AN ILLUMINATING INTRODUCTION TO ANTENNAS.

Dale P. Clement, AF1T. 49 Corbin Road, Henniker, N.H. 03242-3367.

5 April, 2009.

This Demonstration is a result of my attempts to teach non-technical folks who were studying for their Technician Class Amateur Radio Licenses. The initial success led to an expansion which covered topics for the General Class and Extra Class exams. I hope that some of you will use similar techniques to encourage others to share in our wonderful Radio pursuits, and also to educate the general public about some of the technology they may take for granted. The Demonstration can be tailored to suit various audiences. I have presented it to Amateur Radio Clubs (including HF and VHF groups), engineering conferences, science museums, physics and electronics classes, and a Boy Scout Radio Merit Badge group.

Various properties of Radio Frequency (RF) energy and antennas are shown by illuminating small lamps within a somewhat darkened room. I chose 432-MHz because a whole arsenal of UHF antennas will fit into a suitcase or on a table-top (a half-wavelength dipole is only about 13-in., or 33-cm., long). Besides, I had the equipment — an old Microwave Modules MMT-432/28 generates several RF watts, when driven by a few milliwatts at 28-MHz. from a home-built cw/DSB transmitter. The 28-MHz. unit is small (3-in. x 5-in.) and can vary carrier and audio levels to permit transmission of CW (Morse code), AM, and DSB (suppressed-carrier). The 432-MHz. RF energy can be fed to a small source antenna, which is aimed away from the audience (heed the RF safety rules!). A simple easy-to-make candidate is the WA5VJB "Cheap Yagi" with aluminum-wire elements on a wooden boom. Mine is a two-piece 8-element version (airline transportable), which may be rotated for horizontal or vertical polarization. Remember to identify your call-sign every ten minutes when transmitting in the Amateur band — the energy is traveling well beyond the room!

432-MHz models of many antenna types can be readily constructed from No. 10 or No. 12 house wire and wooden support structures. Some of these antennas are more commonly associated with HF than UHF, such as the Moxon rectangle and half-square array. Others, such as the rhombic, are so large at HF that most amateurs only dream about them; UHF versions can fit in a room. Construction for frequencies much higher than 432-MHz. becomes complicated by lead-lengths and tight tolerances. Some of my models have BNC jacks and are optimized for 50-Ω loads. Others have no connectors and are adjusted for maximum brilliance in soldered-on wire-lead lamps.

5 April, 2009,

AN ILLUMINATING INTRODUCTION TO ANTENNAS. , pp

Dale P. Clement, AFIT. 49 Corbin Road, Henniker, N.H. 03242-336

Using small lamps as detectors can dramatically reveal the presence and properties of radio energy to newcomers and old-timers alike. Field-Strength meters may be more sensitive and accurate, but they just are not as exciting! I try to keep far enough away from the source antenna to prevent a lamp from getting too bright and burning out. Good lamp types include the No. 49 (2.0V @ 60 mA), and so-called "grain-of-wheat" wire-lead lamps with 1.5v or 2v filaments. More powerful types such as the No. 47 (6.3v @ 150mA) are not sensitive enough over great distances without increasing the source power to an unsafe level. Using ≤120-milliwatt lamps is practical in a 10-ft. to 30-ft. space with a ≤ 5 watt source transmitter.

One problem with incandescant lamps is their non-constant impedance with temperature changes. For example, a No. 49 lamp measures ~5.1 Ω when cold (~4.6 Ω for a Chinese version), and ~33 Ω with 2VDC applied. This will of course differ at 432-MHz., primarily due to lead inductance. I solder my No. 49 lamps to short RG-58/U cables attached to BNC connectors. For some antenna models, I use directly-soldered "grain-of-wheat" lamps with short leads.

I have also experimented with bright Light-Emitting Diodes (LED's). They are indeed more sensitive and require less energy than incadescant lamps, but exhibit a variable impedance in the opposite direction. A red LED needs ~2v just to turn on, and at low current (< 100 µA) it may have thousands of ohms, whereas at full brilliance (not much more than 2v, and 20 mA or 30 mA current) impedance will be under 100-Ω. This means that the change in brightness will be less pronounced when moving an antenna than with incadescant lamps. My typical LED detector is mounted on a small circuit-board containing a hot-carrier diode (H.P.-2800), small bypass capacitor (< 500 pF.), and current-limiting resistor (~33 Ω). My most sensitive LED, which can light over 100. feet from the source, uses a voltage-doubler (two diodes) to deliver the 2VDC. An additional problem for audience viewing results from the directional beamed light of an LED.

5 April, 2009.

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Should you wish to recreate a similar demonstration, be sure to guage your audience. The topic possibilities are extensive, but for most people a few simple activities, such as rotating an antenna to show polarization, or holding up a reflector/director (with audience participants!) to make a simple Yagi, will suffice. Your alotted time will be limited. If you have an engineering background, keeping it simple may be difficult! Avoid overwhelming your audience with long technical disussions about complex-impedances, mutual-coupling, or grating lobes. Share your enthusiasm without scaring them away!

Dale Clement, AF1T — 49 Corbin Road, Henniker, N. H. 03242-3367.
November, 2008.

Antenna Demonstration Topics.

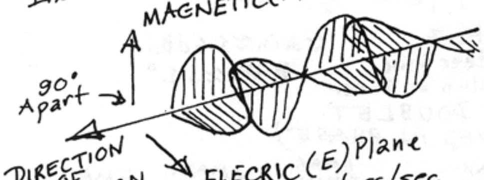
Polarization.
Frequency & Wave Length.
Phasing & Matching.
Terminology.
Half-Wave Dipoles.
Shortened Dipoles.
Ground Effects.
Full-Wave Doublet.
Extended Double-Zepp (EDZ).
Stacked Dipoles.
Long Wires — Harmonic Operation.
V-Beams & Rhombics.
Full-Wave Length Loops — Quad/Delta/Circular.
Small Loops & Halos.
Near-Vertical Incidence Skywave (NVIS) Antennas.
Vertical Dipoles.
Ground Plane Antennas.
Colinear Antennas.
Phased Verticals — Bidirectional & Unidirectional.
Half-Square Array — Bidirectional & Unidirectional.
Parasitic Elements — Reflectors & Directors.
Yagi Antennas.
Stacked Yagis.
Moxon Rectangle.
Driven Arrays — "ZL Special" / Log Periodic.
V-Beams & Rhombics — Terminated.
Parabolic Reflectors.
Effects of Mast & Tower Mounting.
Traps — Multiband Antennas.
HDV & DDD Antennas.
Circular Polarization.

18 March, 2007.

BASIC ANTENNAS.

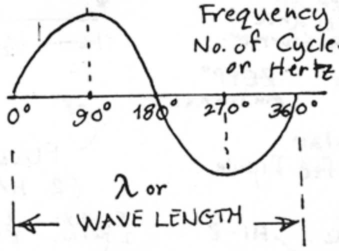
Dale Clement AF1T-
2 Corbin Road, Henniker, N.H. 03242-3367.

ELECTROMAGNETIC WAVE.



Travels 300,000,000 Meters/sec (186,000 Miles per second) in Space.

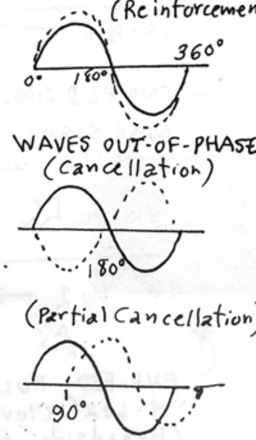
1 CYCLE OF WAVE.

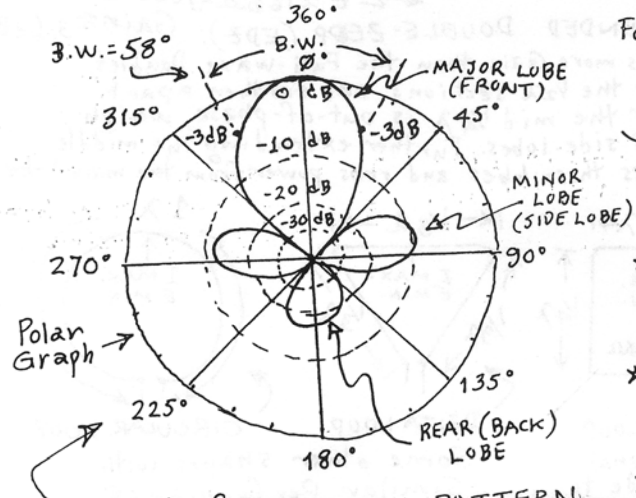


Frequency = No. of Cycles per sec. or Hertz (Hz).

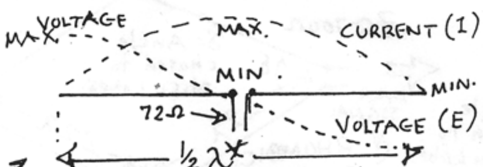
$\lambda_{(Meters)} = \frac{300}{f(MHz)}$, where λ = Wave Length. f = Frequency.

For λ in Feet, multiply Meters × 3.28.





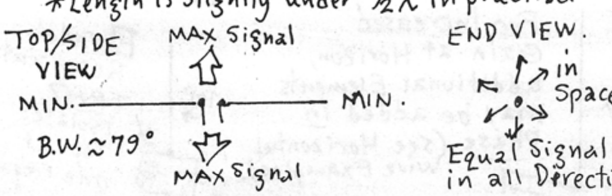
Example of RADIATION PATTERN. (Unidirectional "Beam" Antenna).



HALF-WAVE DIPOLE

This is a most basic and easily constructed Antenna! A BALUN (Balanced-to-Unbalanced) Transformer may be needed for coaxial cable feed.

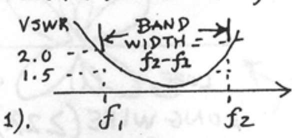
*Length is slightly under ½λ in practice.



TERMINOLOGY

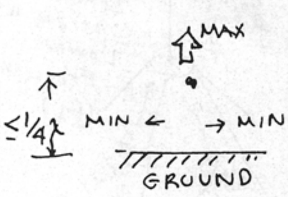
* BEAMWIDTH (B.W. Here) : Angular Distance between points where power drops to ½ (-3dB) maximum. Measured in Degrees. B.W. may differ in E and H planes.
* FRONT-TO-BACK RATIO (F/B Here): Difference between maximum signal (forward direction) and signal in opposite (180°) direction. Measured in dB. A high value indicates good rejection of signals from rear.
* ISOTROPIC RADIATOR: A theoretical "Point Source" with equal radiation in all Directions (3-Dimensional). Often used as a Reference Antenna.

* GAIN: Increase of Signal compared to that of a Standard Reference Antenna, usually stated as dBi (Gain over Isotropic) or dBd (Gain over a Dipole). ØdBd = 2.14 dBi. (-dB values indicate a decrease).
* BANDWIDTH: The Frequency Range over which the Antenna is considered "useful", which must be defined. For example, we may specify VSWR ≤ 2.0 (2 to 1).



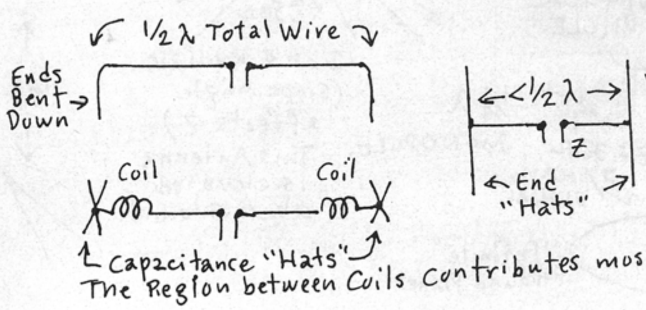
* RESONANCE: Condition where Antenna is purely Resistive. Capacitive and Inductive Reactances exactly cancel ($X_L = X_C$).
* BROAD SIDE: Maximum signal is perpendicalar to the plane of the elements.
* ENDFIRE: Maximum signal is in the plane of the elements, and perpendicular to them.
* NVIS: "Near Vertical Incidence Skywave." Directing the signal nearly overhead for local (not DX!) ionospheric communications, primarily on the 80- or 40-meter bands. (See W4RNL article in Jan/Feb. 2007 QEX).

EFFECT OF GROUND ON HORIZONTAL DIPOLE.



If Ground is ≤¼λ below Dipole, most energy will go upward (not good for DX!). ≥½λ distance gives good signal at horizon.

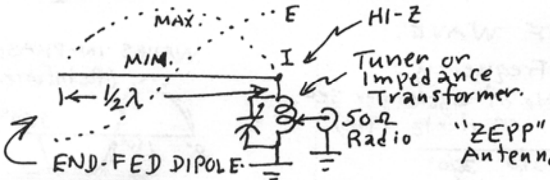
SHORTENED DIPOLES.



Impedance Z goes down as Antenna is shortened.

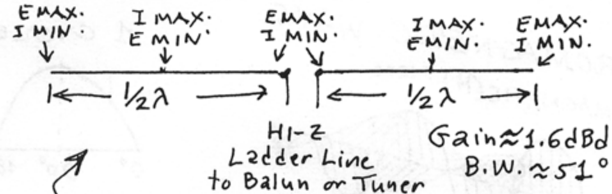
The Region between Coils Contributes most to Field Strength.

Some HORIZONTAL WIRE ANTENNAS

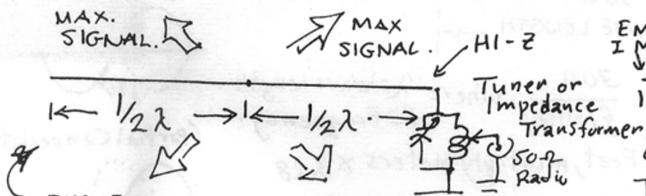


END-FED DIPOLE

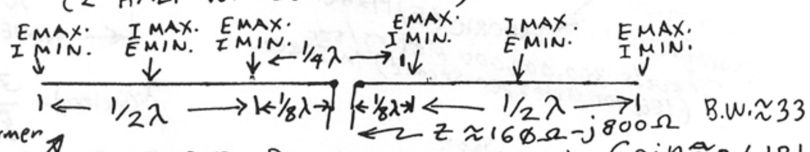
MAX signal is Perpendicular to Wire, just like center-fed Dipole



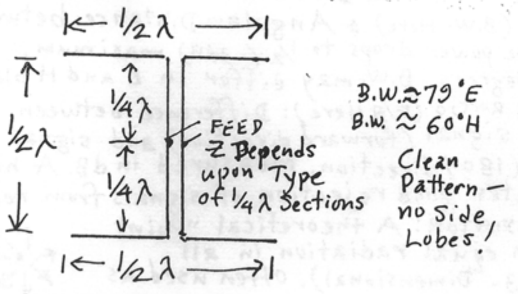
FULL-WAVE DOUBLET. (2 HALF-WAVES IN PHASE)



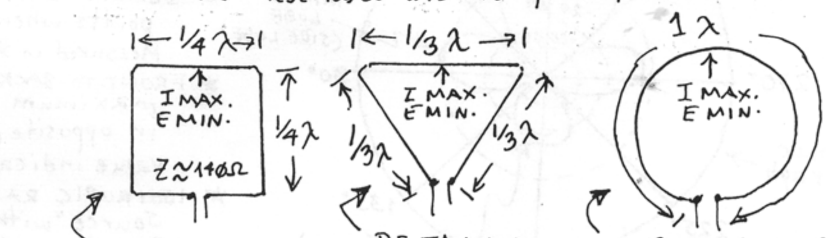
END-FED FULL-WAVE WIRE. "4-Leaf Clover" Pattern. (Broadside out-of-phase).



EXTENDED DOUBLE-ZEPP (EDZ). This has more Gain than the Full-wave Doublet, because the ½λ sections are further apart. However the mid ¼λ is out-of-phase, which produces side-lobes. Further extending the middle increases these lobes and robs power from the main lobe.



BROADSIDE DIPOLES IN-PHASE. Good NVIS Antenna ~⅛λ to ¼λ above and parallel to Ground.

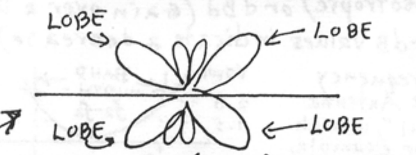


QUAD LOOP (MAX Signal Broadside to Loop).

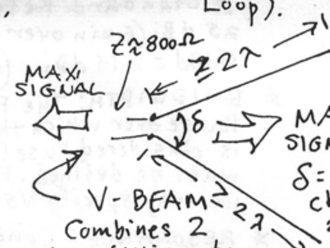
DELTA LOOP

CIRCULAR LOOP

Some other shapes with Similar Performance.

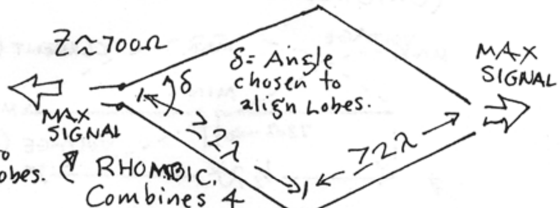


LONG WIRE (≥2λ) has many Lobes of Energy. 2λ Wire has 8 Lobes, 3λ has 12, etc.



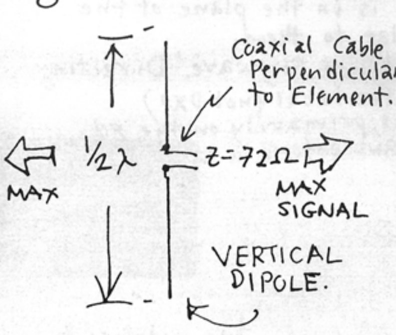
V-BEAM Combines 2 Long Wires to add Energy from Lobes (pairs). Side Lobes cancel partially.

δ = Angle chosen to align Lobes.

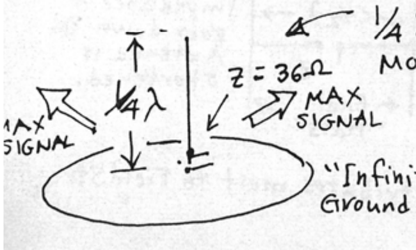


RHOMBIC. Combines 4 Long Wires to add Energy of Lobes. SideLobes cancell partially.

Some VERTICAL OMNIDIRECTIONAL ANTENNAS.

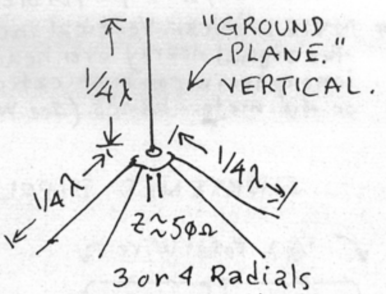


VERTICAL DIPOLE.



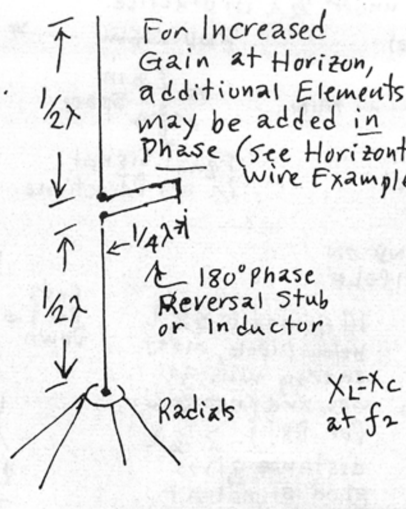
¼λ MONOPOLE.

"Infinite" Ground Plane.



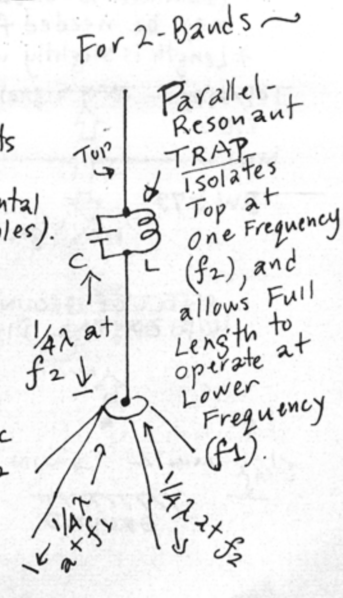
"GROUND PLANE." VERTICAL.

3 or 4 Radials (Slope Angle affects Z) This Antenna is elevated above Ground.



For Increased Gain at Horizon, additional Elements may be added in Phase (see Horizontal Wire Examples).

180° Phase Reversal Stub or Inductor



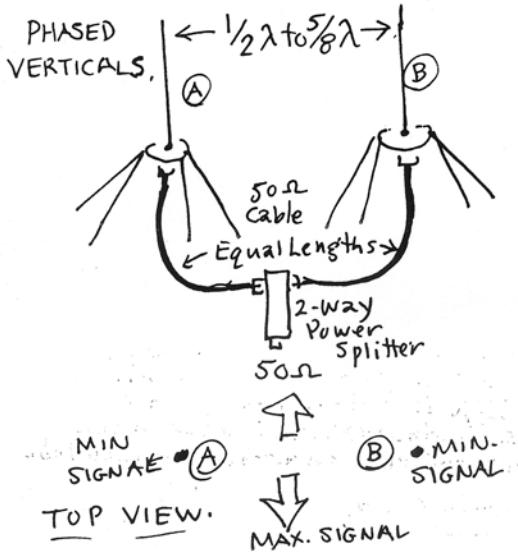
For 2-Bands

Parallel-Resonant TRAP Isolates Top at one Frequency (f2), and allows Full Length to operate at Lower Frequency (f1).

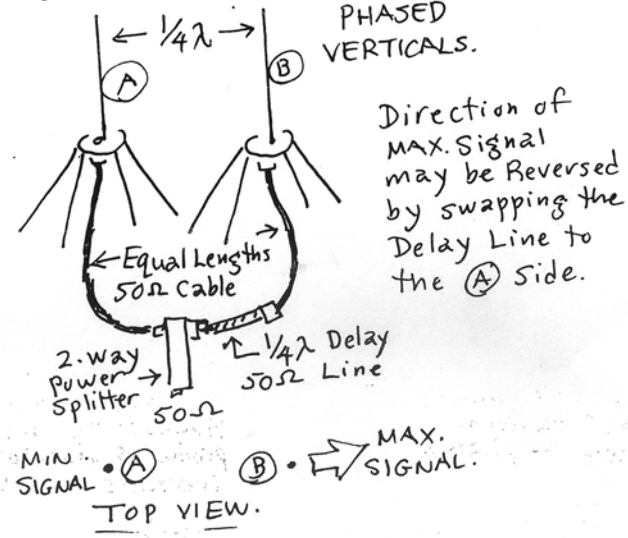
$X_L = X_C$ at f_2

Some DIRECTIONAL VERTICAL ANTENNAS

BI-DIRECTIONAL (BROADSIDE).

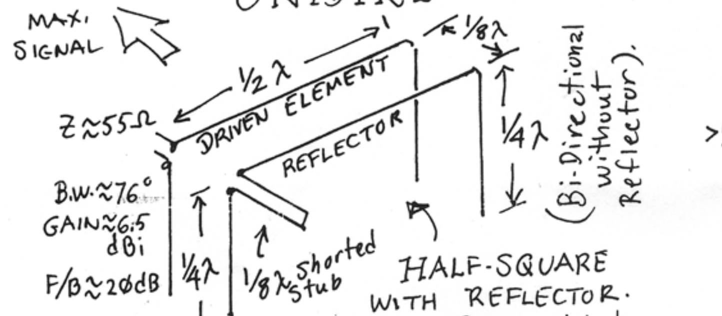


UNIDIRECTIONAL (END FIRE).

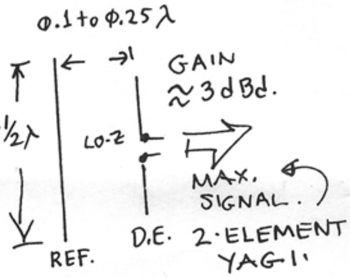


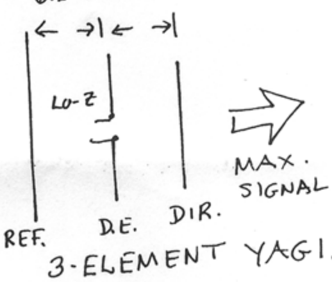
Direction of MAX. Signal may be Reversed by swapping the Delay Line to the A Side.

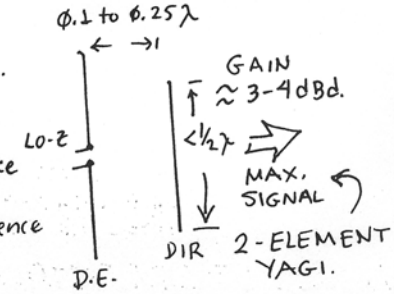
Some UNIDIRECTIONAL ANTENNAS



Works close to Ground! Direction is Reversible by swapping the Stub and Feed Cable. (See W4RNL article in Nov./Dec. 2006 QEX)

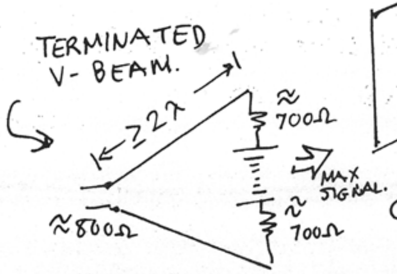


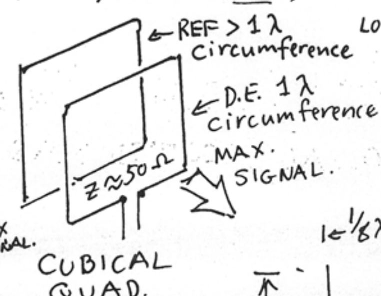


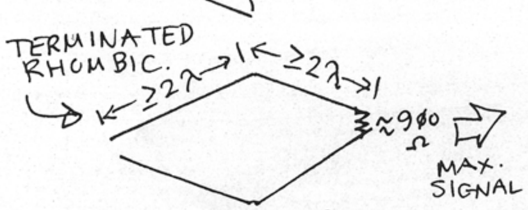


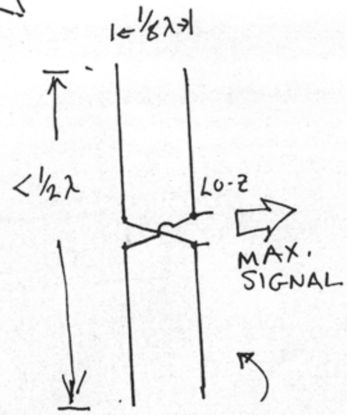
Additional Directors may be added for more Gain (and narrower B.W.).

To Build Cheap VHF/UHF Yagis, see <wa5vjb@ cq-vhf.com>

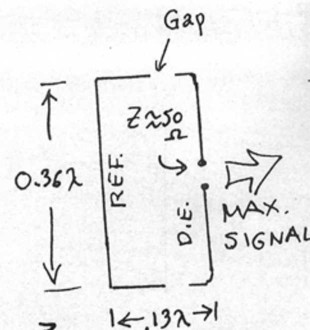








Good Gain and F/B, but difficult to Tune.



This is a small, easily tuned 2-Element Yagi with a broad Forward Lobe and improved F/B.

For Details, see <www.cebik.com/moxon/moxpage.html>