Halifax Amateur Radio Club Basic Course

Antennas

(Chapter 8)

de Fred Archibald VE1FA

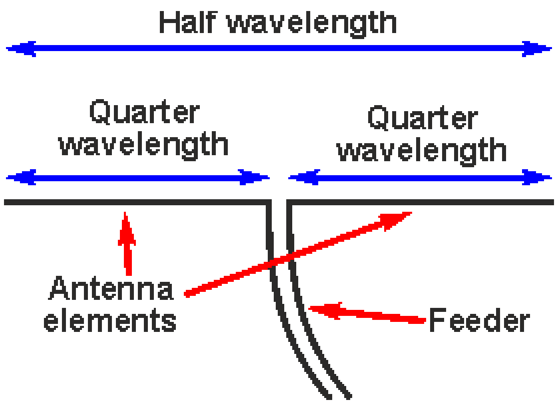
What does an antenna do??

The perfect antenna:

1. 100% efficient
2. Highly directional (high gain)
3. Pointable at any location
4. Poor receiver of natural radio noise
5. Cheap and easy to erect, lasts forever!

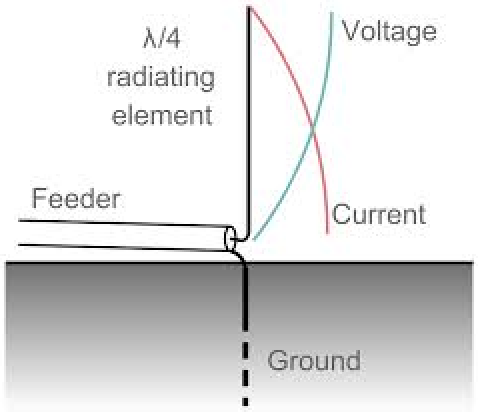
To design, set up, or most efficiently use a good radio antenna, one must understand some basic radio wave physics

Horizontal Dipole



Loop

Vertical



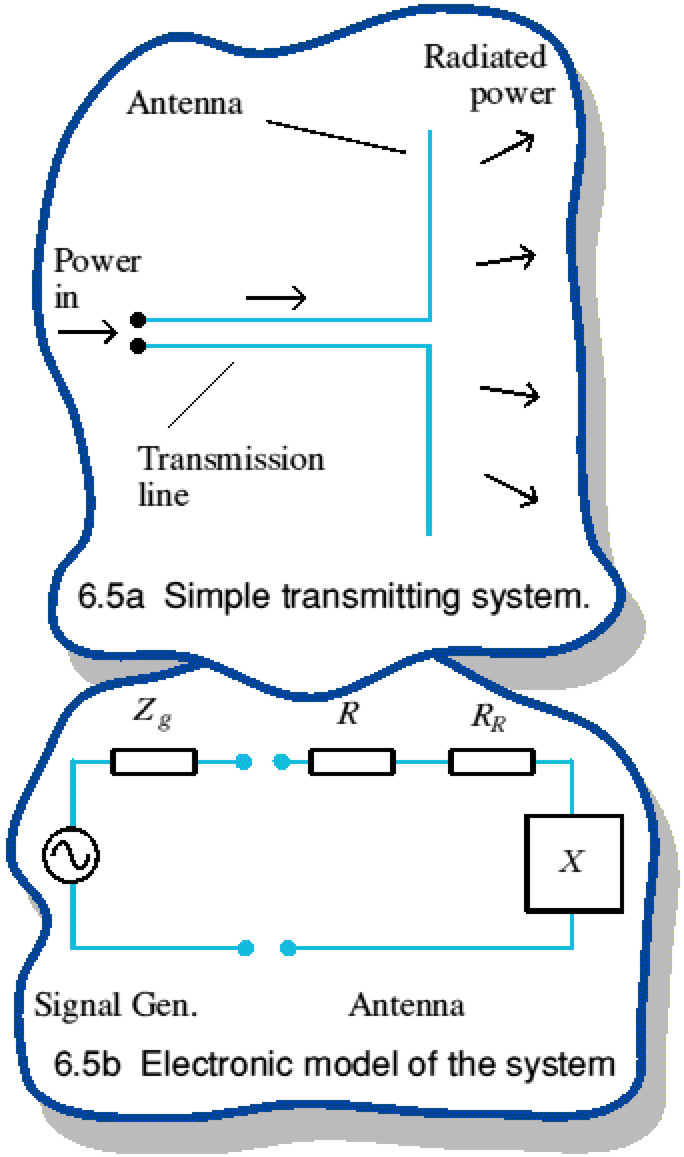
Antenna = "a lossy power converter"

Power in → EM radiation + reflection + R_{LOSS} (resistive loss)

Antenna $Z = R_{LOSS} + R_R + X$

R_R = radiation resistance

R_R = opposition to the conversion of electron-borne energy (electricity) into RF photons (electromagnetic (EM) energy)



Antenna at it's resonant frequency: $X_C = X_L$ so $X = 0\Omega$

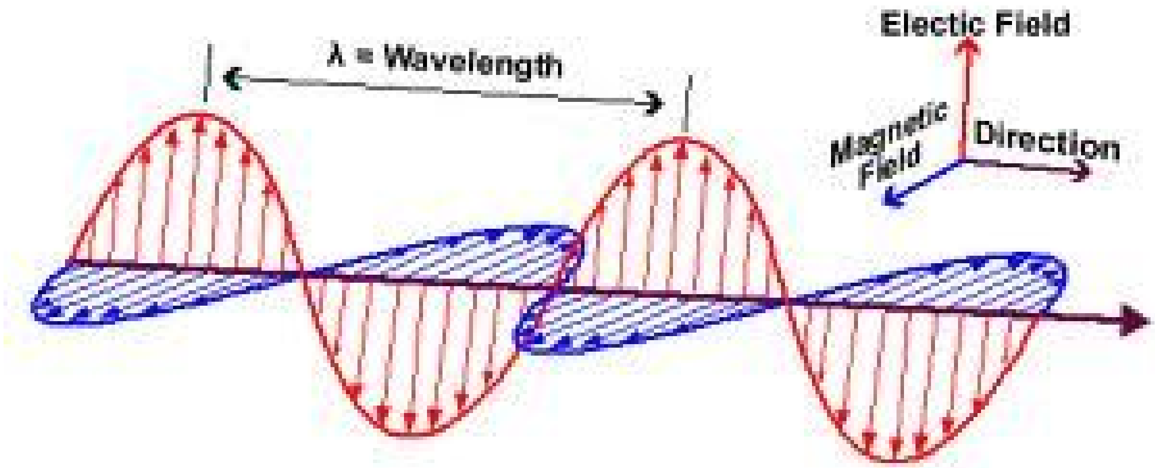
Therefore, in a resonant antenna: $Z = R_{LOSS} + R_R$ only!

$X = 0$ possible $R_{LOSS} = 0$ impossible

Non-resonant (too long) antenna has X_L

Non-resonant (too short) antenna has X_C

Electromagnetic wave in air/space



-Electostatic (electric) (E) field 90° from electromagnetic (magnetic) (H) field

-Both 90° from direction of travel

-Electrostatic (electric) field determines polarization

-Vertical antenna => vertically polarized RF

-Horizontal antenna => horizontally polarized RF

-If RX = TX polarization: optimal reception

- Circular polarization ?

Antenna impedance (Z): -complex combination of R + X_L or X_C

When antenna $X_L = X_C$, X=0, and therefore Z = R, and antenna is resonant

Antenna most efficient at its resonant frequency.

Antenna behaves like an L+C resonant circuit

Every antenna has a resonant frequency

Antenna will have X_L if applied freq > than antenna resonant freq.

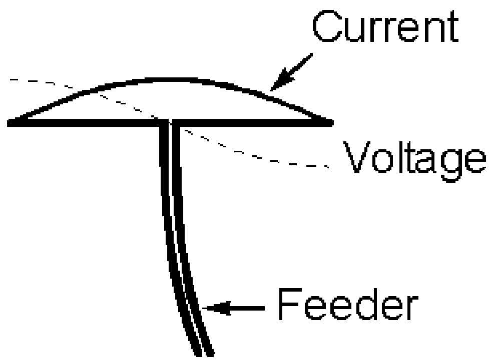
Antenna will have X_C if applied freq. < than resonant freq.

Antenna properties

Feedpoint Z: often designed to be around 50 ohms

$P = I^2 (R + R_0)$ R=ohmic resistance R_o=radiation resistance

Resonant dipole antenna =>
(Z=50 Ω at resonance and 0.5λ above ground!)



Bandwidth: frequency range giving reasonable SWR (standing wave ratio)

Directivity: Gain in a particular direction, and front: back (F:B) ratio (in dB)
Gain compared to theoretical isotropic radiator

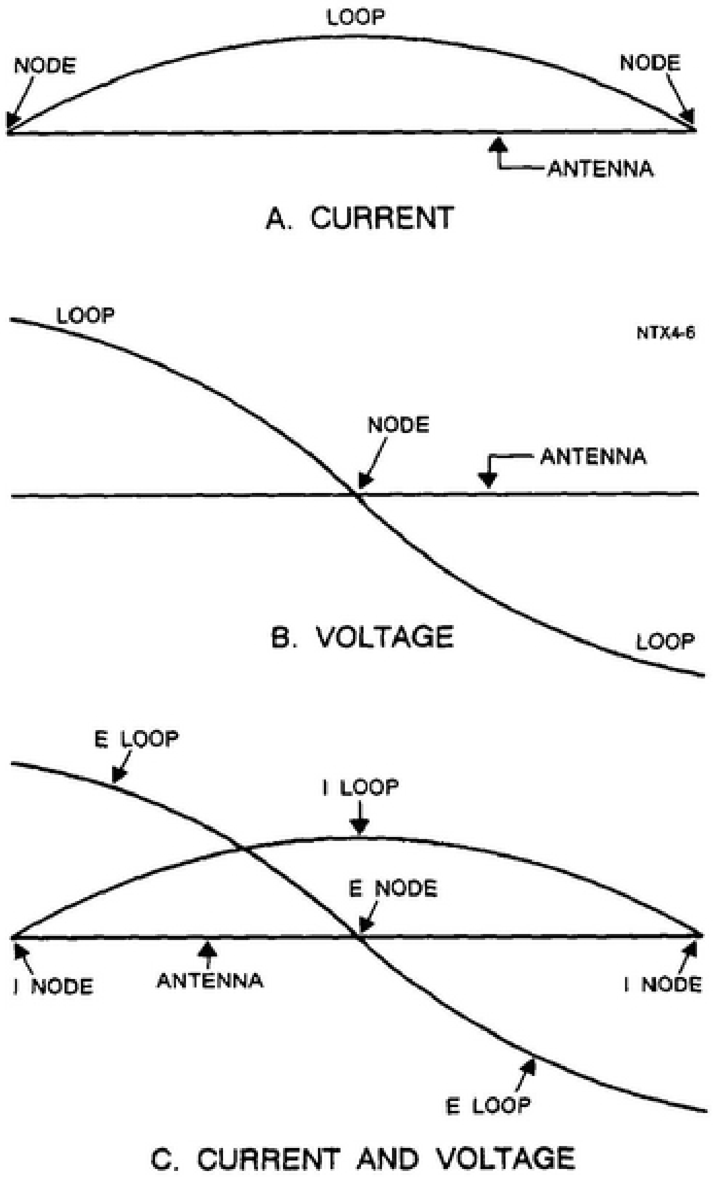
Efficiency: % of RF power radiated as signal (can be 90+% to 0%)

Half-Wave (λ/2) Antenna E + I Distribution at Resonance

-Changes with frequency!

-Changes with antenna dimensions!

-Why would this antenna be fed at its center??



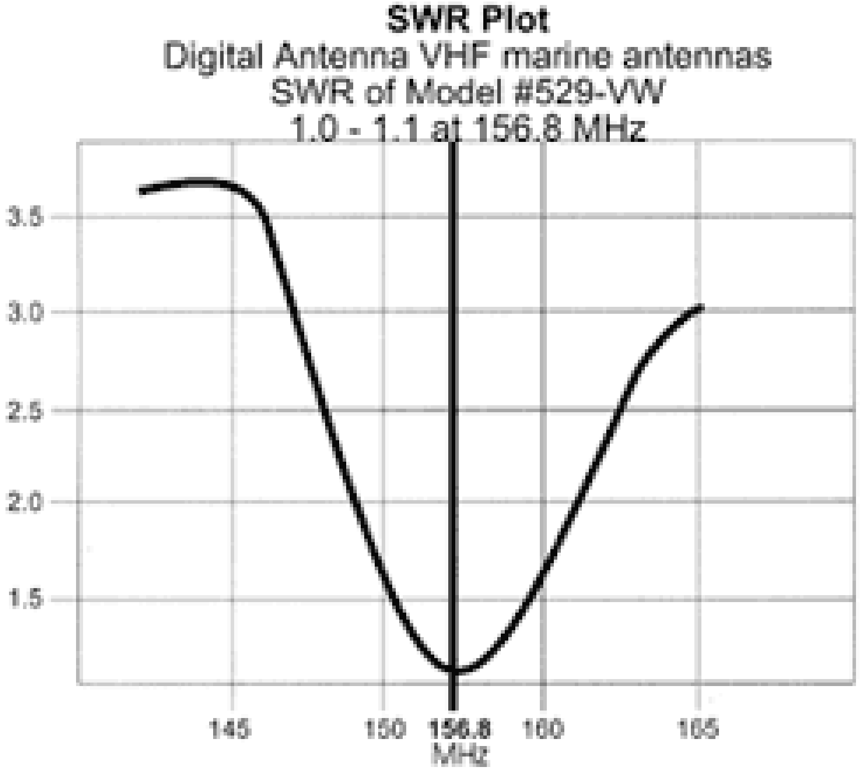
(Voltage) Standing Wave Ratio (SWR or VSWR) = Vmax/Vmin

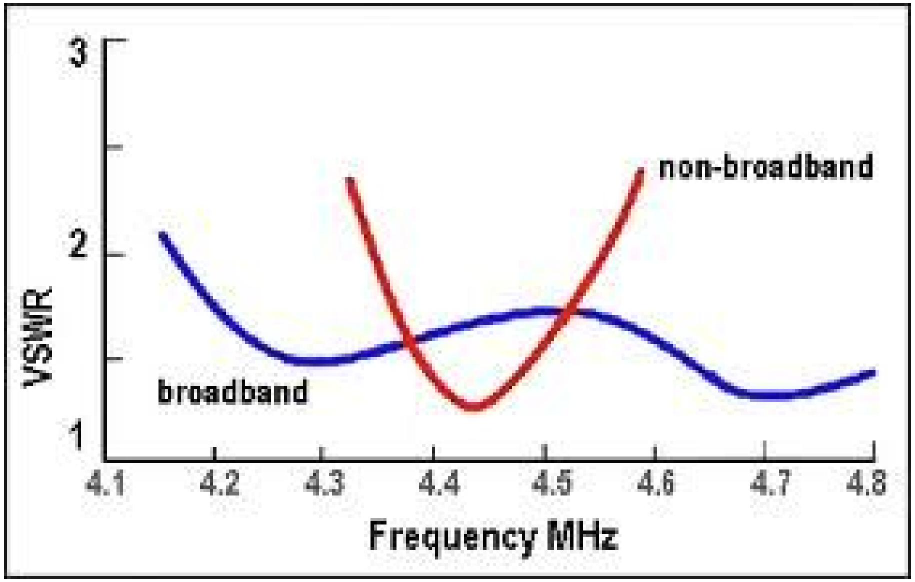
SWR=1.0: perfect Z match!

1.5: max mismatch tolerable by many modern transceivers

>1.5: need a TX to line matching device “antenna tuner”

>2.0: coaxial transmission line losses and voltages increase greatly!





Calculating the lengths of resonant antennas

-works for loops, verticals, dipoles, etc

-ground, nearby conductive objects will affect the exact length giving resonance

-therefore, cut long, trim to desired frequency!

λ = c (m/s)/F (Hz) $\lambda/2$ = 492 feet/F (MHz) ...in free space

$\lambda/2$ = 468' or 143m/F (MHz) ....for dipole 0.5λ above ground*

Example: 40m dipole at 0.5λ above ground

$\lambda/2$ = 468'/7.1 MHz = 65.9' (length of 7.1 MHz dipole)

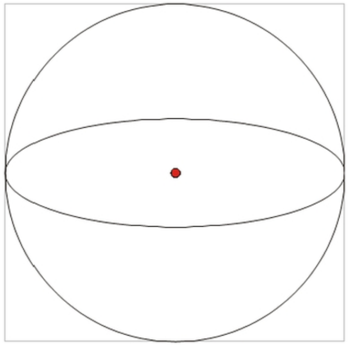
* Ground effect makes dipole seem around 5% longer

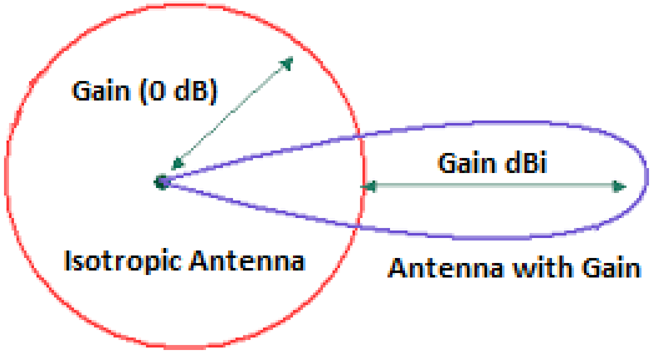
Antenna Radiation Patterns and Directivity

-All antennas directive ,

except isotropic antenna →

(a theoretical reference)





-Directivity measured in "dB gain" (dBi) and Front:Back (F:B) ratio (in dB)

-Effective Radiated Power (ERP)

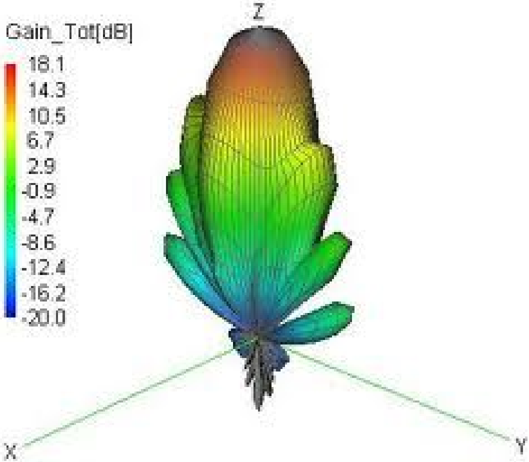
-NEC and related programs (EZNEC, MINNEC) calculate antenna patterns

-Also known as "antenna modeling" :

-Must enter data on: height, ground conductivity, antenna design/dimensions, and frequency

-Millions of calculations usually required!

-Must think in 3D to enter antenna to be analyzed

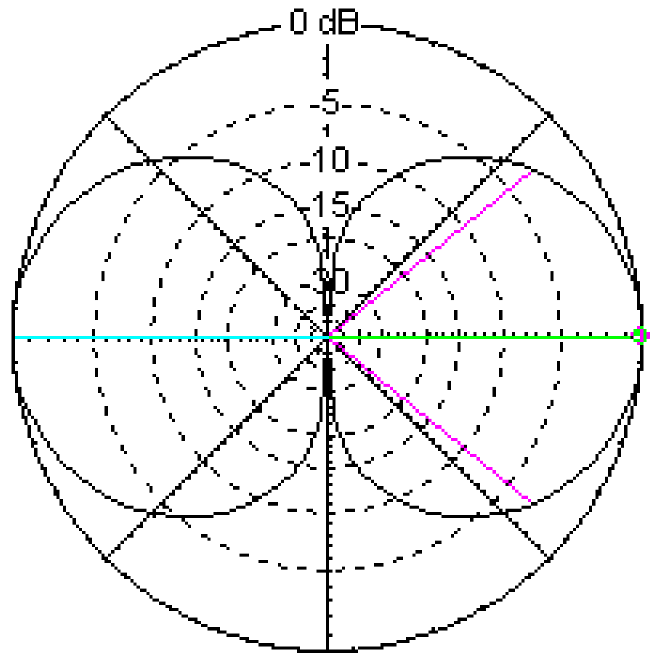


Azimuth Dipole Antenna Radiation Plot

Total Field

EZNEC+

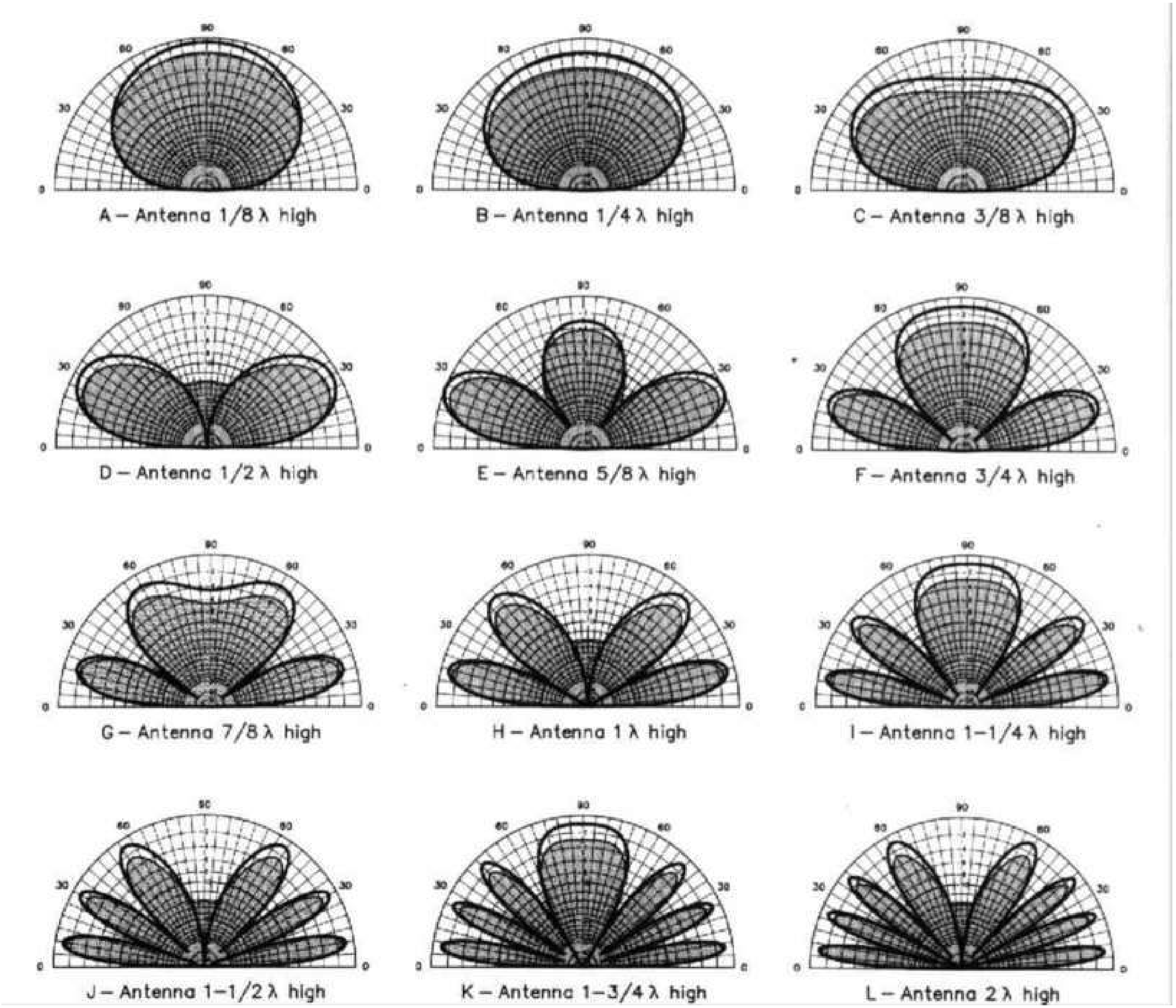
λ/2 above ground, dipole running N-S



7.1 MHz

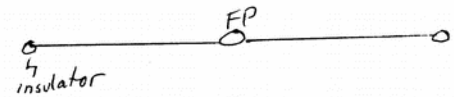
Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	3.22 dBi
Outer Ring	3.22 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	3.22 dBi		
Slice Max Gain	3.22 dBi @ Az Angle = 0.0 deg.		
Front/Side	99.99 dB		
Beamwidth	78.2 deg.; -3dB @ 320.9, 39.1 deg.		
Sidelobe Gain	3.22 dBi @ Az Angle = 180.0 deg.		
Front/Sidelobe	0.0 dB		

Effect of height above ground on a dipole (elevation proj.)

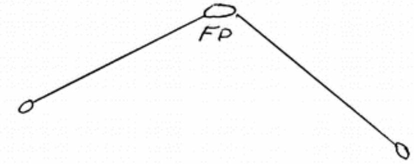


Dipole-derived antennas
(center-fed, half-wavelength long)

Dipole



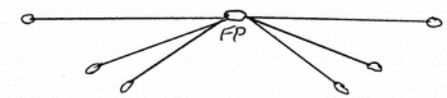
Inverted Vee dipole



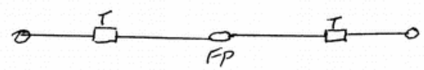
Dipole shortcomings:

1. Usually single band
2. Needs 2-3 supports
3. Low gain/no gain

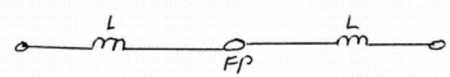
Fan or multiband dipole



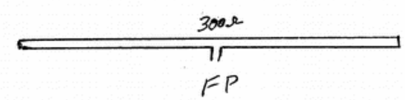
Trap dipole (2-band)



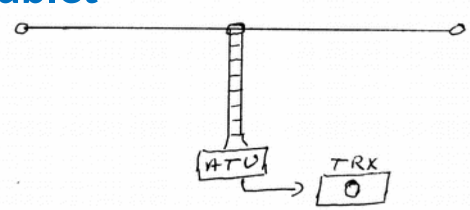
Loaded dipole



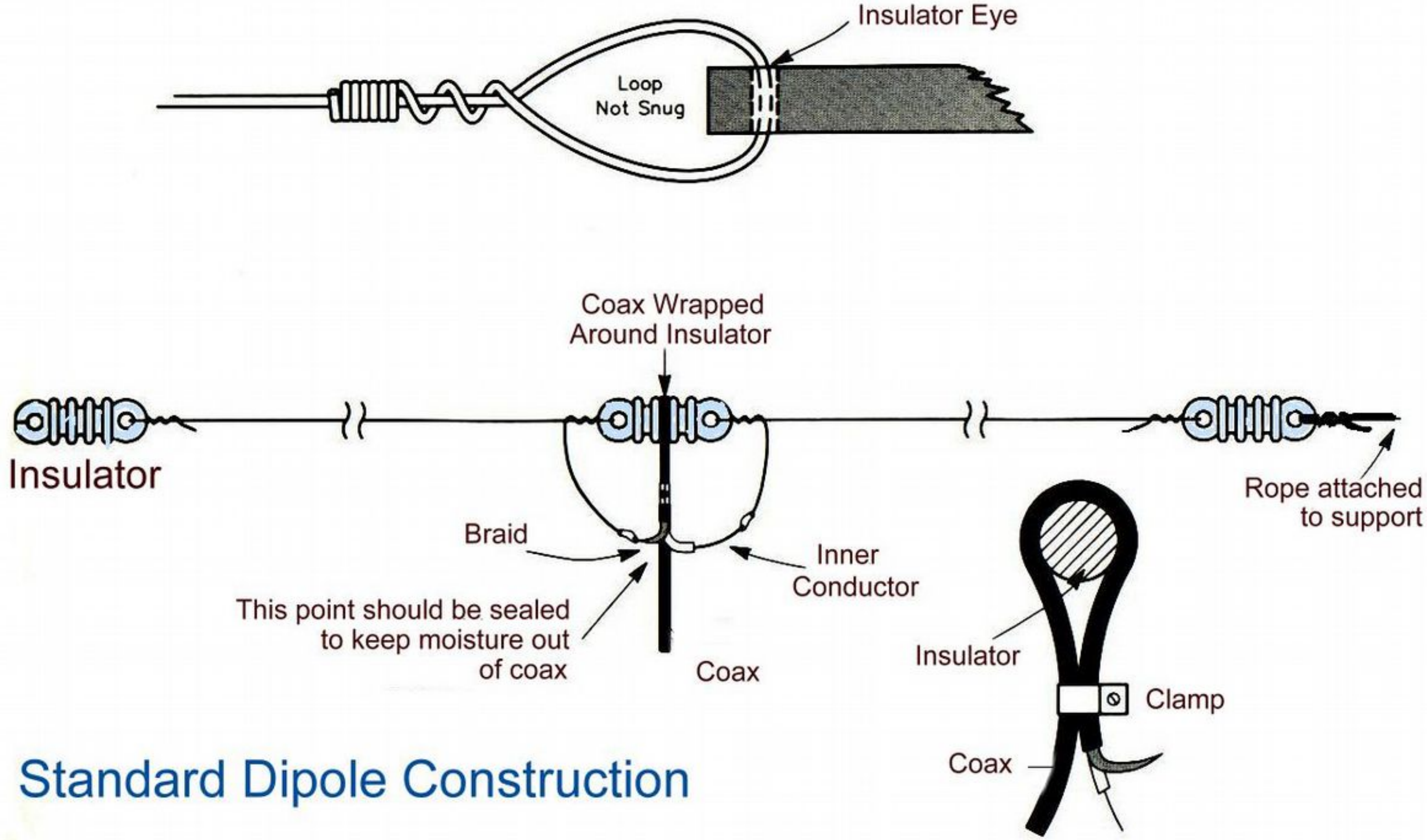
Folded dipole



Non-resonant doublet

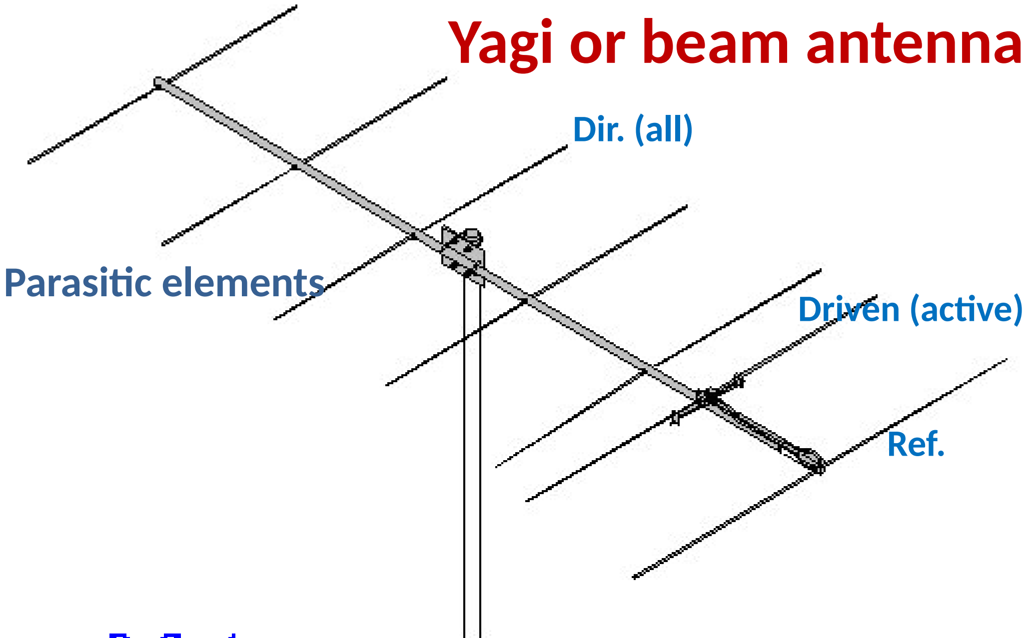


FP = feedpoint for RF
T = trap LC tuned circuit
L = loading coil (makes antenna seem longer)
ATU = antenna tuning unit

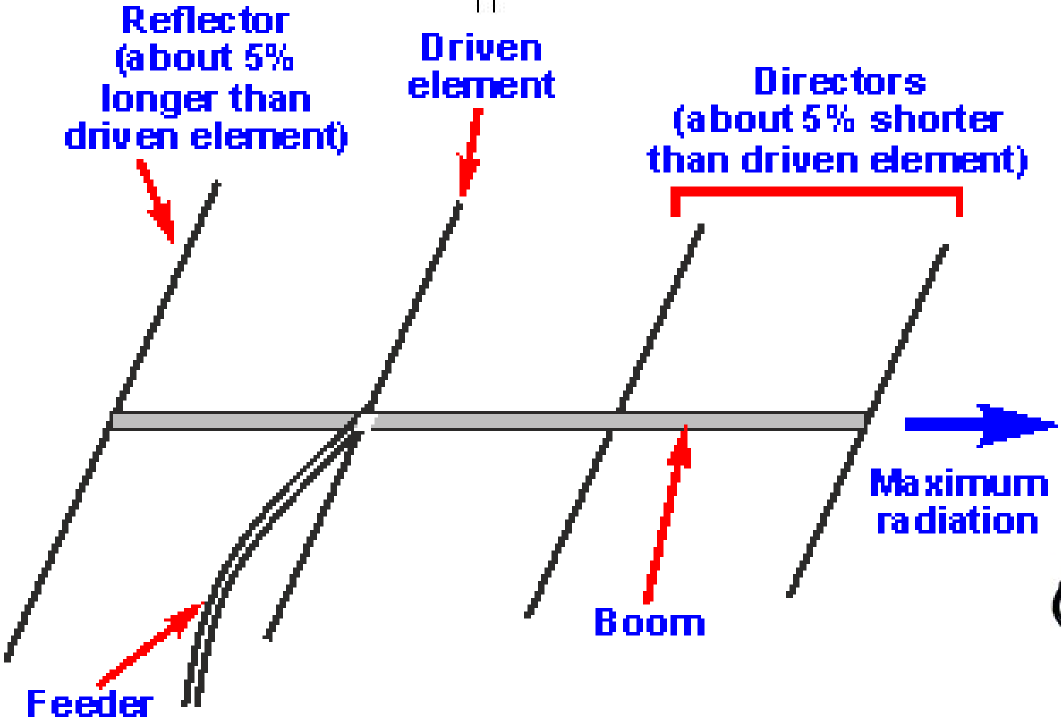


Standard Dipole Construction

Yagi or beam antenna



Hidetsugu Yagi, inventor in 1920s



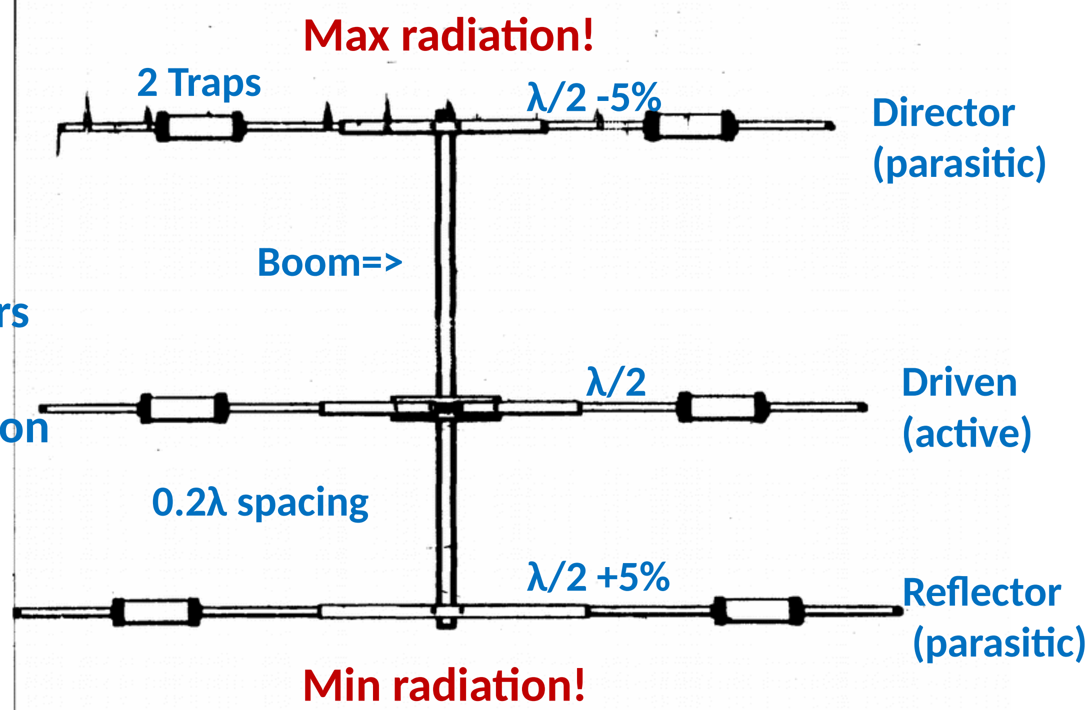
VHF, UHF: small size makes multi elements easy

A real-world amateur yagi:

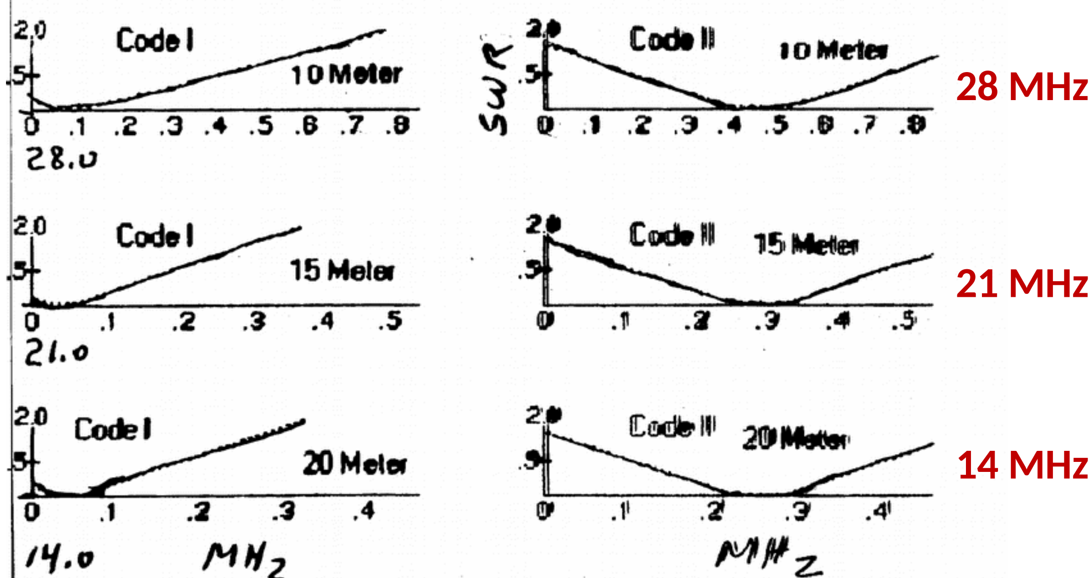
the Mosley CL-33
3-element, 3-band yagi

-Very popular, covers 10-15-20 meters

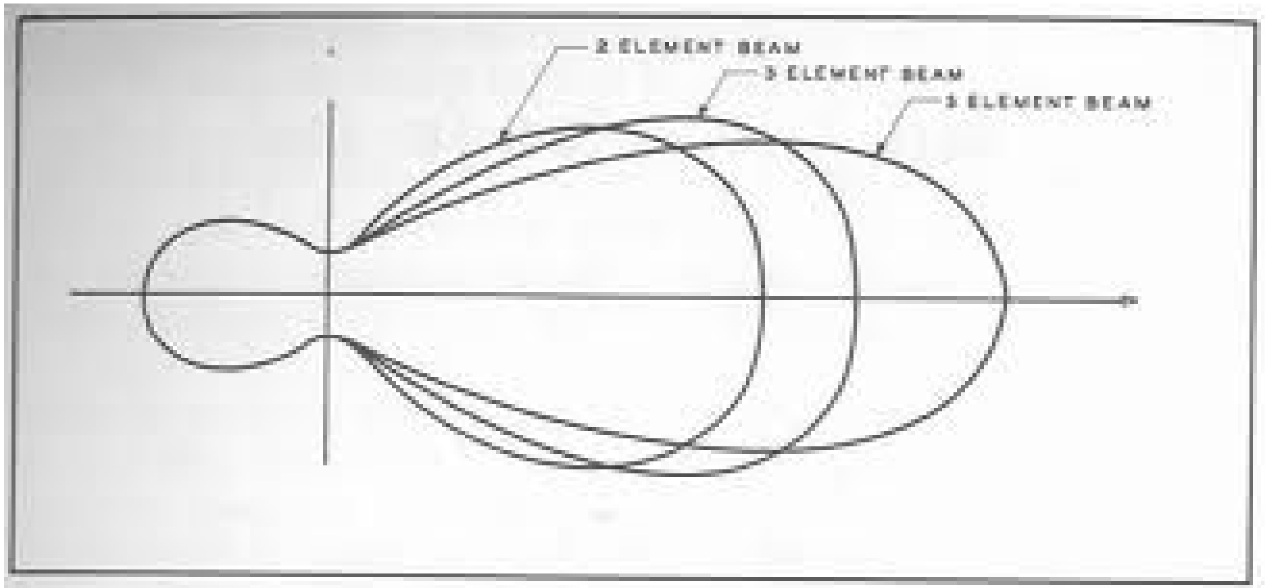
-Aircraft aluminum tubing construction
-Boom = 18'
-Elements = 27-29' long
-Weight 40 lbs.
-Wind load: 6.0 ft^2
-Front:back ratio: 20-25 db
-Forward gain: 7.0-8.5 dBd
9.1-10.6 dBi

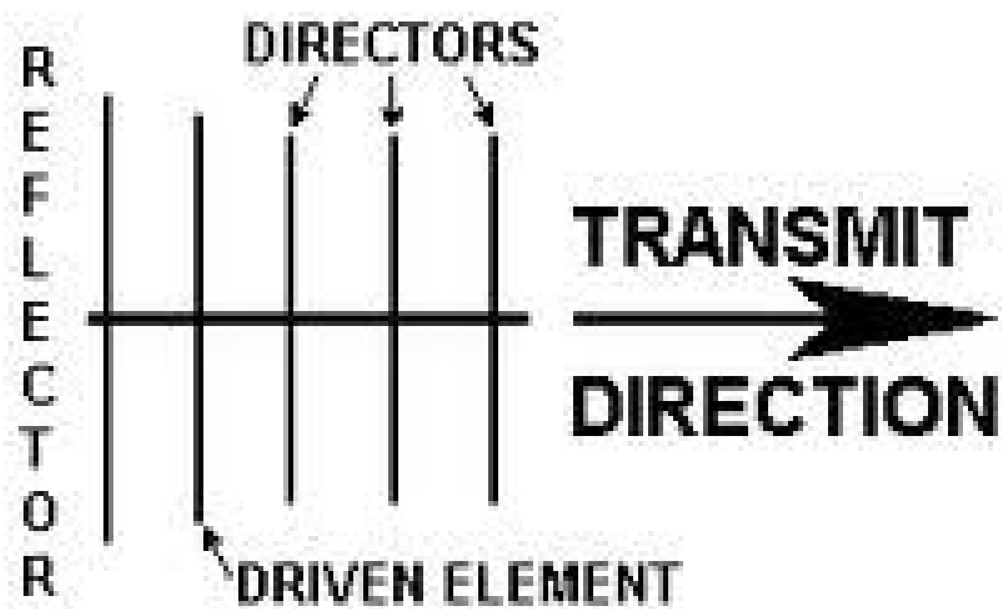


SWR curves for this "Tri-bander" ➔



Yagi Directivity





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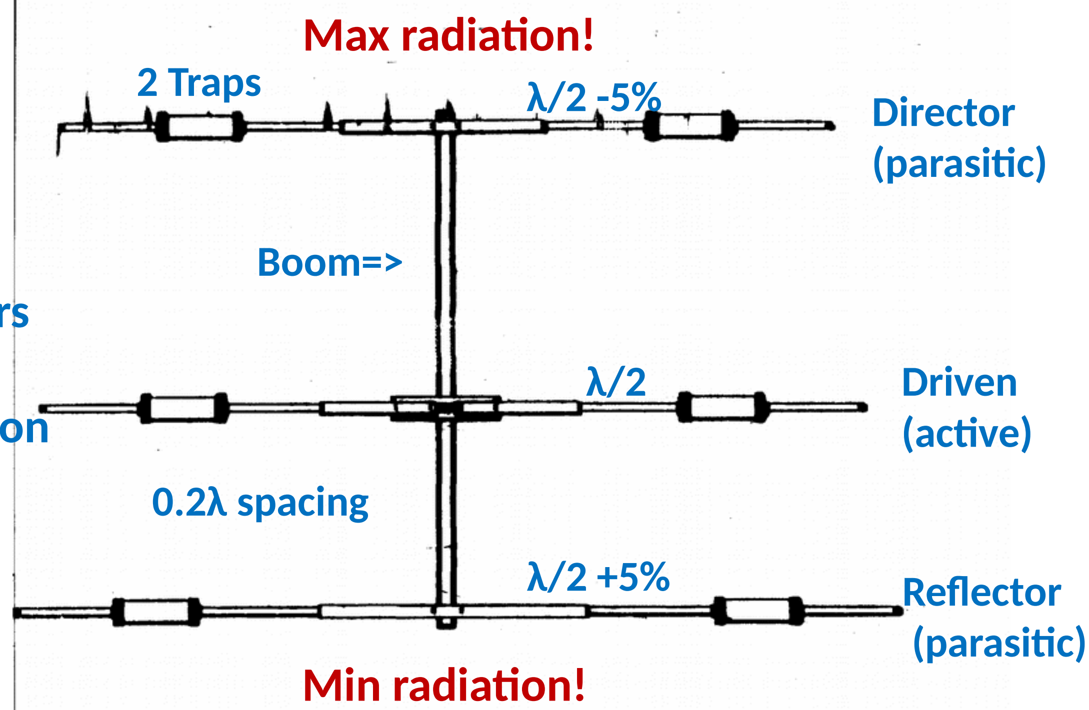

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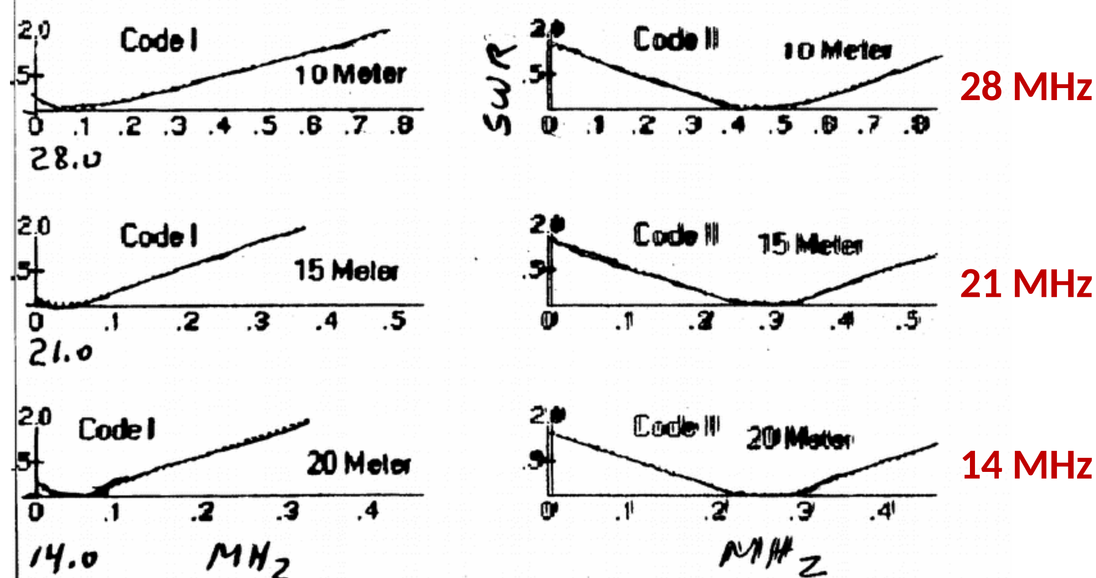


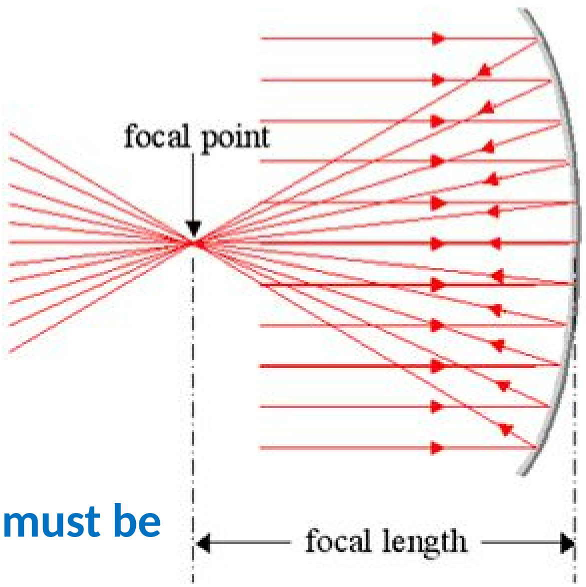
Horizontally polarized multiband Yagi →

Traps for multiband yagi

Vertically polarized monoband yagi, with gamma match →

DX-pedition antennas on 40’ “TV” tower

Parabolic antennas for very high gain



-High F/B ratio

-Highly directional

-The “spotlight” of the RF spectrum

-Dipole, feedhorn, and preamplifier at focus

-Great for UHF => up

-The higher the freq., the more precise the parabola must be

-Mechanically very difficult for low frequencies

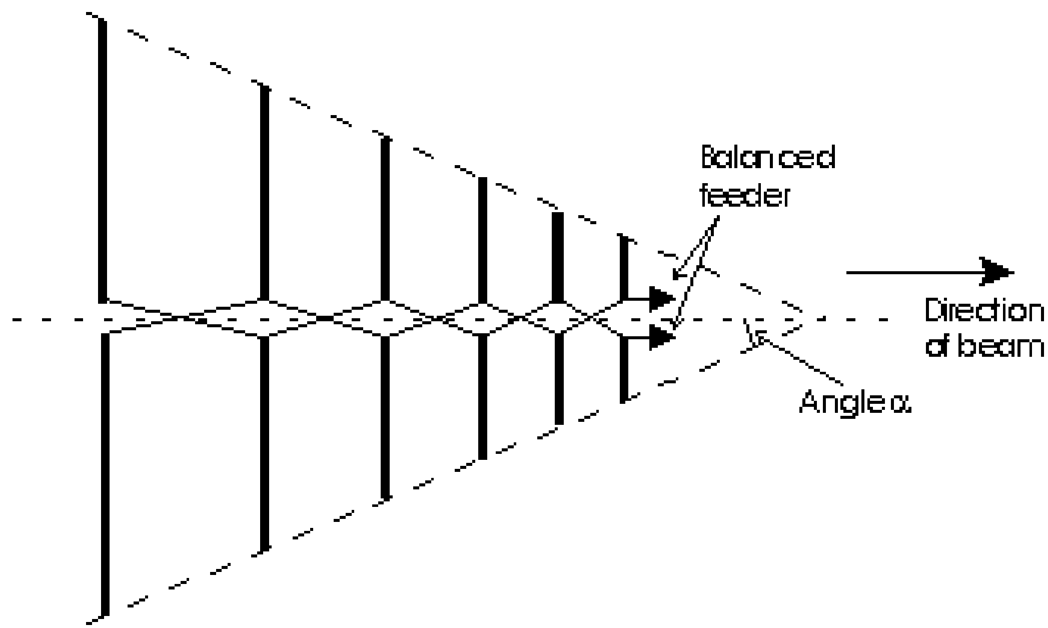
GRID PARABOLIC ANTENNA

Log periodic dipole array (LPDA)

-wide frequency range

-every element active (driven)

-directional



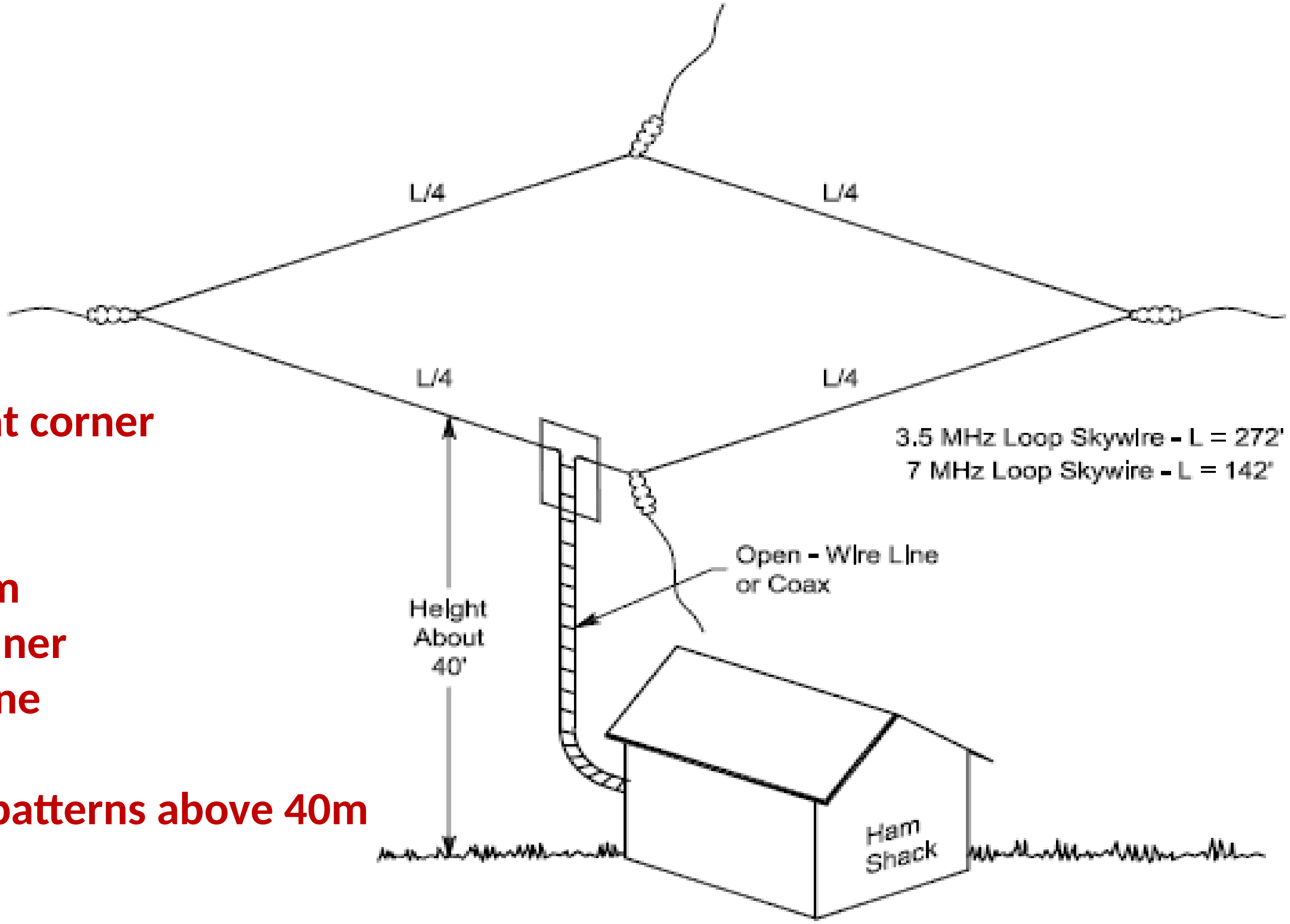
-fed with balanced line at apex

-another dipole derivative!

-relatively low gain, compared to a yagi with the same # of elements

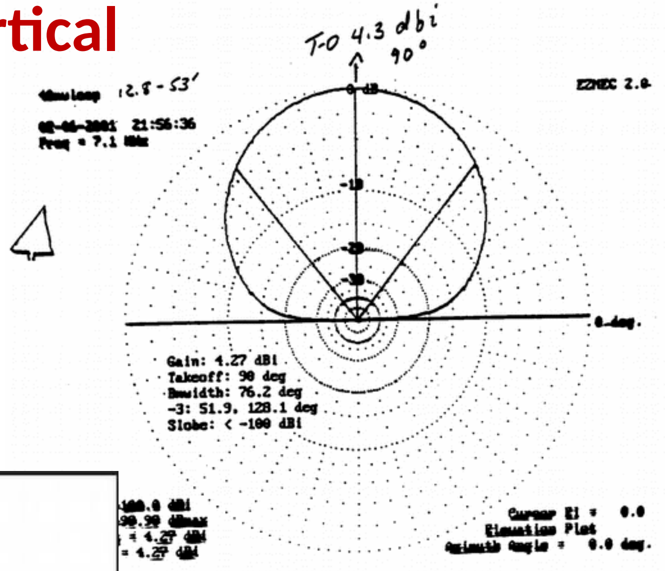
Horizontal Loop Antenna

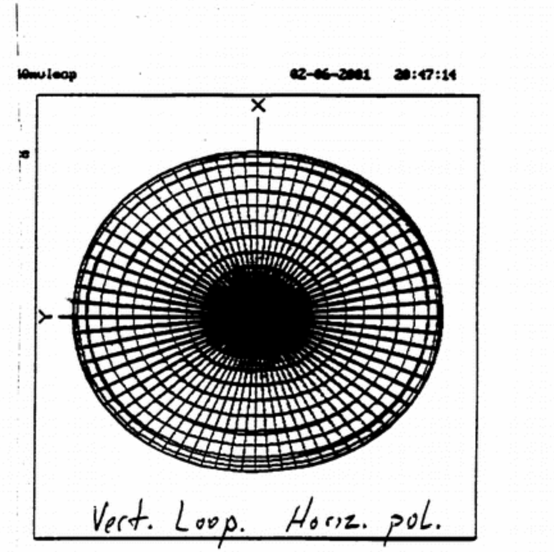
-relatively quiet (low QRN)
-good for all frequencies above resonance
-good radiation pattern on higher bands
-requires multiple supports and room



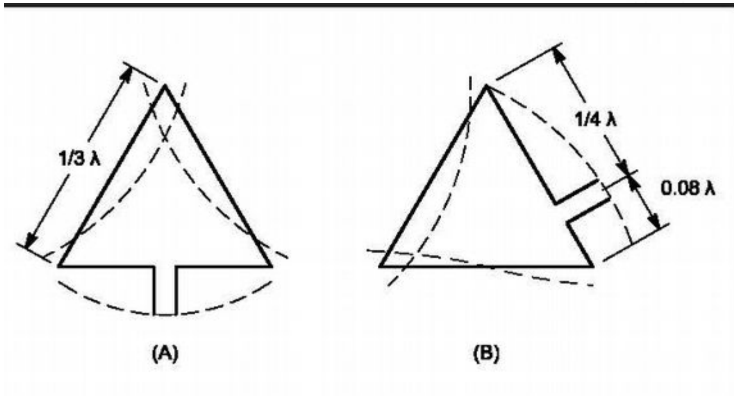
My Loop
-3-sided (Delta), fed at corner
-height =52'
-circumference =486'
-good from 160m-10m
-high power balun+tuner
-450-ohm balanced line
-even good for LF RX
-low-angle radiation patterns above 40m

EZNEC patterns for vertical Delta loop fed at two different points

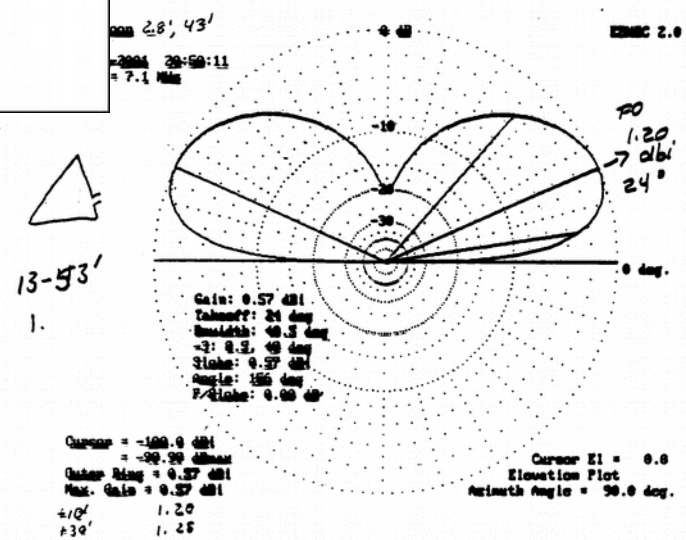


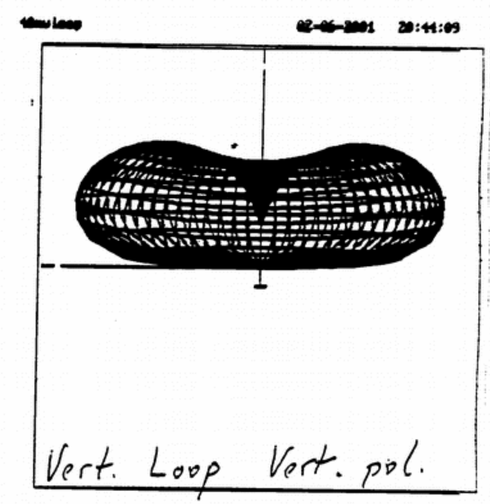


Middle bottom fed=>

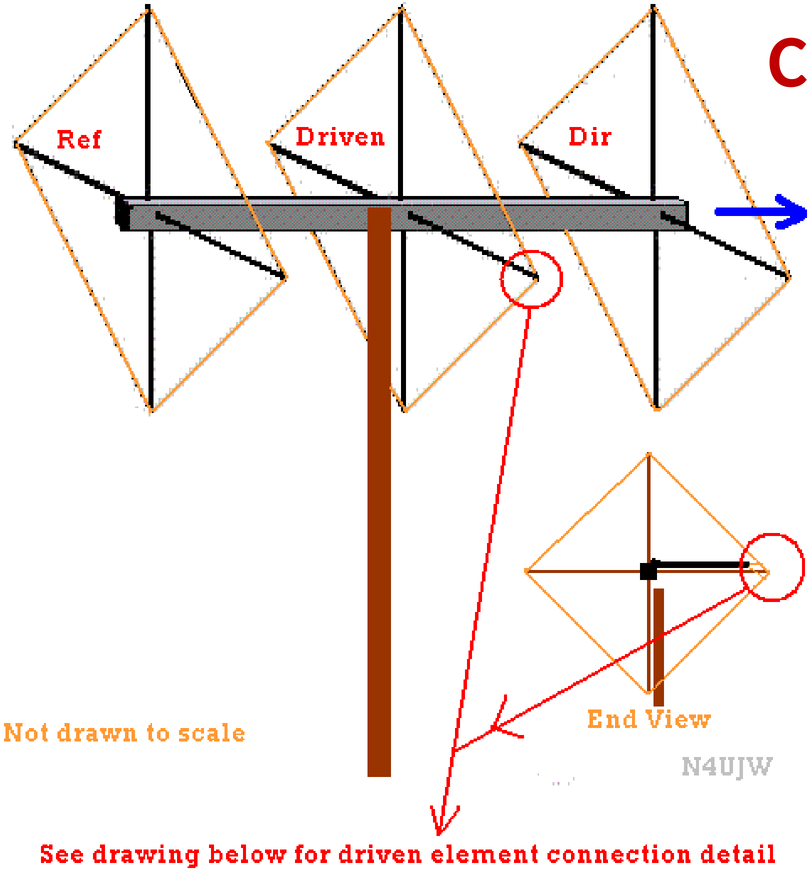


1/4λ down side fed=>





Cubical Quad Directive Antenna



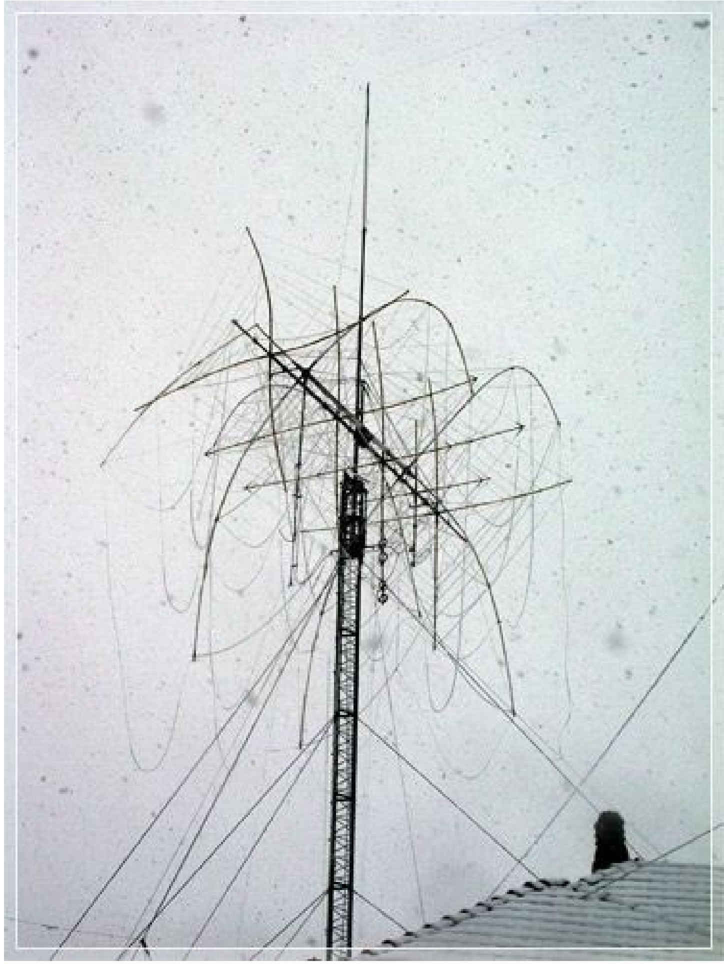
- Based on 1 wavelength loop
- Quiet
- Directive
- Easily multi-banded

20 m 3-element quad

The cubical quad…not great in wind + ice!

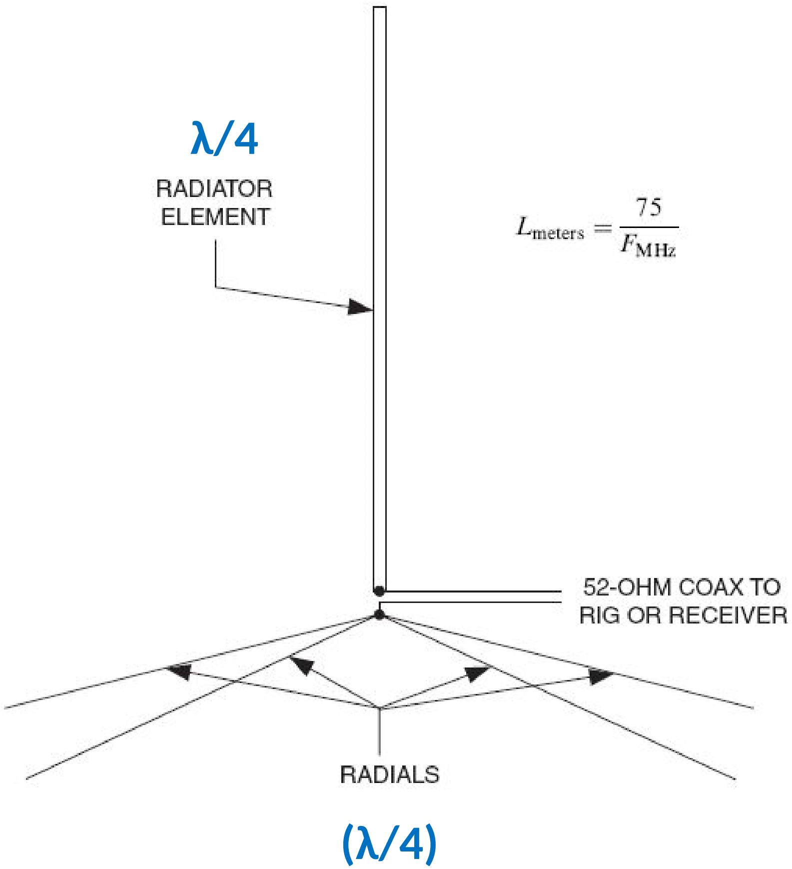
RR6310/A

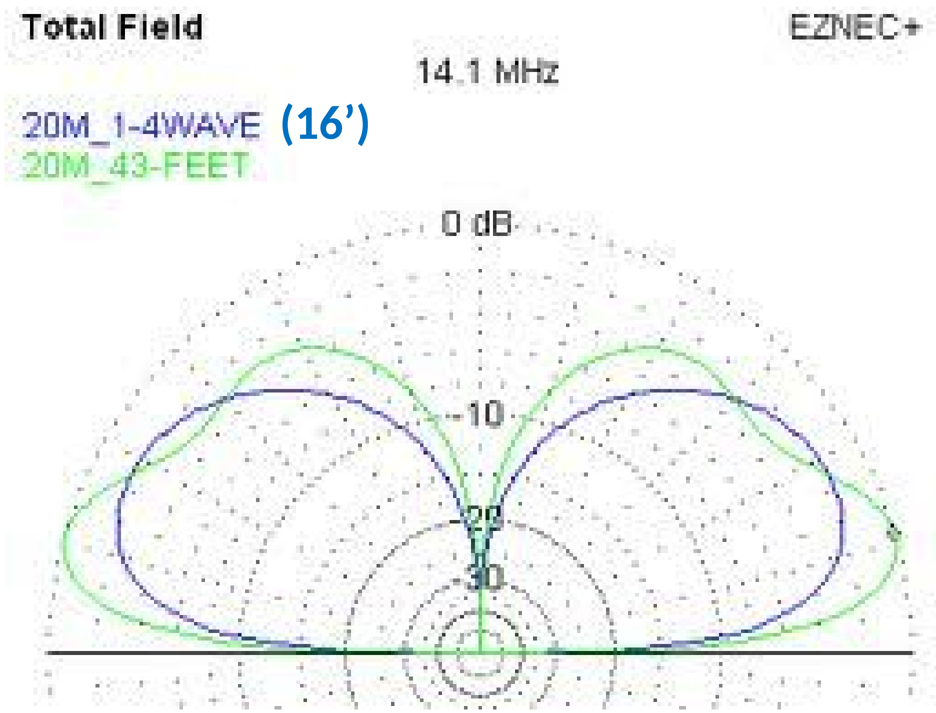
RR6310/B



Stacked yagis after an ice storm

Vertical Antennas





- -single band, omnidirectional
- -low takeoff angle (good for DX!)
- -noisy (low angle pickup acquires atmospheric noise well)
- -radials needed to reduce ground resistance (Z about 34Ω)
- -good ground essential for efficiency

Multiband HF vertical (40-10 m)

-counterpoises replace real ground for lower quarter wave of antenna

-compatible with very small lots

-efficiency??

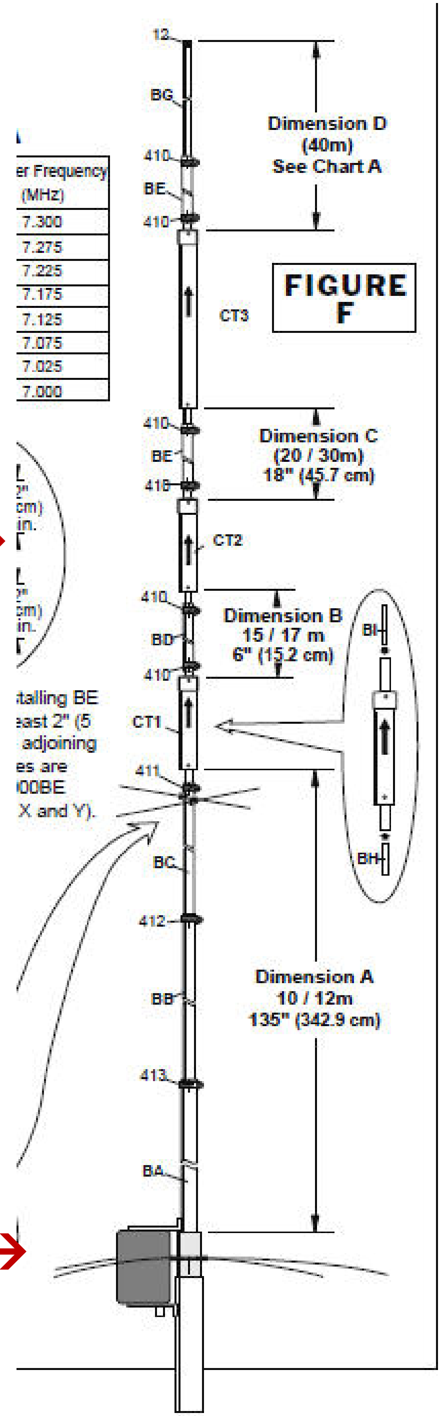
Trap →

Trap →

Trap →

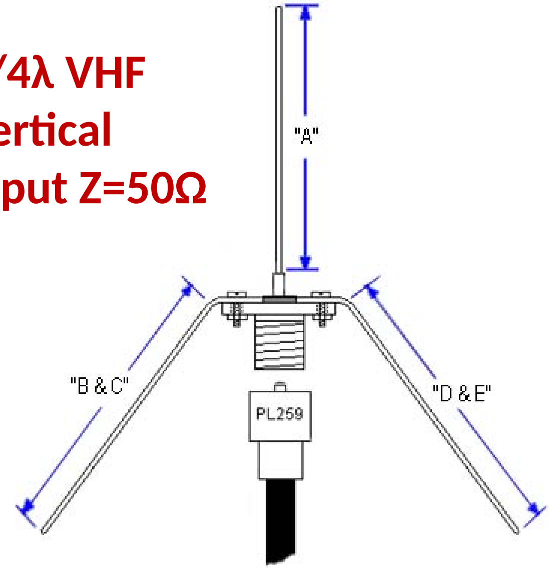
Second counterpoise →

Feedpoint, counterpoise, and matching network →



“Rubber Duck” loaded VHF verticals

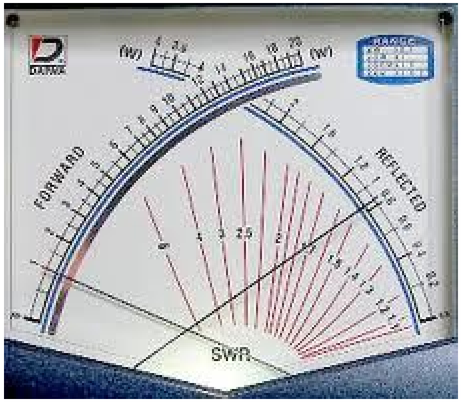
1/4λ VHF Vertical Input Z=50Ω



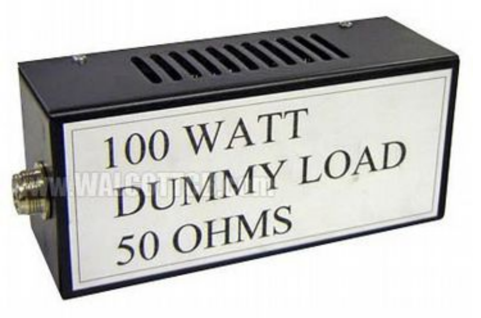
“Mag mount” Vehicle VHF vertical

“J-pole” 5/8λ VHF vertical

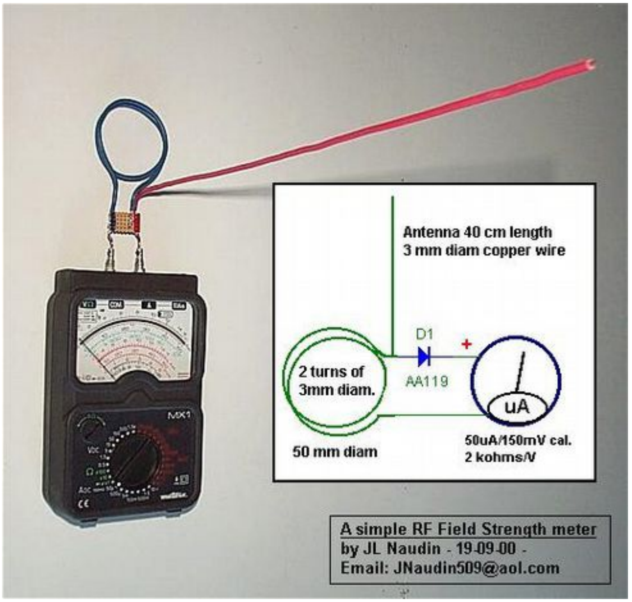
Antenna-Related Equipment



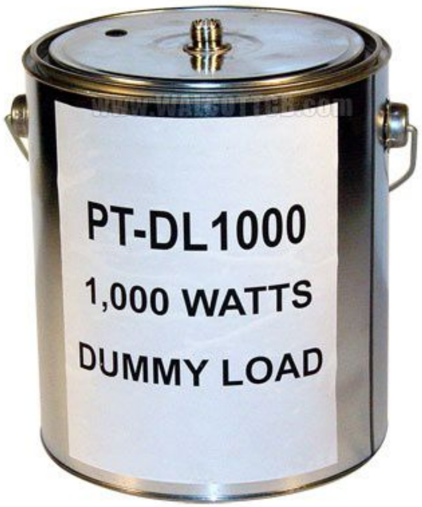
RF Power :SWR meter



Antenna/SWR analyzer



Field-strength meter



Artificial antenna
or dummy load
(pure resistance)

Antenna Safety

Climbing towers, trees, roofs

- -safety belt, harness for towers
  - -safe equipment (quality ropes, ladders, etc)
- -at least two people!
- -training for tower climbing
- -experience for tower put-up, tear-down
- -quality tower components

Electric shock

-lightning protection for high masts, towers, aerials (good grounding, safety antenna disconnect)

AVOID POWER LINES! No wire or metallic antenna parts above, below, or near commercial power lines

Non-ionizing radiation (RF fields):

- -unclear whether any real risk to humans, but should set up station to minimize RF near radio
- -also tends to minimize interference on radio

Antenna installation/erection

-what do you want your antenna(s) to do??

-modeling/calculating/measuring/ planning

-if new, discuss with more experienced hams

-locate, assemble components

-get assistant(s)

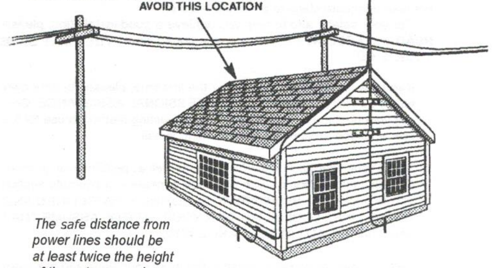
-do it!- following appropriate safety guidelines

SITE SELECTION

Before attempting to install your antenna, think where you can best place your antenna for **safety** and performance.

To determine a safe distance from wires, power lines and trees:
1. Measure the height of your antenna.
2. Add this length to the length of your tower or mast, and then
3. Double this total for the minimum recommended safe distance.

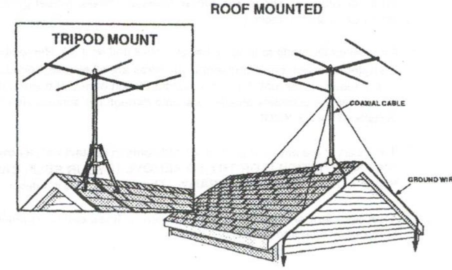
If you are unable to maintain this safe distance, STOP! GET PROFESSIONAL HELP. Many antennas are supported by pipe masts attached to the chimney, roof or side of the house. Generally, the higher the antenna is above the ground, the better it performs. Good practice is to install your antenna about 5 to 10 feet above the roof line and away from power lines and obstructions. Remember that FCC limits your antenna height to 60 feet. If possible, find a mounting place directly above your set, where the antenna wire can take a short, vertical drop on the outside of the house for entry through a wall or window near the set. Your dealer carries a complete line of installation hardware.



The safe distance from power lines should be at least twice the height of the antenna and mast combined.

CHOOSE A PROPER SUPPORT AND MOUNTING METHOD

However you decide to mount and support your antenna always make sure that safety is your first concern. Some of the more common installation methods are illustrated below.



ROOF MOUNTING

The swivel feature of "universal" type mounting brackets makes a convenient antenna mount for flat or peaked roofs. One clamp type bracket is used with 3 or 4 guy wires equally spaced around the mast and anchored to the roof or eaves by eyebolts. Apply roofing compound around the base of the bracket, screws and eyebolts for moisture sealing.

TELESCOPING MAST

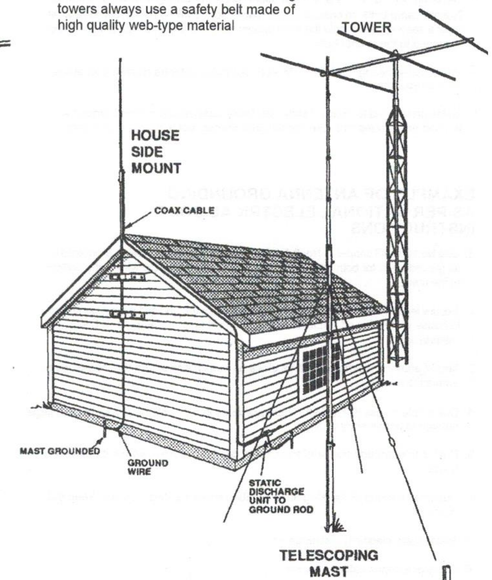
Guy wires should be equally spaced in at least three directions. Use at least three guy wires for each 10 foot section of mast.

SIDE OF HOUSE MOUNTING

The safe distance from power lines is at least twice the height of antenna and mast combined. Where roof overhang is not excessive, the side of the house provides a convenient mounting. Position the brackets over a stud if possible, one above the other, and space two or three feet apart. For metal siding, first mark mounting holes, then drill pilot holes through the siding to accept mounting screws.

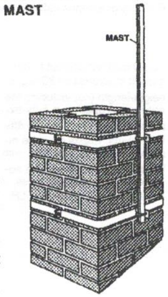
TOWER

Tower safety is paramount to a good installation and requires that you take location, tree growth, soil depth and proximity to buildings into consideration. Tower foundations must be securely based on a solid concrete/ tower mounting plate. An alternative is to sink a 4-6 foot section of tower into a concrete base for an extremely rugged mount. Proper guying is essential to a safe weather-resistant installation that must handle severe wind loading and is best accomplished with preformed guy grips, torque brackets and turnbuckles. When working on towers always use a safety belt made of high quality web-type material



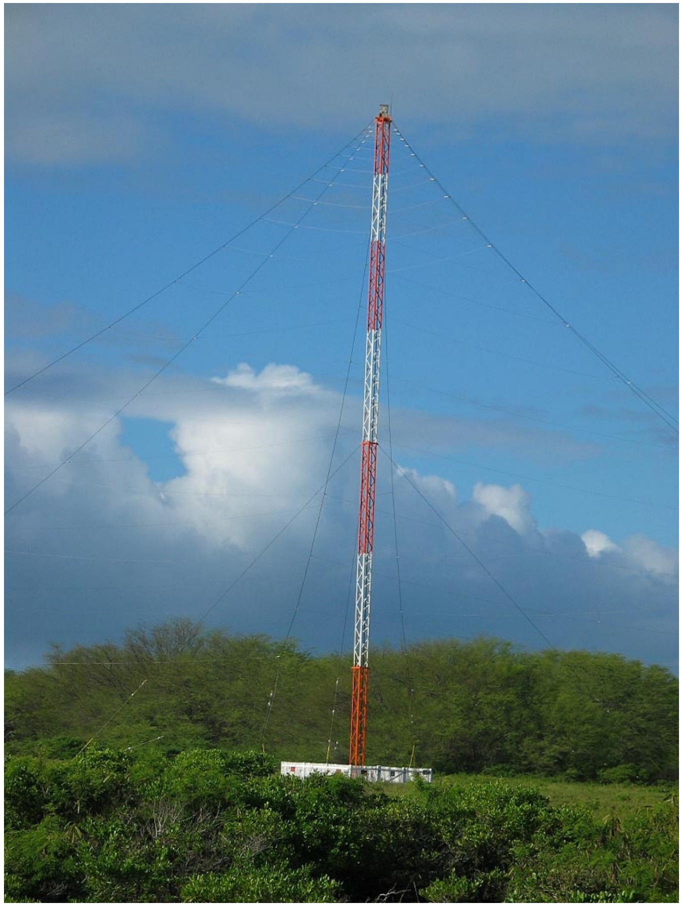
CHIMNEY MOUNTING

The chimney is often an easy and convenient mounting place. But the chimney must be strong enough to support the antenna in high winds. Do not use a chimney that has loose bricks or mortar. A good chimney mount makes use of a 5 or 10 foot, 1-114" diameter steel mast, and a heavy duty two strap clamp-type bracket. Install the upper bracket just below the top course of bricks, and the lower bracket two or three feet below the upper bracket. For maximum strength, space the brackets as far apart as possible.



END

Of Transmission Lines and Antennas



Questions??

Quick Antenna Review

Antennas: Convert AC currents in conductor into electromagnetic radiation with 2 fields (electrostatic and electromagnetic) at right angles to each other.

Q.: EM radiation speed?

Q.: What is an isotropic radiator (antenna)? What is it used for?

Q.: Relationship between RF current (I) and radiated signal? RF voltage (E) and radiated signal?

Resonant antennas: mostly based on half-wave dipole or full-wave loop
Advantages? Disadvantages?

Q.: Relationship of X_C to X_L at resonance??

Q.: Why feed a half-wave dipole in the middle?

Non-resonant antennas: Advantages? Disadvantages?