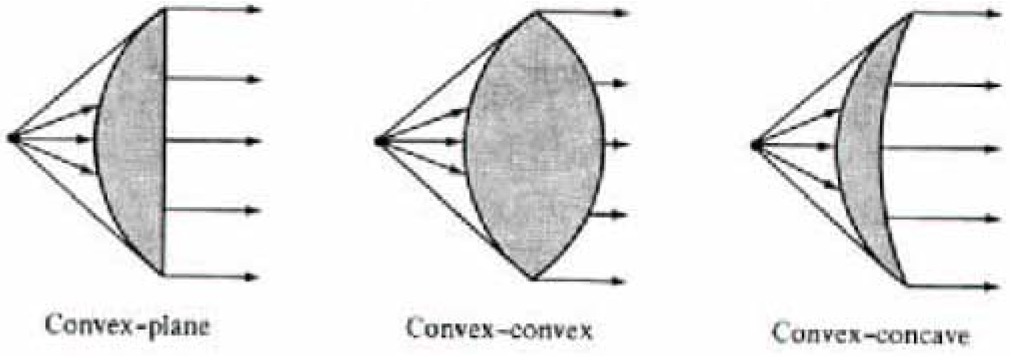
- Max Plank Institut fur Radioastronomie radio telescope, Effelsberg (Germany), 100-m paraboloidal reflector;

- National Astronomy and Ionosphere Center (USA) radio telescope in Arecibo (Puerto Rico), 1000-ft (304.8-m) spherical reflector;

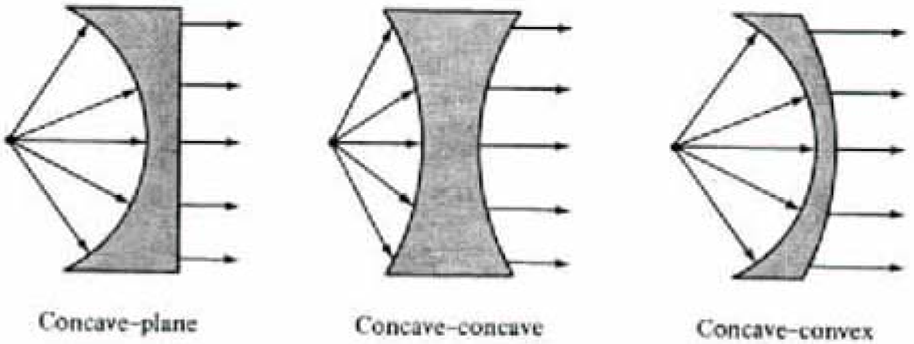
- The Green Bank Telescope (the National Radio Astronomy Observatory) – paraboloid of aperture 100 m.

F. Lens antennas

Lenses play a similar role to that of reflectors in reflector antennas. They collimate divergent energy into more or less plane EM wave. Lenses are often preferred to reflectors at higher frequencies (f > 100 GHz). They are classified according to their shape and the material they are made of.



(a) Lens antennas with index of refraction $n > 1$



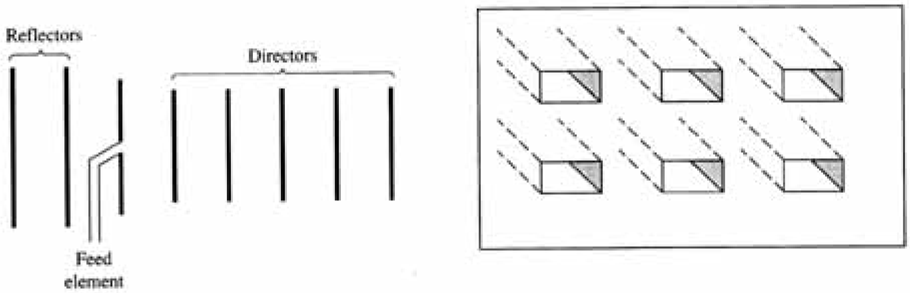
(b) Lens antennas with index of refraction $n < 1$

3.2. Antenna arrays

Antenna arrays consist of multiple (usually identical) radiating elements. Arranging the radiating elements in arrays allows achieving unique radiation characteristics, which cannot be obtained through a single element. The careful choice and control of the phase shift and the amplitude of the signal fed to each element allows the change of the radiation pattern electronically, i.e. electronic scanning. Such arrays are called phased arrays. The design and the analysis of antenna arrays is a subject of its own, which is also related to signal processing. Intensive research goes on nowadays, concerning smart antennas, signal-processing antennas, tracking antennas, etc. Some commonly met arrays are shown in the figure on the next page.

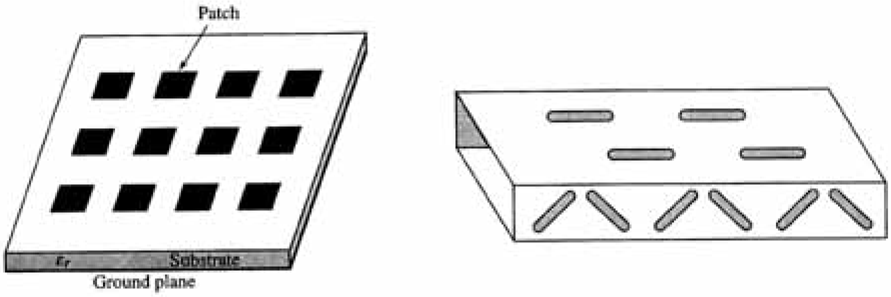
4. Wireless vs. cable communication systems.

There are two broad categories of communication systems: those that utilize transmission lines as interconnections (*cable systems*), and those that use EM radiation with an antenna at both the transmitting and the receiving end (*wireless systems*). In areas of high density of population, the cable systems are economically preferable, especially when broadband communication is in place. Even for narrow-band communication, such as voice telephony and low-data-rate digital transmission, it is much simpler and cheaper to build wire networks with twisted-pair cables, when many users are to be interconnected.



(a) Yagi-Uda array

(b) Aperture array

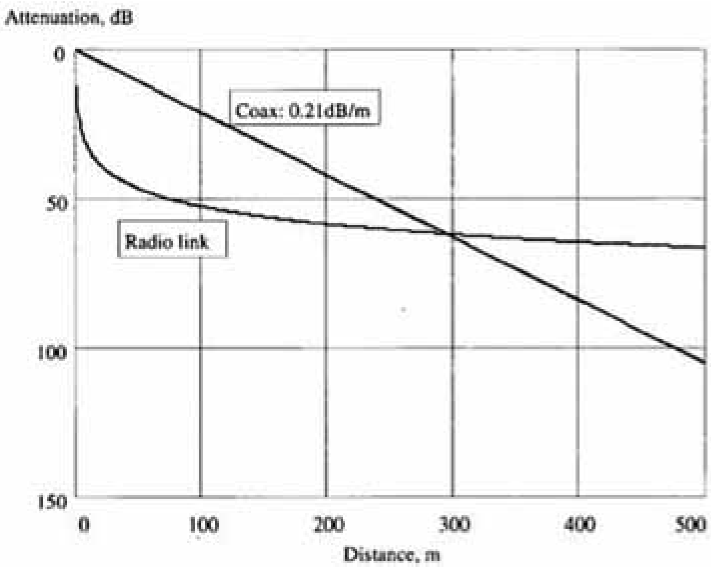


(c) Microstrip patch array

(d) Slotted-waveguide array

Such lines introduce an attenuation of around 2-3 dB/km at frequencies about 10 kHz. These lines are not suitable at higher frequencies because of the higher losses and dispersion. At higherfrequency carriers, carrying broadband signals (TV transmission and highdata- rate digital transmission), coaxial cables are commonly used. The loss is around 4-5 dB/km. The least distortion and losses are offered by the optical-fiber transmission lines, which operate at three different wavelengths: 850 nm (. 2.3 dB/km), 1300 nm (. 0.25 dB/km) and 1550 nm (. 0.25 dB/km). They are more expensive though and the respective transmitting/receiving equipment is costly. Transmission lines provide a measure of security and noise-suppression (coaxial, optical-fiber), but they are not the best option in many cases (long distance, wide spreading over large areas, low frequency dispersion).

A fundamental feature of all transmission lines is the exponential increase of loss power. Thus, if the loss is 5 dB/km, then a 20-km line will have 100 dB power loss (input power is reduced by a factor of 10-10), a 40- km line will have a 200 dB power loss. This makes it rather obvious why wireless systems are preferred for long-range communications, and in scarcely populated areas. In most wireless channels, the radiated power per unit area decreases as the inverse square of the distance *r* between the transmitting and the receiving point. Doubling the distance *r* would decrease the received power by a factor of 4 (or 6 dB will be added). Thus, if a particular system has a 100 dB loss at r=20 km, doubling of its distance will result in 106 dB loss (as compared to 200 dB loss in a cable system). The comparison between the coaxial-line losses and free-space attenuation at *f*=100 MHz is given in the figure below.



Modern personal mobile communications services

● cordless elephony	home environment businesses – PABX (Private Automatic Branch Exchange) PHS (Personal Handyphone System) in Japan
● digital (and analog) cellular telephony	Northern America: PCS-1900 (Personal Communication Services) Europe: GSM-900 (Global System for Mobile Communications) and DCS-1800 (Digital Communications Systems)
● mobile data transport	packet-switched data transfer (MOBITEX, DataTAC, etc.) PCS two-way data communications; paging
● personal satellite communications	INMARSAT, EUTELTRACS, Iridium, Globalstar
● global navigation systems	GPS, GLONASS, ODYSSEY

Besides, there is a variety of special application of wireless technology in
- radar systems
- microwave relay links
- satellite systems (TV, telephony, military)
- radio astronomy
- biomedical engineering, etc.

5. The radio-frequency spectrum.

Table 2.1: General designation of frequency bands

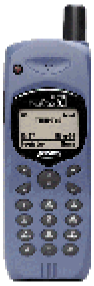
Frequency band	EM wavelength	Designation	Services
3-30 kHz	100-10 km	Very Low Frequency (VLF)	Navigation, sonar• , submarine
30-300 kHz	10-1 km	Low Frequency (LF)	Radio beacons, navigation
300-3000 kHz	1000-100 m	Medium Frequency (MF)	AM broadcast, maritime/ coastguard
3-30 MHz	100-10 m	High Frequency (HF)	Telephone, telegraph, fax; amateur radio, ship-to-coast and ship-toaircraft, communication
30-300 MHz	10-1 m	Very High Frequency (VHF)	TV, FM broadcast, air traffic control, police, taxicab mobile radio
300-3000 MHz	100-10 cm	Ultrahigh Frequency UHF)	TV, satellite, radiosonde, radar
3-30 GHz	10-1 cm	Super high Frequency (SHF)	Airborne radar, microwave links, satellite, land mobile communication
30-300 GHz	10-1 mm	Extremely High Frequency (EHF)	Radar, experimental

- Sonar (an acronym for Sound, Navigation and Ranging) is a system for underwater detection and location of objects by acoustical echo. The first sonars, invented during World War I by British, American and French scientists, were used to locate submarines and icebergs. Sonar is an American term dating fromWorld War II.

Table 2.1: Microwave-band designation

Frequency	Old	New
500-1000 MHz	VHF	C
1-2 GHz	L	D
2-3 GHz	S	E
3-4 GHz	S	F
4-6 GHz	C	G
6-8 GHz	C	H
8-10 GHz	X	I
10-12.4 GHz	X	J
12.4-18 GHz	Ku	J
18-20 GHz	K	J
20-26.5 GHz	K	K
26.5-40 GHz	Ka	K

All lectures are available at: http://www.ece.mcmaster.ca/faculty/georgieva/antenna_dload/



EH ANTENNAS

Ted Hart W5QJR
CEO EH Antenna Systems

www.eh-antenna.com

INTRODUCTION:

Ham Radio has been a birthplace for and nurtured many important inventions and discoveries. I have participated in some of those and benefited from others over the last 55 years that I have held the call W5QJR. Although I have previously presented new concepts to Hams (including the Antenna Noise Bridge in 1967 and the Small High Efficiency Loop Antenna in 1984), I now have the privilege and opportunity to present one more, one that will benefit every Ham.

I have invented and patented a new antenna concept called the EH Antenna. Note that it is a concept, rather than a particular antenna, and is therefore applicable to all antennas. What will it do for Hams? It will allow reduction in the size of the antenna, increase the efficiency, increase the instantaneous bandwidth, reduce receiver noise, and virtually eliminate EMI. Maybe not all of those virtues are important to you, the reader, but the one that is important justifies using an antenna that has most or all of those features.

Sound too good to be true? That is what many have said until they actually used an EH antenna. Yes, you can buy one from the factory in Italy or a kit from George, but more importantly, you can build your own with very little expense in time or money. We will include details in this article. In addition to being able to construct an EH Antenna, this is a new area for experimentation that can be enjoyed by all Hams. Now you can conveniently build and test an antenna for frequencies as low as seven MHz in the Ham shack.

THE CONCEPT:

All antennas to date (except the CFA) are based on the Hertz concept of resonant wires. Unfortunately, these antennas have a very large E (electric) and H (magnetic) field near the antenna and do not create Poynting Vector radiation until the fields have traveled about 1/3 wavelength from the antenna. This is known as the boundary between the near and far field of the antenna. The EH Antenna creates the Poynting Vector radiation at the antenna, thus it essentially moves the far field to the antenna. This effectively reduces the magnitude of the E and H fields to the physical sphere of the antenna. Since the E and H fields have been reduced in magnitude, EMI has been virtually eliminated. When used for receiving, the EH Antenna allows transformation of radiated energy to the receiver terminals, but does not allow local E or H fields to be transformed, thus “noise” is eliminated. We need to examine each of the virtues of this new concept to allow the reader to understand and be able to apply this new concept to the reader’s antenna farm.

ANTENNA SIZE:

A small antenna will radiate as well as a large antenna – if you can feed it properly. Unfortunately, as the size of the wire antenna is reduced, so also is the radiation resistance reduced. In addition, the inherent capacity of the antenna is also reduced. When a wire antenna element (2 elements make a dipole or 1 element against ground makes a ground plane antenna) approaches . wavelength, it becomes self-resonant,meaning that the value of self-capacity equals the inductance of the antenna. As the wire becomes very short compared to the wavelength at the operating frequency, there is very little inductance and very little capacity. Thus, a large loading coil is needed to restore resonance. The coil has loss resistance and that resistance can be much larger than the radiation resistance, thus the overall efficiency of the antenna becomes very low. For example, a 75-meter mobile antenna with a large center-loading coil is less than 3% efficient. If the capacity of a short antenna is increased by making the antenna diameter large, the necessary loading coil inductance is reduced, thus the efficiency increases. However, since the radiation resistance remains low, the efficiency has been increased but remains low.

Now, how can we increase the radiation resistance without increasing the size of the antenna? We can convert this antenna to an EH Antenna, allowing the element length to be short, yet the antenna system can now have high efficiency. How can we convert a typical Hertz antenna to an EH Antenna? We will present that information later, after we have discussed the other virtues.

INSTANTANEOUS BANDWIDTH:

Short loaded antennas and small loops are noted for their narrow bandwidth. Bandwidth is related to the ratio of the tuning inductance (loading coil) to the resistance of the antenna system (the sum of loss resistance and radiation resistance, including the loss resistance in the coil). We have already explained that the loading coil can be significantly reduced if the natural capacity of the antenna is increased. Thus, by reducing the necessary tuning inductance and increasing the radiation resistance, we can have a wide band antenna, commonly referred to as a low Q antenna. In this case, Q is not quality factor, but simply the ratio of the operating frequency to the instantaneous bandwidth, and also the ratio of the inductive reactance of the tuning coil to the resistance of the antenna. In this case, low Q is good. There are special cases where resistive loading is incorporated to lower the Q (increase the bandwidth) while sacrificing efficiency. We do not want to settle for less than both low Q and high efficiency.

NOISE:

When an antenna is used for reception, we would refer not to hear the noise generated by motors, power line leakage, or other forms of E or H field noise, including that from lightning strikes. This type of noise is not radiated noise, but rather the presence of a local E or H field. When a wire antenna is in the presence of an E or H field, the wire will develop a current that is fed to the receiver as noise. In the case of an EH Antenna, only radiated signals will be converted to energy applied to the receiver. Again, this will become obvious later. By the way, there are three components from lightning, a radiated field and large E and H fields. The EH Antenna can only reject the E and H fields. The radiated field occurs primarily at very low frequencies, with large harmonics.

EMI:

Either an E or H field, not a radiated signal, normally causes electromagnetic interference (EMI). This is a similar action to the noise discussed above. However, in this context we are discussing “noise” radiated from the antenna. In the case of a Hertz antenna, the E and H fields are very large to allow combining the fields to create Poynting Vector radiation at a large distance from the antenna. The E and H fields of the EH Antenna are contained within the sphere of the antenna, since the radiated field is created at the antenna. The small fields virtually eliminate EMI. The small EH Antennas have an additional feature – since the phasing is correct only over a relatively narrow frequency range, these antennas virtually eliminate harmonics.

IMPLEMENTING THE EH ANTENNA CONCEPT:

By now you are saying WOW, was this written on April 1 as a joke? How can we improve on Hertz antennas that have been around for 120 years? Simply by aligning the E and H fields of the antenna to be in time phase, the Poynting Vector radiation occurs at the antenna, not at some far field distance. And how do we do this? Simply by adding the appropriate amount of phase shift. Actually, once the antenna has been brought to resonance, we need only add a phase delay to cause the current to lag the voltage 90 degrees. There are many ways to do this, but I have a favorite I will share with you. In fact, I use a simple network that provides both the appropriate delay and also provides the proper impedance matching.

E AND H FIELDS OF AN ANTENNA:

You need to understand the E and H fields of an antenna before going into the circuit details of the network. **Figure 1** depicts a short fat dipole. However, a wire dipole would have similar electric (E) and magnetic (H) fields. It is important to note that the E field lines (only a few are shown) must leave or enter the surface at right angles to the surface and are circular between surfaces. The E field lines are shown in red and only a cross section is depicted. H field lines are orthogonal and surround the E field lines.

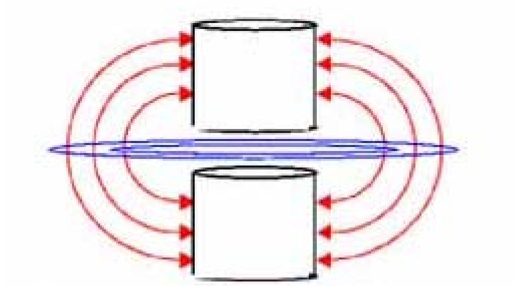


FIGURE 1 - E AND H FIELDS OF AN ANTENNA

Since the magnitude of the fields increase and decrease at the rate set by the operating frequency, we can depict their amplitude variation as sine waves as shown in **Figure 2**. Note that the H field lines are ahead of the E field lines in time phase by 90 degrees. The applied voltage between the two elements of the

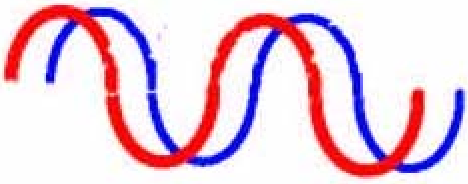


Figure 2 – RELATIVE PHASE OF THE E AND H FIELDS

antenna creates the E field lines. The H field lines are a result of current flow through the natural capacity between the elements, thus that current is called displacement current. Since current through a capacitor leads the applied voltage, the H field leads the E field in time phase. To create an EH antenna, it is only necessary to delay the current relative to the voltage with a simple network between the feed line and the antenna.

By delaying the phase of the H field 90 degrees, the two fields are then in phase and radiation is created. My friend George prefers to think of this as power factor correction, where maximum power is radiated when the fields are in phase. Nature effectively does this at a distance (in the far field) from the Hertz antenna. This has been referred to as a happy accident of Nature. The independent E and H fields are considered to be reactive fields because they do not radiate power. On each half cycle, the fields build up then collapse back on the antenna. If the large magnetic field encounters a ferrous object, for example a chain link fence, eddy currents will be induced on the fence creating heat. That wasted power prevents some of the H field from returning to the antenna, thus the overall efficiency of the antenna is reduced. The E field can also be affected by items in the field. An obvious example is my favorite antenna test equipment, a fluorescent tube. Another example is the variation of radiation resistance as a function of height for a horizontal dipole. Conversely, when a vertical EH Antenna is raised above ground there is some affect on tuning, but the radiation resistance does not change significantly because of the small E and H fields.

It is very important to note that the radiation resistance of a EH Antenna is a function of the phasing described above. For a Hertz antenna, the current and voltage applied to the antenna are in phase, thus the E and H fields are 90 degrees out of phase. When the current is delayed relative to the voltage, to align the E and H fields in time phase, the radiation resistance increases as evidence of being an EH Antenna. Tests indicate that a phase shift of about +/- 3 degrees from alignment is equivalent to a change from a VSWR of 1.0:1 to a VSWR of 2:1.

To effect radiation, the ratio between the E and H field must always be 377 ohms. Since the smaller is the H field, by increasing the capacity a larger H field can be developed relative to the applied voltage due to a reduction in the impedance of the antenna. For wire antennas, this occurs as the wire length increases. Many years ago, an equation that was empirically derived was presented in QST to quantify this relationship. $R_R = 273(LF)^2 x10^{-8}$ where L is length in inches and F is frequency in MHz. This applies only to a wire antenna used as a conventional Hertz antenna. It is interesting to calculate the radiation resistance of a Hertz antenna of a given size, then convert it to an EH Antenna and note the difference. One example – for a wire that is 15 inches in length at 14.2 MHz, R_R = 0.124 ohms. For an 8 foot mobile whip on 75 meters, R_R = 0.4 ohms.

By the way, it should now be obvious why we named this new concept the EH Antenna. Many have said the EH Antenna can not be true because it violates the laws of Physics. It is true that it does not obey the same laws as the Hertz antenna, because it is no longer constrained to be a simple resonant wire antenna.

A PREFERED PHASING NETWORK:

With an understanding of what to do; now we turn to -> how to do. Let us assume we have an antenna with a capacity of about 10 pFd and a radiation resistance of about 20 ohms operating on 40 meters. At seven MHz, the reactance of the capacity is 2,274 ohms. The phase angle of the antenna impedance is a leading 89.5 degrees. Please see **Figure 3** – not drawn to scale. The leading phase angle must be compensated by adding a lagging phase angle of 89.5 degrees. In other words, add an amount of inductive reactance to equal the capacitive reactance. This antenna would then be defined as being resonant. To convert the antenna to a EH Antenna, we need to add an additional lagging phase angle of 90 degrees (to correct for the phase lead of displacement current), for a total of 179.5 degrees. Therefore, we can now say the impedance of the transmitter/receiver is 50 ohms and the antenna impedance is 20–j2274, and we need a phase delay of 179.5 degrees.

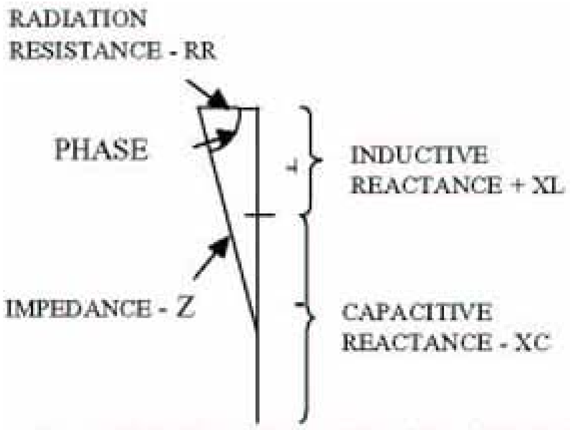


Figure 3 – **VECTOR DIAGRAM OF AN ANTENNA**

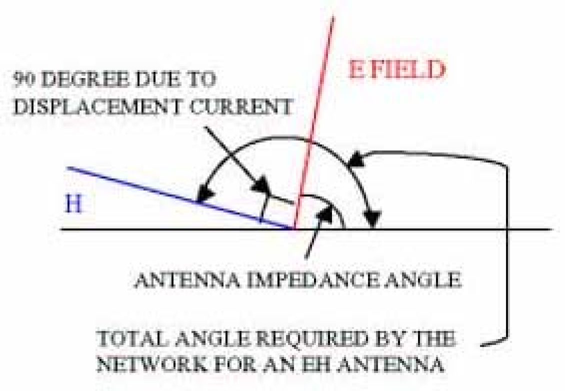


Figure 4 **– PHASING OF AN EH ANTENNA**

A network that will handily provide this transformation is composed of an L network followed by a T network. If we choose to allow the L network to transform from 50 to 25 ohms, there will be a corresponding phase delay of 45 degrees. Therefore, that amount of phase delay can be subtracted from 179.5 to give 134.5 degrees, the necessary design value for the T network. With that information, you can go to the web site of Dr. Grant Bingaman (www.qsl.net/km5kg) and it will readily allow you to use a program to determine the component values of the network. By the way, if you do any experimenting, this program is a must. Another program written by Jack will be found in the tools section of this web site. A schematic of the network is shown in **Figure 5**. A T network is comprised of two coils and the L network has one. We have combined the input coil of the T network with the L network coil, thus the overall network has been reduced to two coils. For most implementations, I use a single coil with taps, except I place part of L2 between the dipole elements. There are two (2) reasons for this. First, if the feed wires going to the dipole are phased properly to cause the antenna to radiate, there will be radiation from the feed wires. A few turns at the antenna will cause a phase difference in the feed wires and prevent radiation from them. Secondly, there is a concern of high voltage, and this is reduced on the feed wires going to the antenna by the use of a coil as shown.

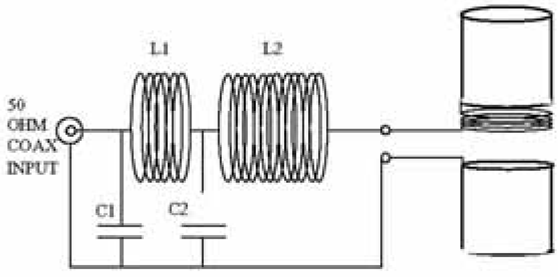


Figure 5 **– A PREFERRED NETWORK TO FEED AN EH ANTENNA**

The equivalent circuit of an antenna, as shown in **Figure 6**, has the following items in series;

1) Radiation resistance

2) Antenna capacity, and

3) Antenna inductance.

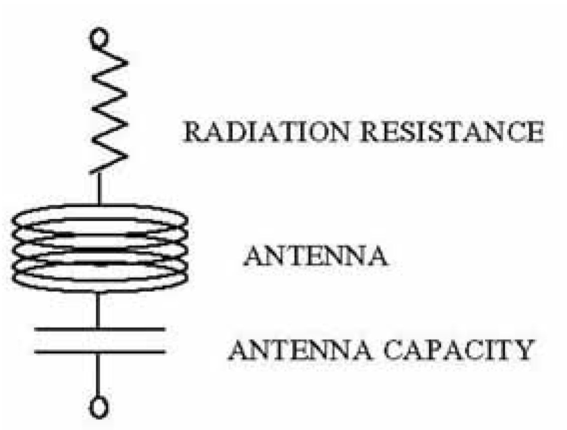


Figure 6 **– ANTENNA EQUIVALENT CIRCUIT**

The radiation resistance is self-explanatory. The antenna capacity is also obvious. Since we have a very small antenna, how can there be inductance? We have said there is displacement current through the antenna capacity. Where there is a current, there is inductance. Maybe that is easier to understand if we say that current flowing on a wire creates an inductance. Note that it is not the wire, but rather the current that creates the inductance.

The current through the antenna is calculated from the equation $P=I^2R_R$. The voltage across the antenna is calculated as the current times the impedance of the antenna, or $V=I(R_R+j(X_L-X_C))$. As you will see from the example 20-meter antenna below, the current is high due to the small radiation resistance, and the small capacity results in high capacity reactance, thus the voltage is high. This is another reason the L+T network was chosen. The network capacitors are low voltage, while the high voltage is developed across L2. The tradeoff requires the capacitors to have high current capability. The amount is specified in the Bingo program.

Above we went through an example using only capacity and radiation resistance. We have found that the inductance can be estimated as follows: measure the capacity of the antenna and multiply that value by about 1.4 times. In other words, the inductive reactance subtracts from the capacitive reactance, thus effectively creating a larger virtual capacitor than measured. Now, go back and redo the example with this new value of virtual capacity for a more accurate model of the antenna.

For those of you who do not have a technical background, please have someone in your Ham club explain all of this to you. It simply is not possible to explain this new concept without getting into this level of detail. Later we will present an example antenna you can duplicate without doing any math.

VARIATIONS ON THE THEME:

Antennas come in many physical configurations. We want to first detail a 20 meter EH dipole and feed network that you can easily duplicate. All you need is a piece of pipe that is made of insulated material such as wood or, preferably, plastic pipe. The dipole elements for 20 meters will only be about 7.5 inches long – **yes, 7.5 inches long on 20 meters** – and can be made of aluminum foil from the kitchen. You will need a couple of capacitors and some wire for the coils. You can readily build the antenna and tune it in a single evening. Then you can test it to prove to your self that it performs as well as that commercial 20 meter vertical (16 feet tall) with a large ground radial system. For those who prefer to chase DX, increase the length of the elements of the EH antenna. We know that a 5/8 wavelength vertical produces more signal at low angles than does a 1/4 wave vertical. In the same way, a longer element of an EH Antenna will produce more signal at lower angles. Why? This is best answered by looking at the E field lines of the antenna in **Figure 7** (they are a little exaggerated). The E field lines cause the H field to increase in size, thus enhancing the radiation by narrowing the pattern. Another method of enhancing the antenna pattern gain is the use of a bi-cone as shown in **Figure 8**. Here, if we consider the intensity of the E field lines in volts per meter, then thelesser length of the lines increases the intensity. I told you there was a lot of room for experimenting with the EH Antenna. Just so you know, I prefer to use 45 degree cones for the bi-cone antenna with a sloping radius of 1% of a wavelength or greater. However, I have had excellent results with cones that are only 0.5 % of a wavelength, but larger cones give more gain. To put that in perspective, on 20 meters a wavelength is 984/14x12 = 843 inches. Therefore, 0.5% = 0.005x843 = 4.2 inches. That is a small antenna. You do need to understand that we prefer element lengths of 1% to work low angle DX, but on the low bands (below 10 MHz) we prefer 0.5% elements to give a broader antenna beam width for general Ham communications. So why did we pick 7.5 inch elements (0.9%) for our example? There are a large number of back packers that use portable QRP rigs, and they need the smallest high performance practical antenna to stuff into their bag, and the extra gain will help and has a minimal increase in size or weight.

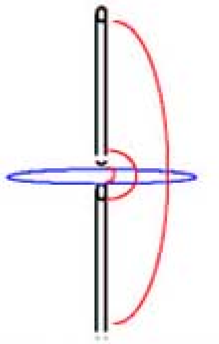


Figure 7 – E FIELD LINES FOR LONG ANTENNAS EXAGERATED

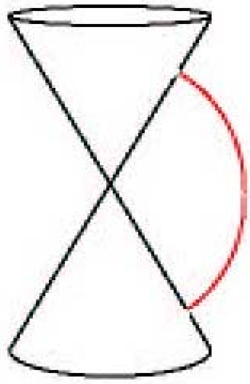


Figure 8 – BI-CONE TO ENHANCE THE E FIELD

ANTENNA HEIGHT:

Although we can build very small antennas with very good bandwidth, there is one very important concept that must be emphasized – the laws of Mother Nature. The antenna can not radiate at low angles unless the center is about 1/4 wavelengths above ground, or a multiple of odd quarter wavelengths, with a null along the horizon when the antenna is 1/2 wavelength above ground. 1/4 wavelength at 14 MHz is 17.5 feet. Any value between 12 and 20 feet is good.

A 20-METER DIPOLE:

Now we will design and construct a very real, very practical, and very compact 20-meter antenna. This antenna can be scaled to other frequencies. For this antenna, purchase a piece of plastic pipe that has an outside diameter of about 1-inch. The pipe is for water, thus the pipe will be specified as an inside dimension. 1/4 inch pipe will have an OD of about 1-inch.

Step 1. Wrap the pipe with aluminum foil, copper, or other conductive material to make 2 elements spaced the diameter of the pipe. You can put glue on the plastic pipe or wrap the foil or metal with either clear tape or scotch tape. We had some thin sheet copper, and that is what you see in the photograph. You can also use copper pipe for the elements and separate them with a plastic spacer available at the plumbing store.

Step 2. Measure the capacity between the elements. Ours has a value of about seven pFd.

Step 3. – Since we do not currently have an equation to predict the value of radiation resistance, from experiments I can tell you it will be about 30 ohms.

Step 4. Now we have the necessary information to calculate the network values. Use the programs suggested previously. The network values are as follows:

- C1 = 225 pFd and must handle a current of 1.4 amps at 71 volts RMS for 100 watt transmitters.

- C2 = 291 pFd and must handle a current of 3.4 amps at 133 volts RMS for 100 watt transmitters

Buy, beg or steal the necessary capacitors. Beware of the current rating for the power you operate with. Any capacitor will work for QRP. Mica compression trimmers are good for any power thru 100 watts.

- L1 = 0.92 uHy. This translates to 2.5 turns on #16 wire around the plastic pipe.

See the photograph for detail.

- L2 = 13.61 uHy. This translates to 21 turns of #16 wire around the plastic pipe plus 4 turns between the antenna elements. Space L2 about one diameter below the lower cylinder. Due to capacity between the coil and the elements, closer spacing will effectively place capacity across the antenna and thus reduce the bandwidth.

Step 5. A – Tuning the antenna requires adjusting the amount of total inductance to set the desired resonant frequency. Course adjustment is determined by the number of turns, final adjustment is done by spreading the turns. Alternately, I put a small piece of wire soldered to the lower cylinder and placed across the gap. Bending that wire allows frequency adjustment of several hundred KHz. Slug tuning also allows adjusting the inductance.

Step 5. B – To achieve minimum VSWR it is necessary to adjust the value of the T capacitor (C2) and where it is tapped on the coil. C1 can be a fixed value because it is not necessary to adjust it. However, if it is variable, it is easily tuned to correct for a slight change in inductance. I prefer to do my initial tuning with a signal generator and a simple diode field strength meter. The signal generator allows changing frequency while the field strength meter indicates the frequency of maximum signal, then the relative signal power while adjusting the T capacitor. Antenna experimenters will have their own techniques and test equipment. Final adjustment is then done by trimming the T capacitor and spreading L1 for perfect VSWR. Once the VSWR is set, the frequency can be changed over a wide range with almost no change in VSWR.

Step 6. Record the 2:1 VSWR bandwidth. This one measured 245 KHz.

Step 7. Measure the +/- 3 dB bandwidth. For this antenna, it is 390 KHz, about the same bandwidth as a full size dipole. This is a Q of 36.4. Now, since Q = XL/R, then R = XL/Q. Since XL =1296, then R = 35.6 ohms. Since the RF resistance of the coils is 2.18 ohms (from the program), the radiation resistance is the total minus 2.18, therefore the radiation resistance = 33.43 ohms. For fun, compare that to the radiation resistance of the same antenna length if it were a Hertz antenna. Previously we calculated a value of 0.124 ohms. Now, we can calculate the efficiency as $R_R/(R_R+R_L)$ = 94%. This is equal to -0.27 dB, not bad for a very small antenna. Now you see the true effect of the EH Antenna concept.

Step 8. Calculate the current thru the antenna. For 100 watt transmitter power it is P = I^2R, therefore I = (P/R)^.5 = 2.8 amps. For 5 watts QRP it is 0.14 amps.

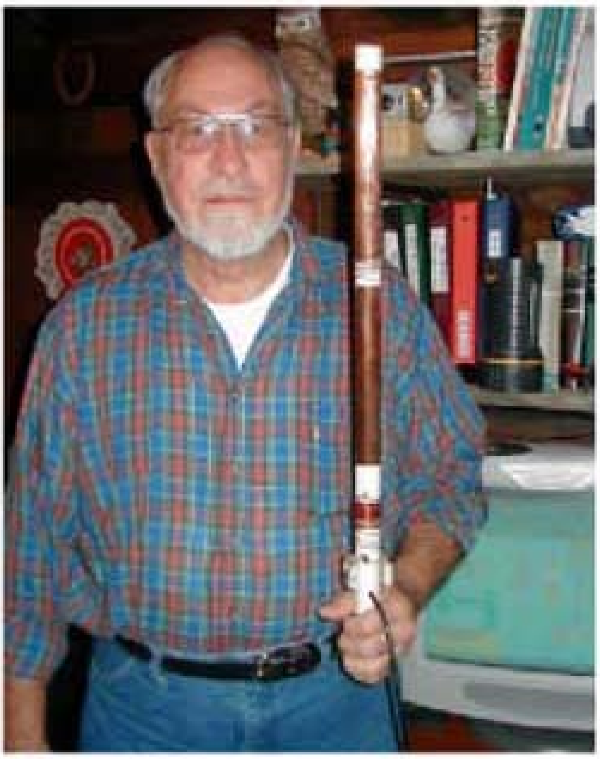
Step 9. Calculate the voltage across the antenna where V =IZ, where Z = the sum of the radiation resistance and the capacitive reactance. For a100 watt transmitter V = 2.8*(33.4+j1144) = 3204 volts. For QRP the voltage is 160 volts RMS. Just be careful of RF burns near the center of the antenna. he result of this activity is shown in **Figure 9**, a photograph of the antenna (with the author in the background).

SUMMARY:

If there is a mystery surrounding the EH Antenna, it must be to find an answer to the following question: Since the concept is so simple, why has it taken so long to discover the EH Antenna concept?

It is my hope that all hams will benefit from this new concept. There is much more information posted on our web site **www.eh-antenna.com**.

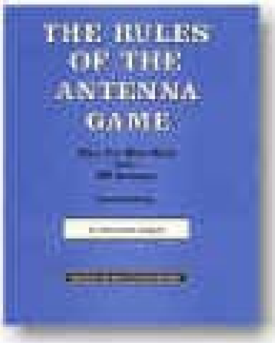
Because there are many Hams that are not able to get on the Internet, please feel free to copy this article and give it to other hams or publish it in your Ham magazine. Building these antennas is a great club project.



Ted Hart, W5QJR, is the author for two excellent books, **The Rules of the Antenna Game** and ***Small High Efficiency Antennas* - THE LOOP**. I have the books in my library and enjoy them very much. All the books are available at **www.antennex.com**

THE LOOP

***Small High Efficiency Antennas* - THE LOOP**



THE RULES OF THE ANTENNA GAME

The Rules of the Antenna Game

The Loop:

Early loop antenna designs fell by the wayside due to lack of theory and poor implementation. In this book, Ted has made the Loop practical as a high efficiency antenna by explaining the causes, thus the cures for those early failures of many homebrew transmitting loops to work well. In this book, the theory, math, and construction methods needed to build a working Loop are described in great detail, and in clear concise language for everyone to understand. In fact, this book may be the only source for the solutions of the misunderstood Loop and dispels the myth that antennas must be large to be efficient. In fact, today, even broadcast stations are making use of small transmitting loops.

The Rules of the Antenna Game:

This book is crammed with facts that will definitely increase your understanding of how the antenna game is played -- no, not about regulations, but what Mother Nature says is okay!. Antennas for transmitting and receiving follow the same rules of Mother Nature who tells us what one can or cannot do. Ted has really laid down the rules in a manner that can easily be understood. You can quickly learn more about the factors that effect an antenna than is apparent from other antenna books. And, this book uses only enough simple math necessary to get the point across. Graphs and diagrams are used throughout to further clarify. Whether a novice or old hand, you will find something useful and of interest.

I trust in EH antennas!

Igor Grigorov, RK3ZK

I am frequently asked, really do I trust in CFA-EH antennas? Really are they work? Indeed do I not see that the antennas cannot work?

Well, what can I answer to this question? Of course, I may give only facts and no more the facts!

But at first, I want to remind the 17 century and the most famous in the times French Academy of Sciences. The academia very easy closed the question about meteorites. They sad:

“ Meteorites cannot be to exist. The meteorite is a stone, and stones cannot be in the sky therefore the sky consists of air, and air cannot keep stones. ”

Of course, “ Meteorites cannot be to exist.” And these stones were thrown out from many museums of the world because the famous Academy forbidden the phenomena. But times are changed, and now we know, that is right, the sky consists of air, but at the same time meteorites are.

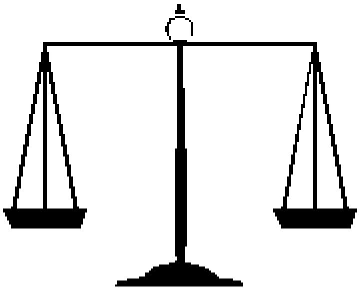
What can I do, when I hear: “Antennas CFA - EH are beyond the bounds of the modern antenna theory,
thereof, the antennas are trickery and the antennas cannot work”.

Of course, I think, “Te antennas cannot work and meteorites cannot be to exist.”

It is very easily to have even a minimal knowledge on antennas and physics and on the base to prove, that CFA- EH antennas do not work, moreover, the antennas can not work, and they newer will work … Ah, yes, “ stones can not be in the sky therefore the sky consists of air, and air can not keep stones ”. It was already early.

But it is much more difficult to carry out experiments, to construct a working design of the antennas, to compare it to other antennas. Certainly, it demands a great time, and in general it is easier to close the subject with the CFA- EH antennas, to have proved, that the antennas do not work.

I carried out many experiments with CFA- EH antennas, well, not all my experiments were successful, but some of these experiments have forced me to trust in opportunities of CFA- EH antennas. I hope, that I be able to finish my experimenters with the antennas up to level when I could publish my work not being afraid that I will undergo to severe criticism. But now I want give you some examples of CFA- EH antennas in ex- USSSR Military Forces.



Malyshev Plant

One my old friend (we together were studied at Kharkov Radio Institute) worked at Malyshev Plant in Kharkov city. (Now he lives and works at other place.) May be you know, that Malyshev Plant produces tanks. May be you know, that tanks have a radio and have a huge antenna, sometimes the antenna has length more then 3 meters. Such long antenna is not sustainable in a battle.

So, the friend told me (it was at the end of 80), that at some experimental groups of tanks the huge antennas were changed for a small one. The small antenna was as an apple in its shape and in sizes. The antenna was established at the back of the tower of the tank. And the antenna did equal operation as the huge three meters antenna. At that time I even have seen some photos of tanks with such strange small antennas. I know nothing how the antenna worked, I did not manage to get any data on it, but the antenna is very similar to CFA- EH antennas on its view. After disintegration of the USSR, the designer of the small antenna left Malyshev Plant for an unknown direction.

May be the tanks have a secret short antenna, that is very sustainable in a battle.

Main battle tank T-84

Main battle tank T-80 UD

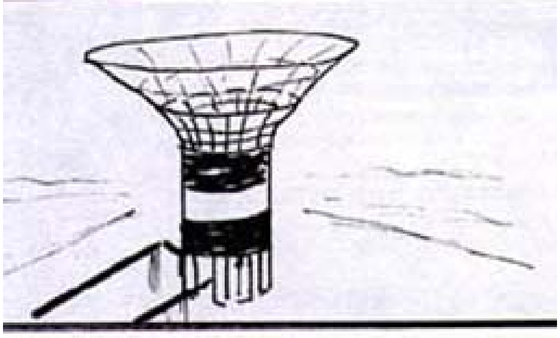
It is other example. I think you know, that underground wire antennas use for underground radio centers of global communication (***see Reference [1]***). These antennas have many lacks, and I do not want about the specific lacks. I want say about another thing. One my friend, who in due time worked on services of such underground radio centers, told to me, that he did works to replacement the long underground wire antennas to antennas, which were similar to their shape to the CFA- EH antennas. Suddenly I found out the prove to his words at ***Monitoring Times magazine***, September, 2001, page 75. There is a picture of an antenna that is referred as ***"a Russian signal source location antenna"***. May be, may be…. a signal source location antenna… I do not want argue, though, I have some arguments... But, let it be so …a signal source location antenna.

But every one can to compare the antenna with a CFA (I reproduce the CFA antenna from www.cfa-kabbary.tripod.com. They produce CFA antennas for many countries of the World.), and, can see, that the antennas are equivalent to each other! (I take courage to reproduce the antenna from ***MT*** without the permission of the magazine, because all my attempts to get in touch with the magazine are failed. They do not answer to me…)

So, nevertheless military use the antennas… Why then there is such criticism of CFA- EH antennas for a civil use? I do not know… I only may do guesses. Well, now every one can try CFA- EH antennas and make own decision. Ted gives us very good guide for them!

Reference: Grigorov I.N.: Urban Antennas, Volume 1. – Published by antenneX Online Magazine, Corpus Christi, Texas USA. ISBN: 1-877992-18-6

A Russian signal source location antenna



, and a Russian signal-source locating antenna (C).

CFA antenna