Antennas

A Short Course

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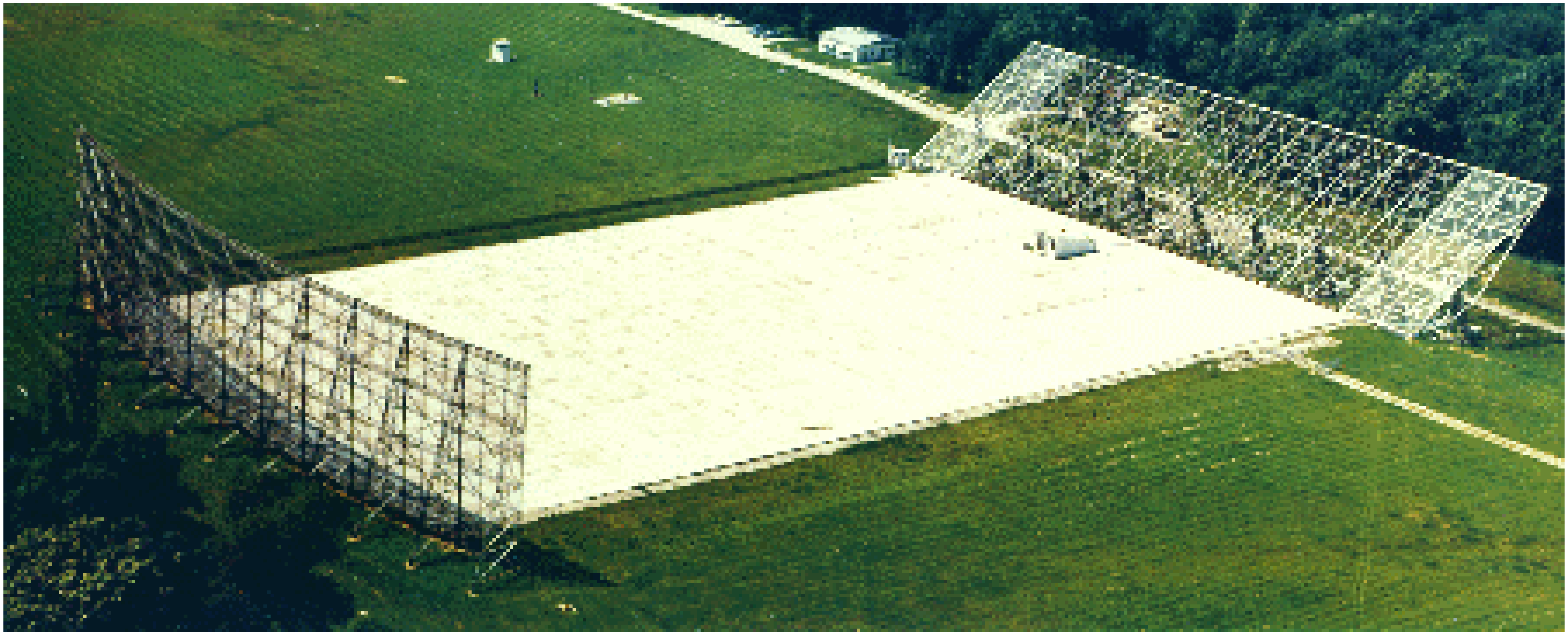
John Kraus – W8JK
June 28, 1910 - July 18, 2004

- Invented the helical antenna, the corner reflector, and the W8JK End-Fire array.
- In 1950 designed and built the “Big Ear” radio telescope at Ohio State University, which was used to carry out the Ohio Sky Survey, and start the first SETI program.
- Wrote the “Bible” on antennas



Kraus' "Antennas"

- First edition - 1950 - This book outlined classical antennas and theory, and was referred to by many as the *Antenna Bible*.
- Second edition – 1988 - A major upgrade to the 1950 edition, incorporating the latest developments in antenna technology.
- Third edition – 2002 – Co-authored with Ronald J. Marhefka. Many chapters written by experts in their field. Updates include computer modeling and terahertz waves.
- Not cookbooks for antennas – lots of math

Let us now develop a more general expression for the directivity. Let the radiation-intensity pattern be expressed as

$$U = U_a f(\theta, \phi) \tag{3}$$

and its maximum value by

$$U_m = U_a f(\theta, \phi)_{max} \tag{4}$$

where U_a = a constant

For the special case where

$$f(\theta, \phi)_{max} = 1 \tag{5}$$

then $U_m = U_a$ and (3) can be written

$$U = U_m f(\theta, \phi) \tag{6}$$

The average radiation intensity is

$$U_0 = \frac{P}{4\pi} = \frac{\iint U_a f(\theta, \phi)\, d\Omega}{4\pi} \tag{7}$$

where P = total power radiated
$d\Omega = \sin\theta\, d\theta\, d\phi$ = element of solid angle

The directivity D is then given by

$$D = \frac{U_m}{U_0} = \frac{U_a f(\theta, \phi)_{max}}{\dfrac{\iint U_a f(\theta, \phi)\, d\Omega}{4\pi}} = \frac{4\pi f(\theta, \phi)_{max}}{\iint f(\theta, \phi)\, d\Omega} \tag{8}$$

Equation (8) can be reexpressed as

$$D = \frac{4\pi}{\dfrac{\iint f(\theta, \phi)\, d\Omega}{f(\theta, \phi)_{max}}} = \frac{4\pi}{\Omega_A} \tag{9}$$

where Ω_A is defined as the *beam area*, or beam solid angle. It is given by

$$\Omega_A = \frac{\iint f(\theta, \phi)\, d\Omega}{f(\theta, \phi)_{max}} \tag{10}$$

From (1) and (9),

$$D = \frac{U_m}{U_0} = \frac{4\pi}{\Omega_A} \tag{11}$$

and

$$4\pi U_0 = U_m \Omega_A \tag{12}$$

Since $U_0 = P/4\pi$,

$$P = U_m \Omega_A \tag{13}$$

where P = total power radiated

The square-corner reflector is a simple, practical, inherently wideband antenna producing substantial gains (11 to 14 dBi). Typical design data for a 90° (square) corner reflector with bow-tie dipole for wideband (2 to 1 frequency range) operation are given in Table 12-2.

The driven element is a 45° Brown-Woodward (bow-tie) dipole bent at 90° as suggested in the figure, so that its flat sides are parallel to the reflector. The dipole can be fed by a 300 or 400 Ω twin line with low VSWR over the 2 to 1 frequency range. None of the corner reflector dimensions are critical. A moderate increase or decrease in the reflector dimensions L and R from the values in Table 12-2 results in only small changes in gain. Thus, a 10 percent increase in L and R can increase the gain by a decibel or less while a 10 percent decrease in L and R can decrease the gain by a decibel or more. Also the (center-to-center) spacing s between reflector rods can be increased with only a small gain reduction. However, an increase in the rod diameter d can compensate for the larger spacing, keeping the gain essentially constant.

For operation at a single frequency the dimensions for f_1, f_2 or f_3 may be used depending on the gain desired. However, for f_1 or f_2 values of S, L, R and l, f_3 values may be used for s and d, resulting in fewer reflector elements.

A closed-sleeve dipole, as shown in Fig. 12-15, may be used as the driven element in place of the Brown-Woodward dipole (see Fig. 16-13c for details of the

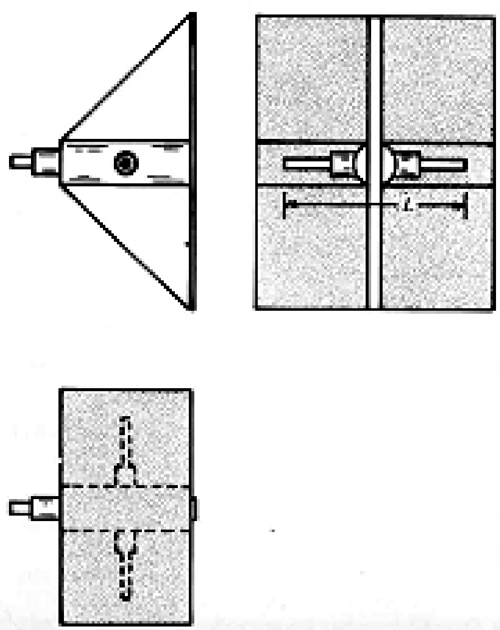
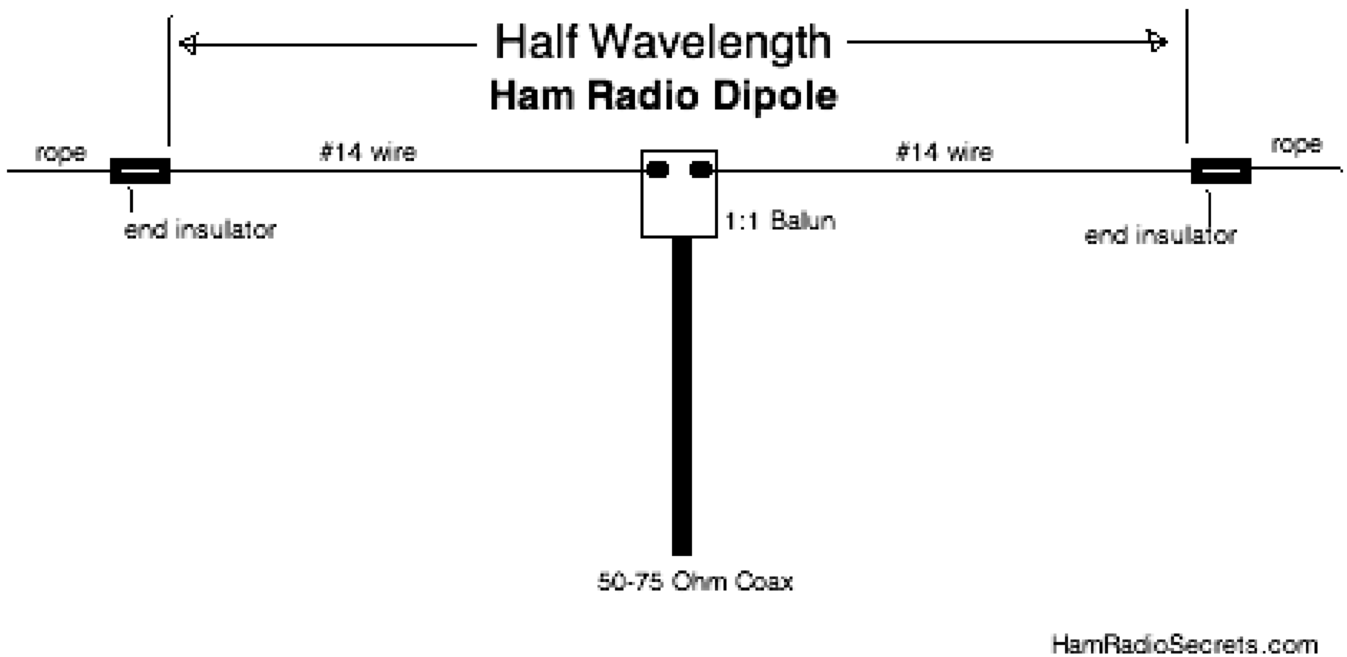


Figure 12-15 Square-corner (solid sheet) reflector with sleeve dipole for wideband operation in side, front and top (or bottom) views. $L = \lambda$ at the highest frequency. Drawing is to scale. (See Fig. 16-13c for dipole details.)

Dipole

- Half-wavelength long
- Divided at center – feedline connection



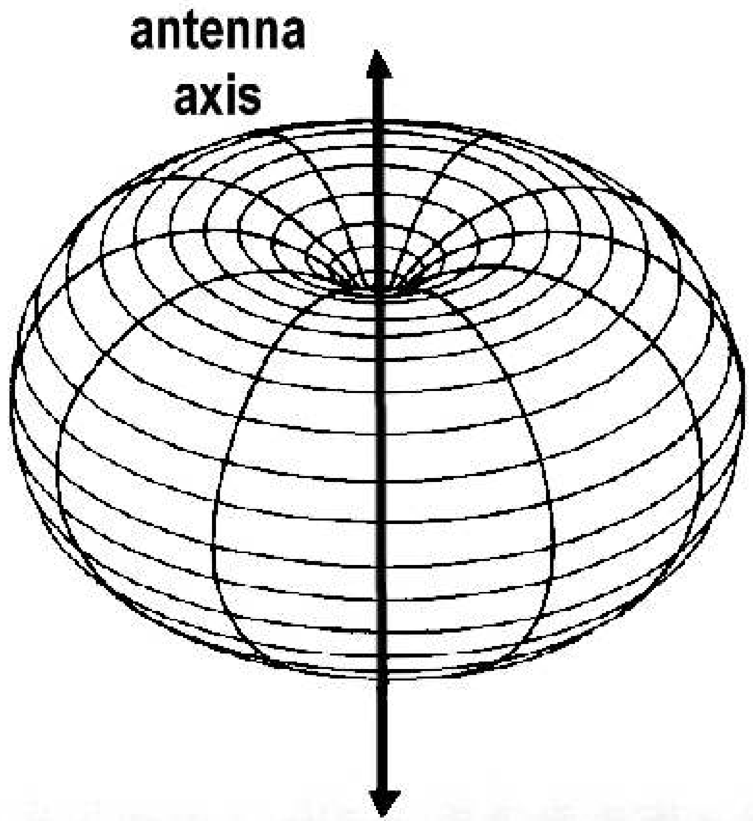
Dipole Variations

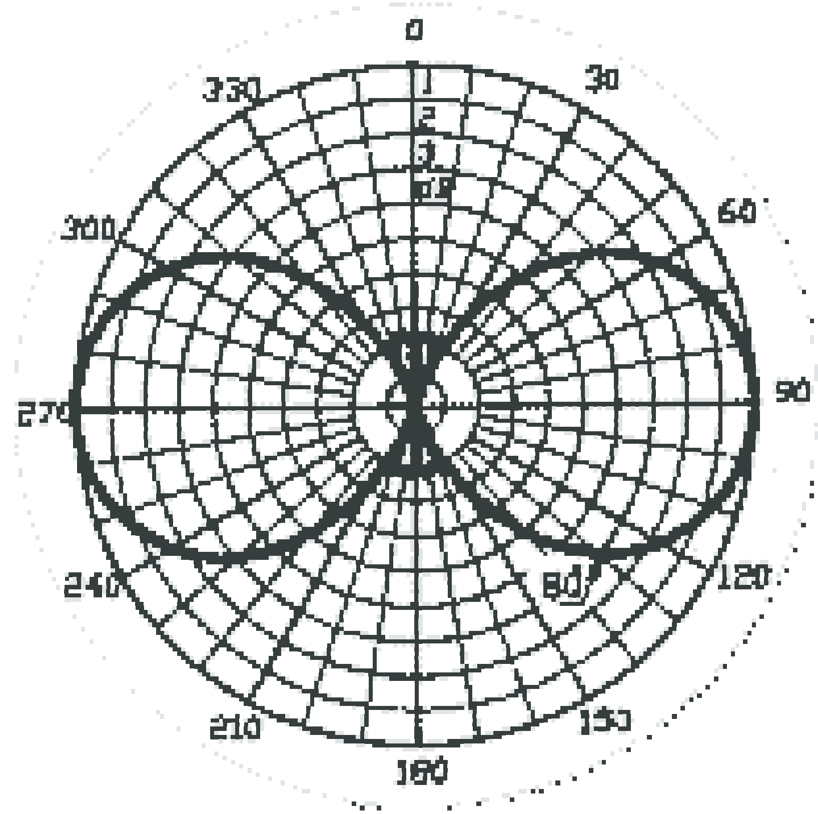
- Folded
- Broad-Band
- Off-center fed
- Shortened
- Sloped

Antenna Critical Characteristics

- Radiation orientation
- Frequency / Resonance
- Bandwidth
- Impedance
- Matching
- Capture Area
- Efficiency
- End effects
- Nearby Parasitic objects

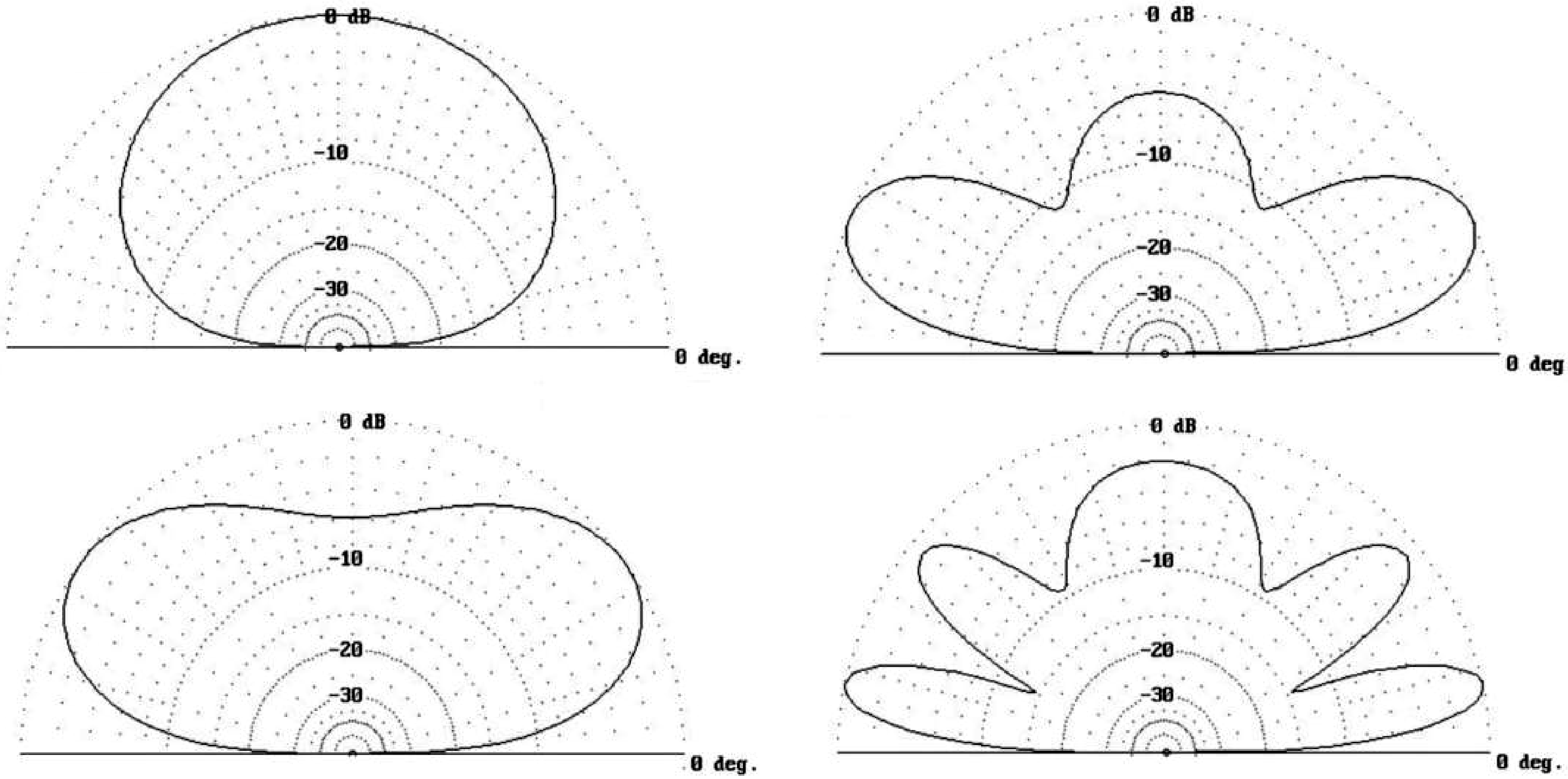
Radiation Orientation





The Dipole “Doughnut”

Radiation Orientation



The Dipole Reality

Dipole Radiation Patterns

- www.ventenna.com – Just put “Ventenna” into Google – it will be the first in the list
- Navigate to “Manuals” page – Click on “Ham”, “More Info”, and “Manuals”
- Scroll down to “Application Notes”
- Download “Dipole Radiation Patterns” – PDF format

Frequency / Resonance

- ARRL Formula – 468/F (MHz)

- Better formula - 5904/F (MHz)
- Provides half-wave length in inches
- Gives free-space length – which is a bit longer than needed, so the antenna can be adjusted (shortened) to resonance
- Easier to shorten it than lengthen it

Bandwidth

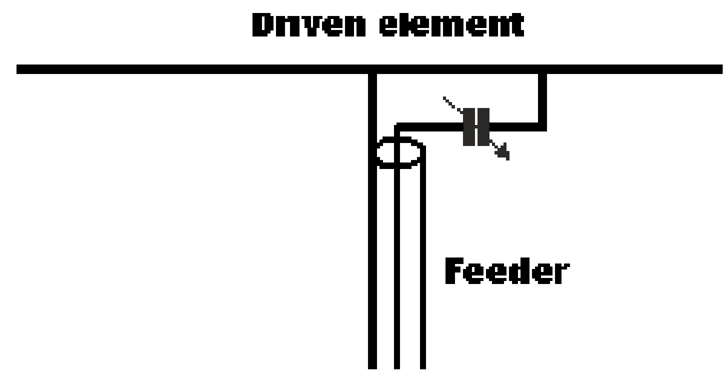
- Thicker element - wider bandwidth
- Typical wire dipole expected to be +/- 1% for 2:1 SWR Bandwidth

Impedance

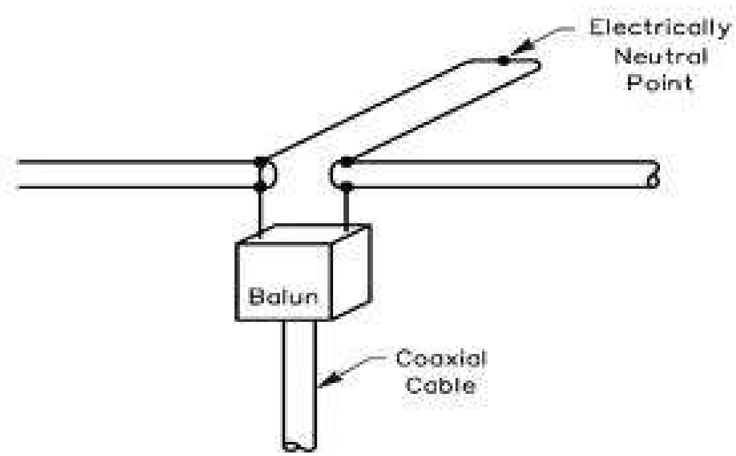
- Dipole Impedance – 72 Ohms
- Connected directly to 50 Ohm feedline gives 1.44:1 SWR
- Matching can bring SWR down to 1:1

Matching

- Gamma Match



- Hairpin Match



Capture Area - larger is better

NASA’s Goldstone 30 Meter (98.5 Ft) Antenna

Radiation Efficiency

- Current is the key
- High current areas should be low resistance
- High current areas should be low impedance

End Sensitivity

- Ends are high impedance points
- Ends are VERY sensitive to nearby objects
- Capacitance effects will result in the need to shorten the antenna to compensate

Mutual Coupling Sensitivity

- Any metallic object within ½ wavelength becomes part of the antenna
- Conductive objects which approximate ¼ or ½ wavelength become parisitic resonators
- Parasitic resonators in the same orientation as the antenna change the directivity pattern

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Other Topics

- Let me know what else you would like to hear about antennas
- E-mail – john@ventenna.com
- Time-sensitive – I will need some time to prepare, so let me know within a week
- Ventennas
- The HFp Portable HF antenna

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