April 2019 Training – To all the Antennas I've loved before

Antenna Concepts for the Amateur Radio Operator

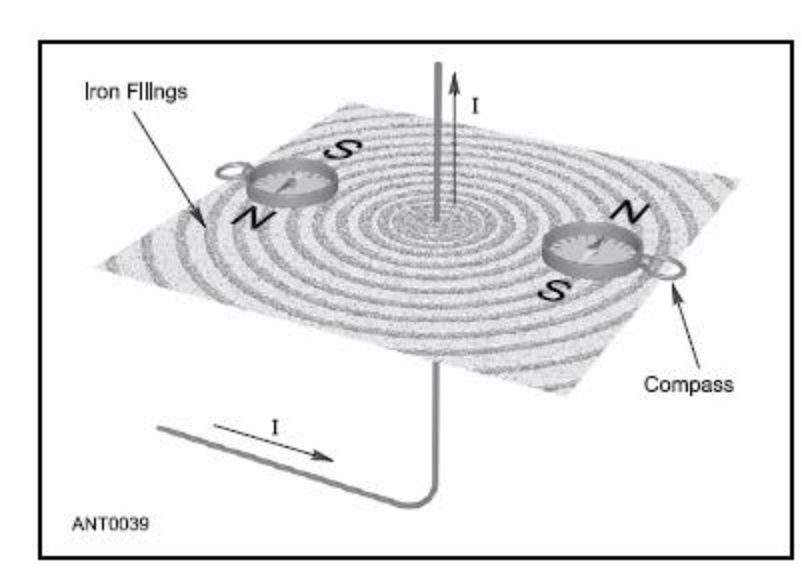
Antenna System Design and Construction

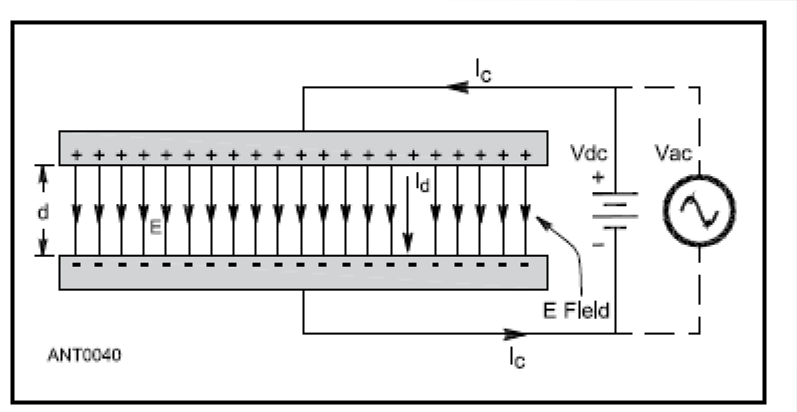
- Design Notes
- Installation Notes
- Field Antennas for HF

VA3PC

ElectroMagnetic Radiation

- 2 Components, an electric field and a magnetic field



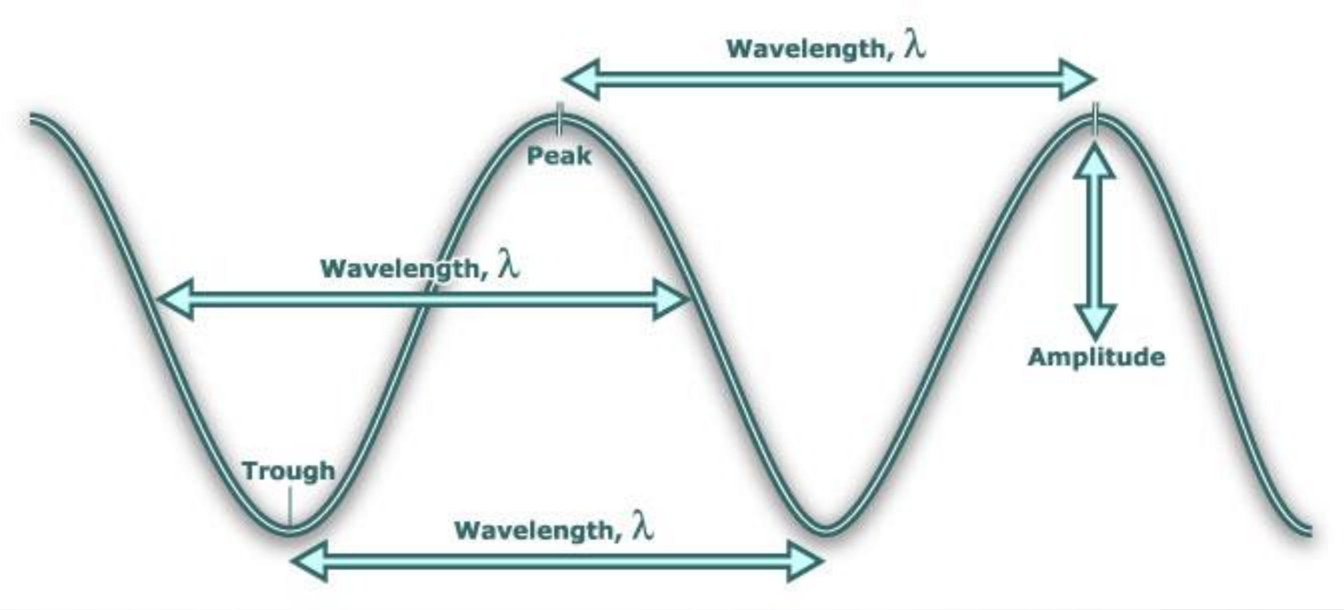


Velocity of Propagation

- 300 m/µs

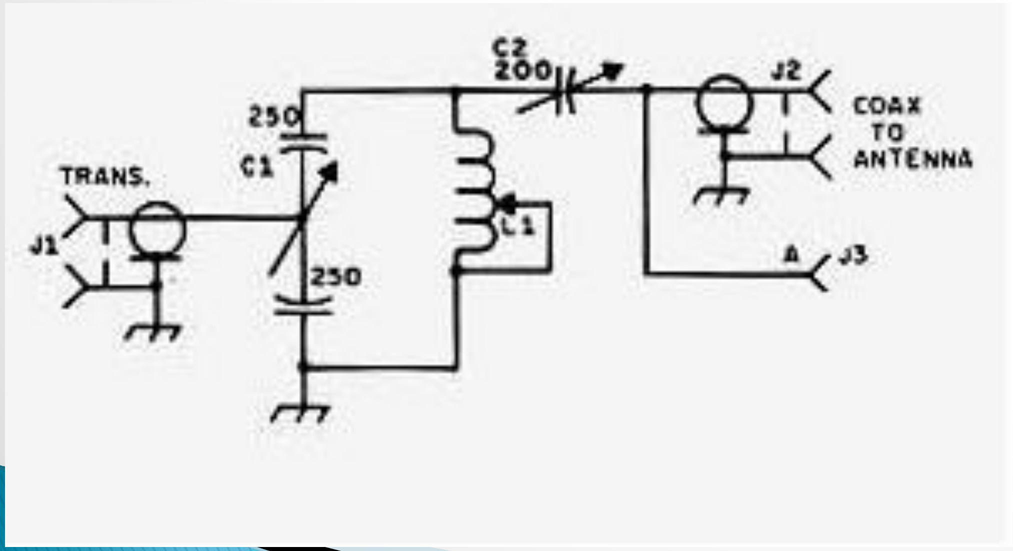
  Knowing the frequency we want to operate on, we can describe the length of the radio wave

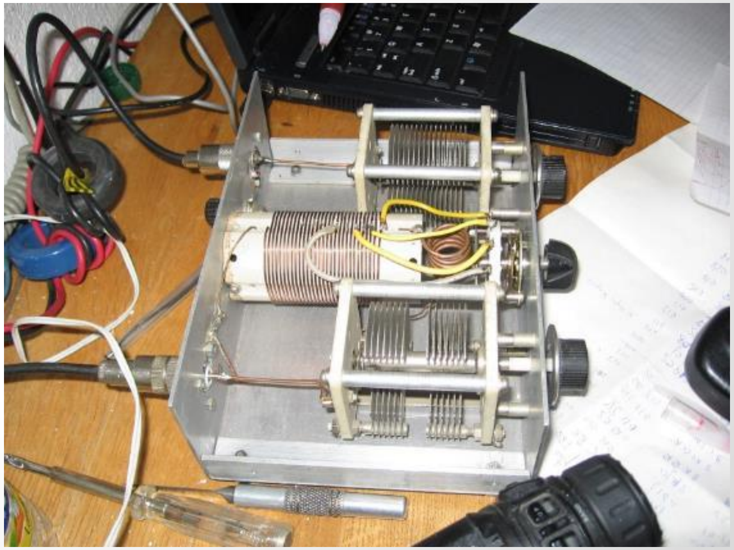
Velocity Factor And Dielectric Constant



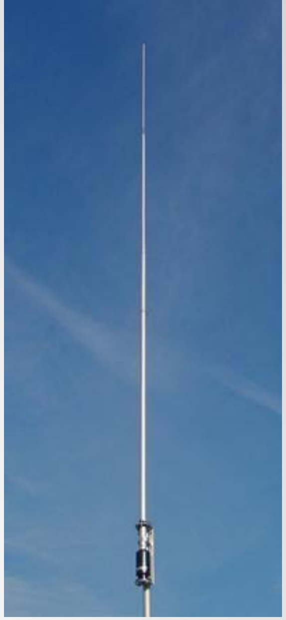
Concept of an Antenna System

- Impedance Matching
- Feedline
- Antenna





1:1 VSWR?



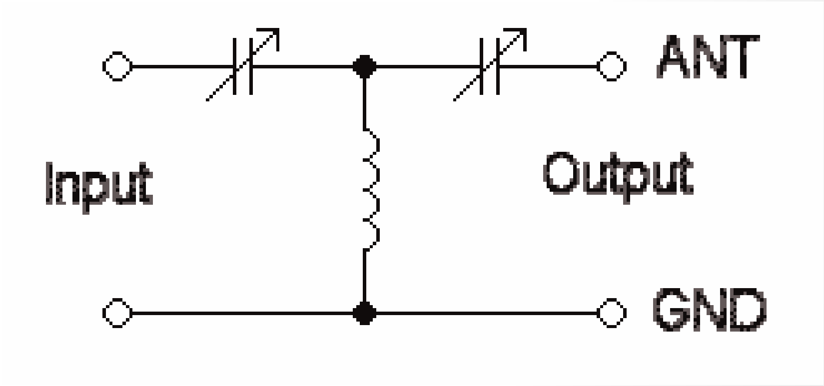
- Your dummy load is 50Ω+j0
  - 1:1 match !!!
  - A 50 ohm resistor is a crappy antenna
- Your non-resonant vertical with base matching xfrmr at base loads up on all bands!
  - And it's turning all your power into heat in the toroid
- Your ¼ wave vertical traverses the whole band without tuning!
  - Resistive losses 'cause you have insufficient radials

Impedance Matching

- Antenna tuners at the transceiver will match the impedance at that point.
- Any impedance mismatch or change will create a standing wave…but…
  - The energy will leave the system
  - Some will be lost as heat (line loss)
  - Some will be lost in if your antenna design is bad (resistive element of feedpoint impedance)
  - Some will be radiated as signal

Tuners

- Don’t push your tuner past the design limits, Plate voltages can be super high!
- Get impedance into the ballpark with a matching xfrmr



Feedline and Losses

- Losses on a transmission line are characterized by the current lost due to resistance.

- If we want to deliver the same power , but make sure I is minimized, what can we do?

Ohm's Law

$E = IR \qquad I = \frac{E}{R} \qquad R = \frac{E}{I}$

Joule's Law

$P = IE \qquad P = \frac{E^2}{R} \qquad P = I^2R$

Where,

$E =$ Voltage in volts
$I =$ Current in amperes (amps)
$R =$ Resistance in ohms
$P =$ Power in watts

Feedline and Losses

Feedline efficiency is important

- In UHF all the time
- At HF if the SWR is high

(* = approx)	With an SWR of 1:1 at antenna Losses in dB per 100 metres at various frequencies					
Cable Type:	**3.5 MHz**	**10 MHz**	**30 MHz**	**50 MHz**	**144 MHz**	**432 MHz**
RG174 *	5	10	15	21	33	59
RG58	**2.5**	**4.3**	**7.7**	**10**	**17**	**32**
RG8 Mini / RG8-X	**1.7**	**2.9**	**5.4**	**7.1**	**13.2**	**26.5**
RG8	**1.06**	**1.8**	**3.2**	**4.2**	**7.6**	**9.1**
RG213	**1.1**	**2.0**	**3.5**	**4.7**	**8.4**	**15**
Ecoflex 10		**1.2**		**2.8**	**4.9**	**8.9**
Westflex 103	**0.6**	**0.9**	**1.7**	**2.7**	**4.5**	**7.5**
450 Ohm Twin	**0.17**	**0.29**	**0.51**	**0.67**		

	With an SWR of 3:1 at the antenna Losses in dB per 100 metres at various frequencies					
Cable Type:	**3.5 MHz**	**10 MHz**	**30 MHz**	**50 MHz**	**144 MHz**	**432 MHz**
RG58	**3.4**	**5.5**	**8.9**	**11.3**	**19.1**	**34.3**
RG8 Mini / RG8-X	**2.4**	**3.9**	**6.6**	**8.4**	**14.5**	**27.7**
RG8	**1.6**	**2.6**	**4.2**	**5.4**	**8.8**	**15.7**
RG213	**1.7**	**2.8**	**4.6**	**5.8**	**9.7**	**17**
Ecoflex 10	!	!	!	!	!	!
Westflex 103*	1	1.5	2.5	3	5	9
450 Ohm Twin	**0.28**	**0.47**	**0.8**	**1.03**		

Acceptable SWR and You

- If the line loss is low and the transmitter is happy (impedance matched at transmitter finals), then all of the power possible will be transmitted to the system (loss in transmatch negligible)

SWR at Antenna	Additional dB Cable Loss Due to SWR	S Unit Signal Loss Due to SWR	Calculated Voltage at 100 watts (50 ohms)	SWR at Tuner
1:1	-	-	70.7	1:1
2:1	0.06	0.01	100.0	1.9:1
3:1	0.15	0.03	122.5	2.7:1
4:1	0.26	0.04	141.4	3.6:1
5:1	0.36	0.06	158.1	4.3:1
6:1	0.47	0.08	173.2	5.1:1
7:1	0.57	0.09	187.1	5.8:1
8:1	0.67	0.11	200.0	6.5:1
9:1	0.77	0.13	212.1	7.1:1
10:1	0.86	0.14	223.6	7.7:1
11:1	0.96	0.16	234.5	8.3:1
12:1	1.05	0.18	244.9	8.9:1
13:1	1.14	0.19	255.0	9.4:1

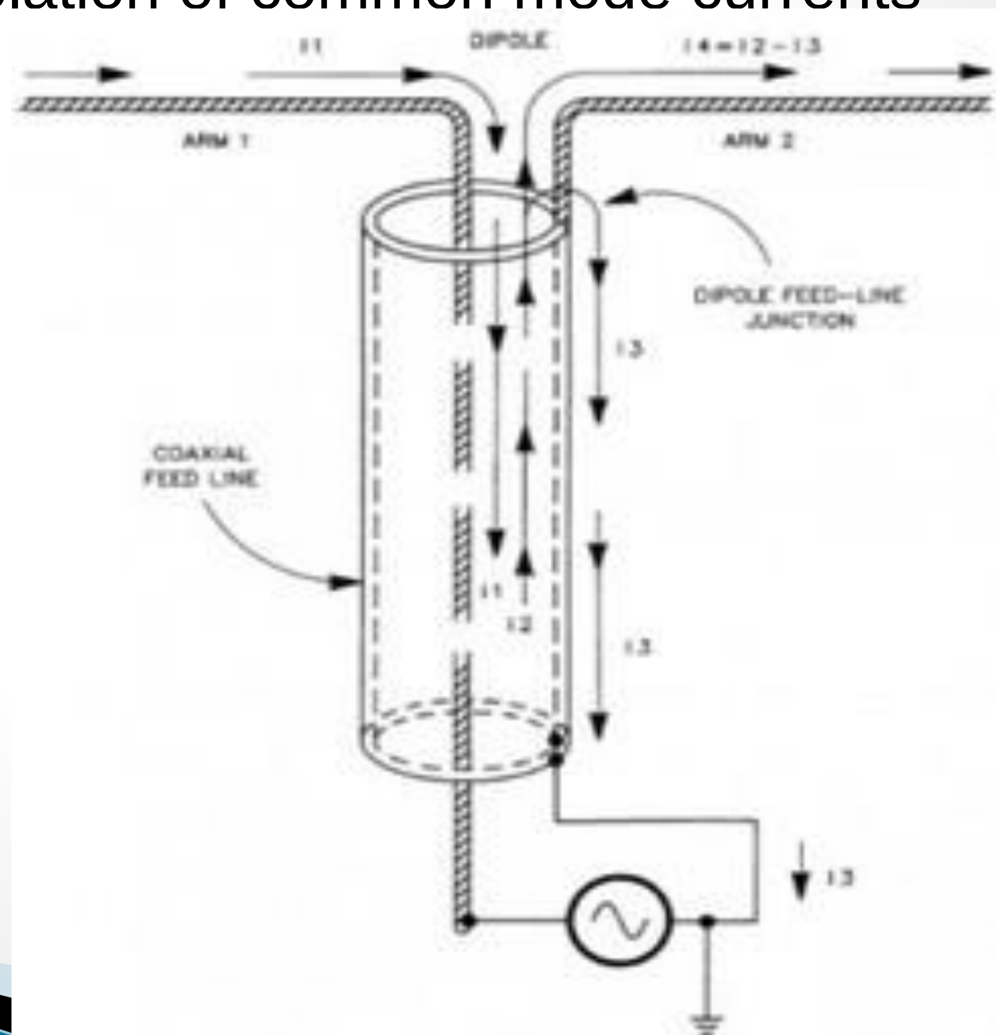
.25dB loss cable (DJ0IQ W9IQ)

A note on capacitive coupling

- Placing your antenna near something will change the radiation pattern
  - This could unbalance the system
  - The potential exists for unwanted stray RF
- Will my balanced line radiate?
  - The spacing between conductors is very small when compared to wavelength
  - I traveling in opposite directs should effectively cancel the magnetic field in the 2
  - Do keep it away from conductors
    - 5 time width of feedline is more than enough

The Balun

- Impedance matching at the antenna feedpoint
- Isolation of common mode currents



Common Mode Choke

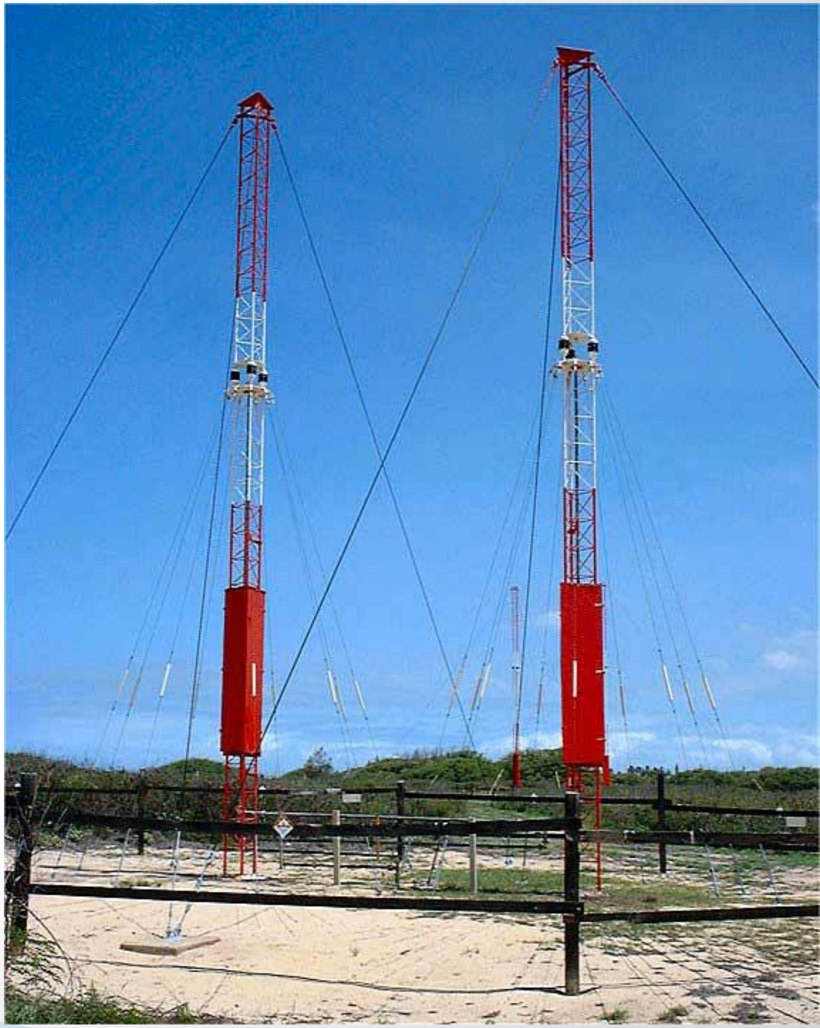
- If your Shack / System design is compromise, you may have RF on your feedline!
- Symptoms?

- Solutions? Potentially a common mode choke may be necessary
  - Coiled Coax
  - Spaced Coiled coax
  - Ferrite Beads
  - Coax Wound over Toroid
  - Coax Loops through Ferrite Cores
    - (http://www.dj0ip.de/rf-cmc-chokes-1/)

http://www.dj0ip.de/rf-cmc-chokes-1/

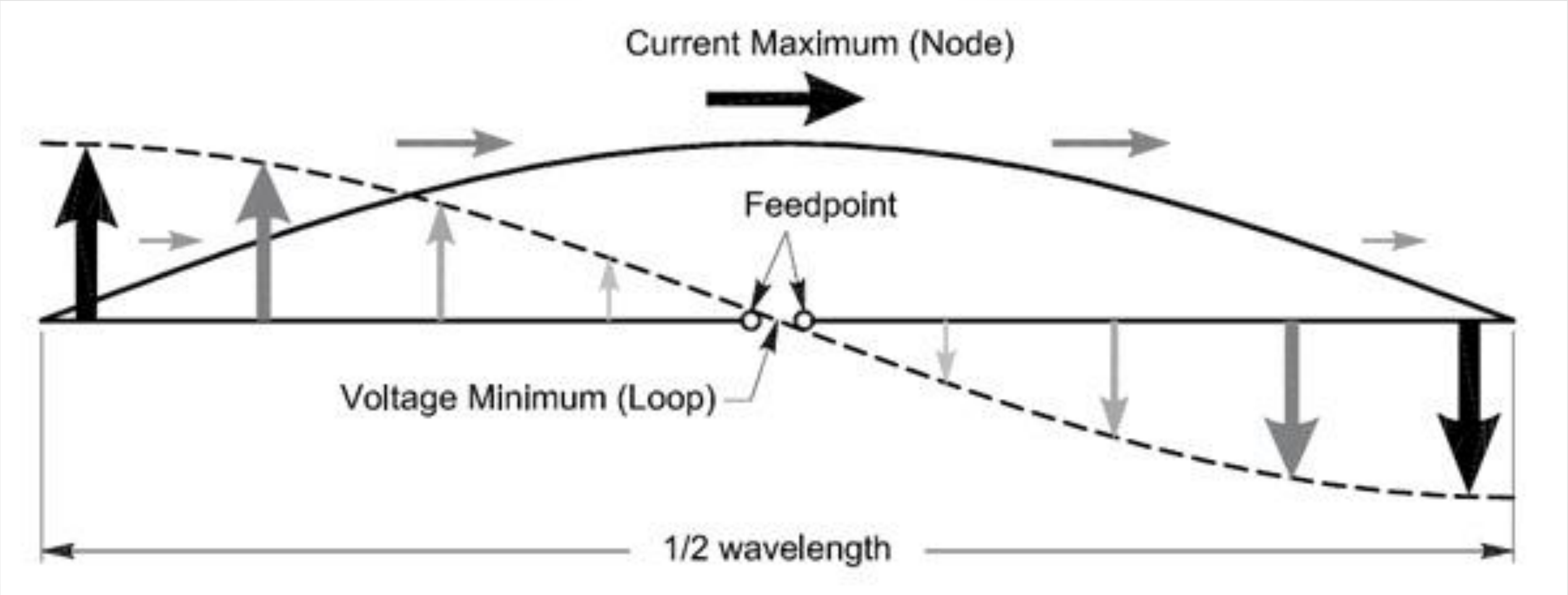
How do we describe our antenna?

- Impedance
- Directivity and Gain
- Polarization



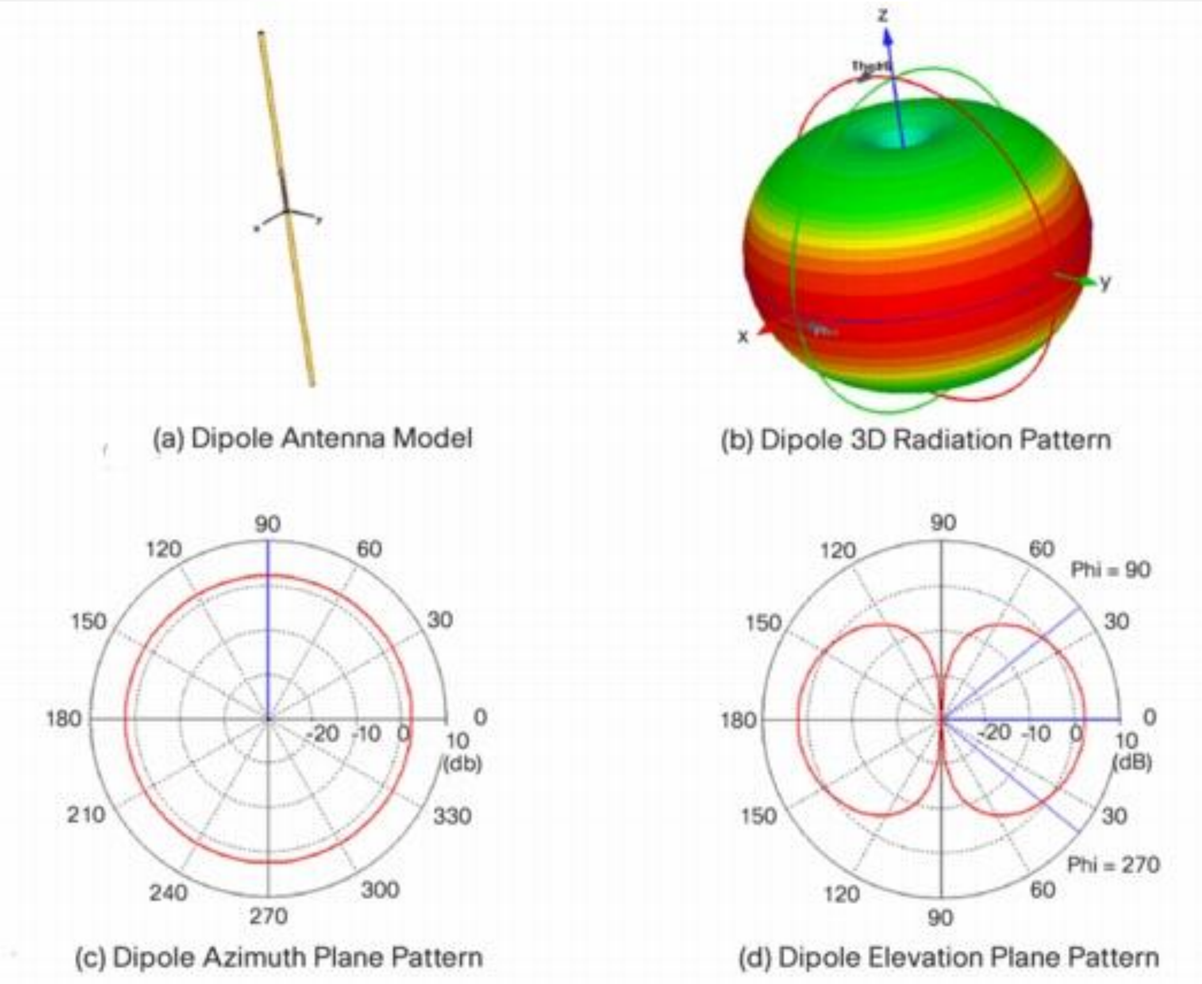
WWVH

Impedance



- Ohm’s law at the feed point (antenna’s self impedance)
- Radiation Resistance

Directivity and Gain



(a) Dipole Antenna Model

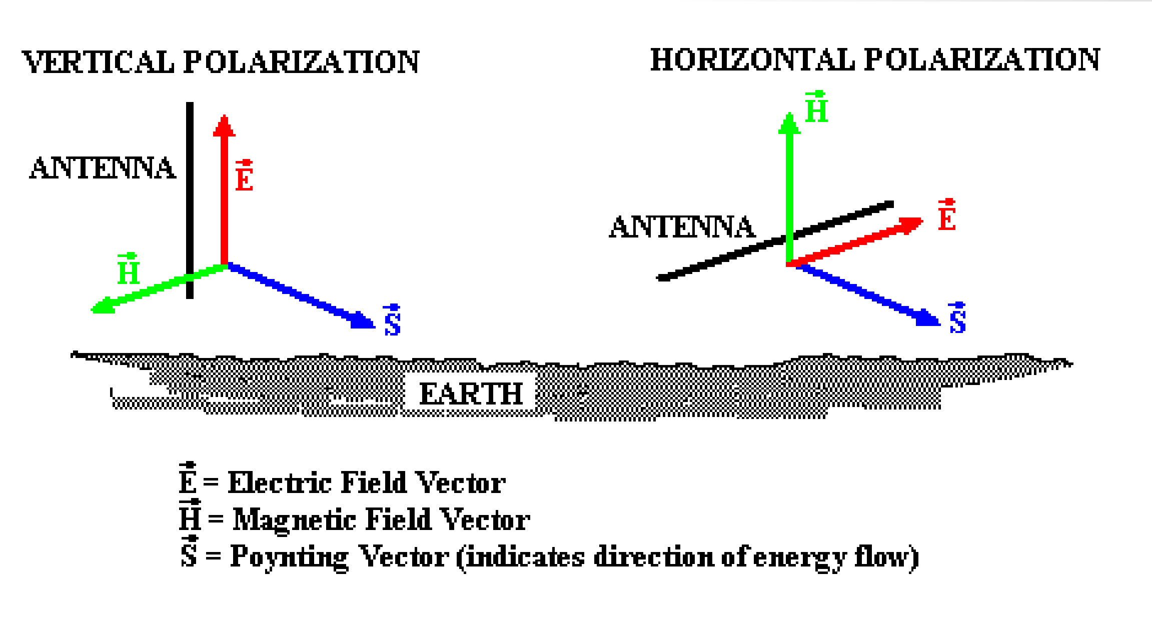
(b) Dipole 3D Radiation Pattern

(c) Dipole Azimuth Plane Pattern

(d) Dipole Elevation Plane Pattern

Radio Wave Polarization

- With <u>*horizontal*</u> polarization the electric lines of force of a radio wave are parallel to the Earth's surface. Horizontal antennas produce horizontal polarization.
- With <u>*vertical*</u> polarization the electric lines of force of a radio wave are perpendicular to the Earth's surface. Vertical antennas produce vertical polarization.

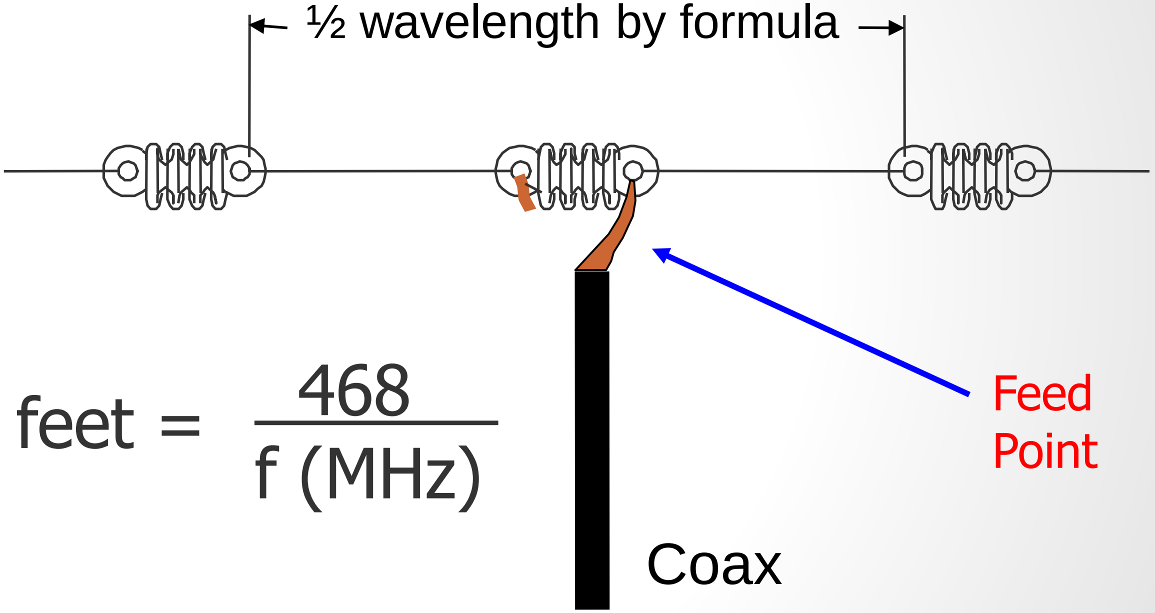


Installation Considerations

Who are you going to talk to?
If you can answer that, you can determine design,
Then solve the technical details ☺

-Antenna height (Line Of Sight, Takeoff Angle)
-Polarization (SSB? FM? SPACE???)
-Safety (Electrical, RF, Lightning)
-Feed line
-Balun and Impedance Matching
-Waterproofing

The 1/2 Wave Dipole



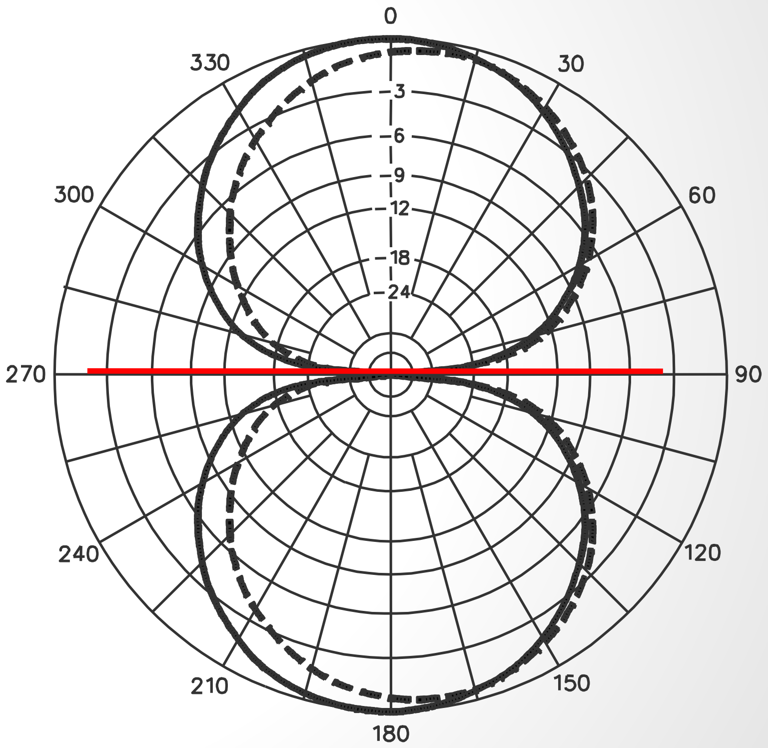
Length of dipole in feet = $\frac{468}{f\ (MHz)}$

The physical length of a dipole and other antennas can be reduced without changing its feed point impedance by adding a **loading coil**.

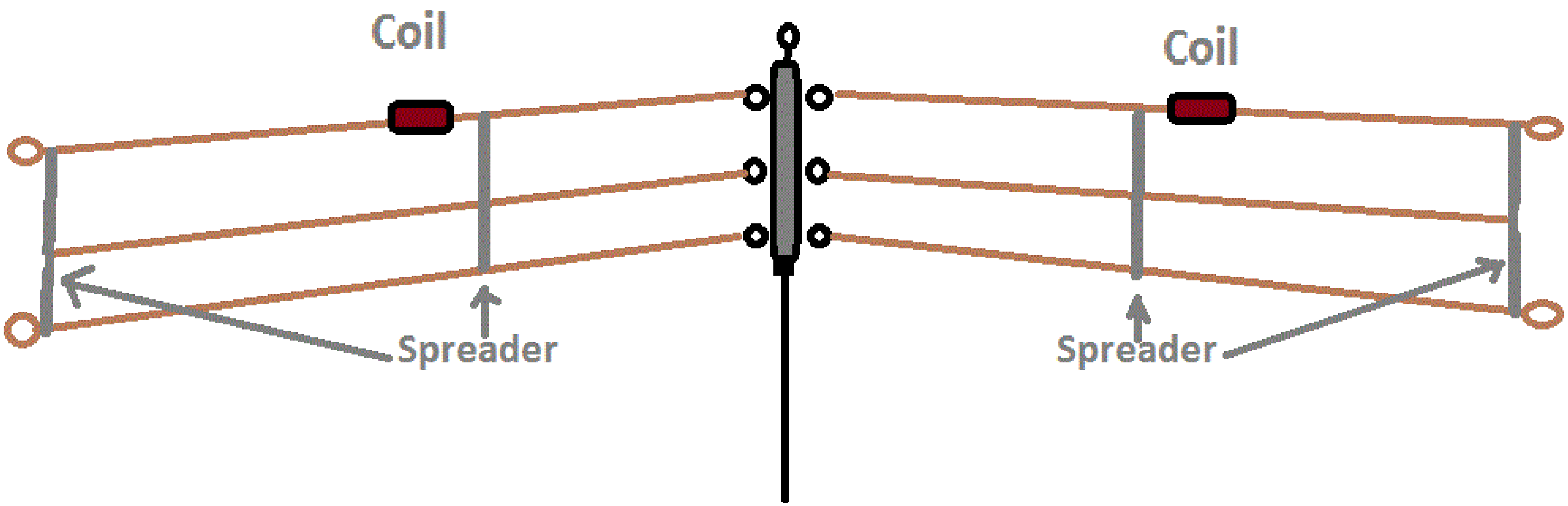
The 1/2 Wave Dipole

Radiation pattern for a dipole antenna looking down from above the antenna.

If the ends of a ½ wave dipole antenna point east and west most of the radio energy is radiated north and south.



Fan Dipole



Modified SRI FAN DIPOLE 80, 40, 20 METERS

All spreaders not shown

Not drawn to scale -- N4UJW

Figure from *ARRL Antenna Handbook, 22nd edition*

Dipole near ground

- Higher antenna gives lower **takeoff angle**, good for DX. Rule of thumb: at least a half-wavelength above ground.
- Lower antenna is more omnidirectional in azimuth, and good for "near vertical-incidence skywave" (**NVIS**).
- Low antenna also called a "cloudwarmer".

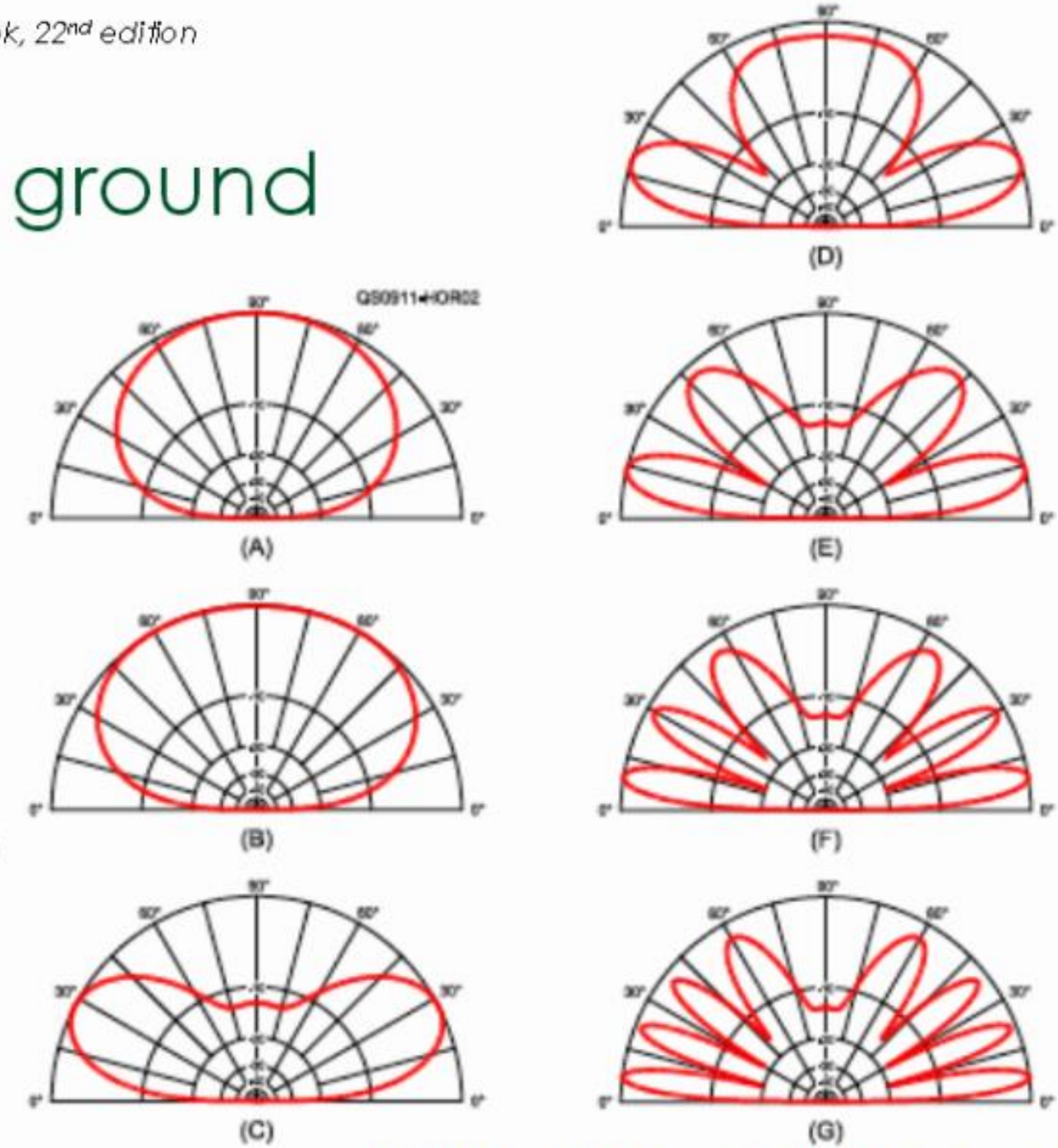
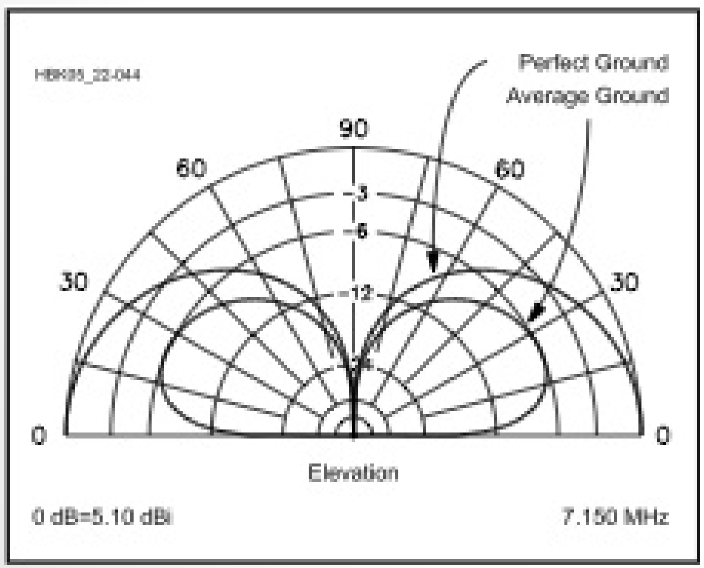
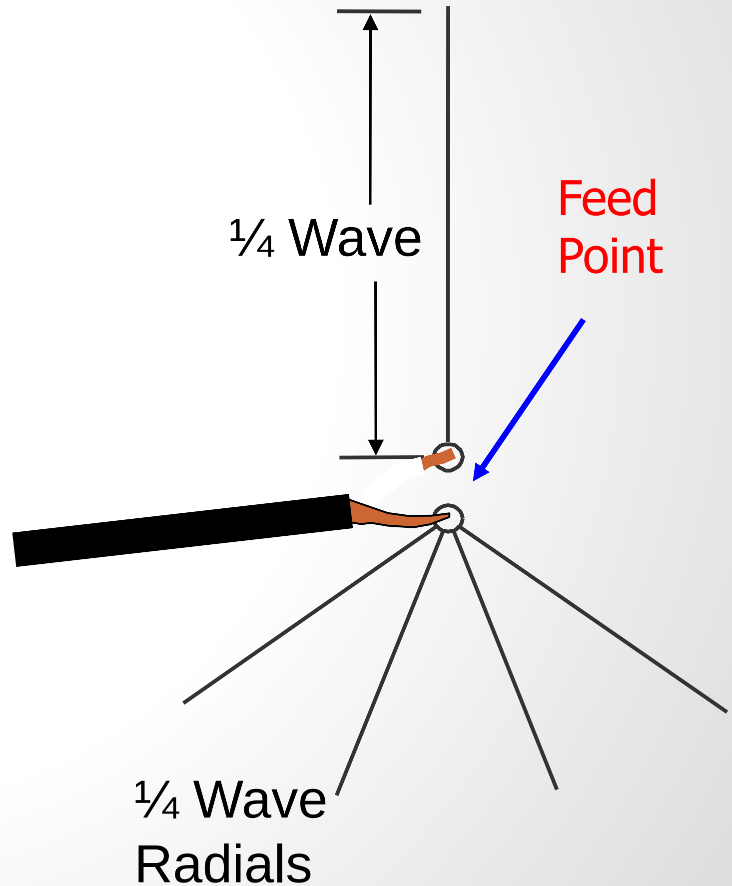


Figure 2.4 — Six radiation patterns for the dipole at different heights: (A) ⅛ λ, (B) ¼ λ, (C) ½ λ, (D) ¾ λ, E) 1 λ, (F) 1½ λ, (G) 2 λ.

The 1/4 Wave Vertical

$$\text{Length of vertical in feet} = \frac{234}{f\ (\text{MHz})}$$





Vertical Antenna Efficiency and Radials

How Many Radials? How Long?
Where is the current highest?

- At the antenna feedpoint in this case, so conduction paths near the feedpoint get us the most bang for the buck! – More Radials is good!
- Diminishing returns after 16 or so radials

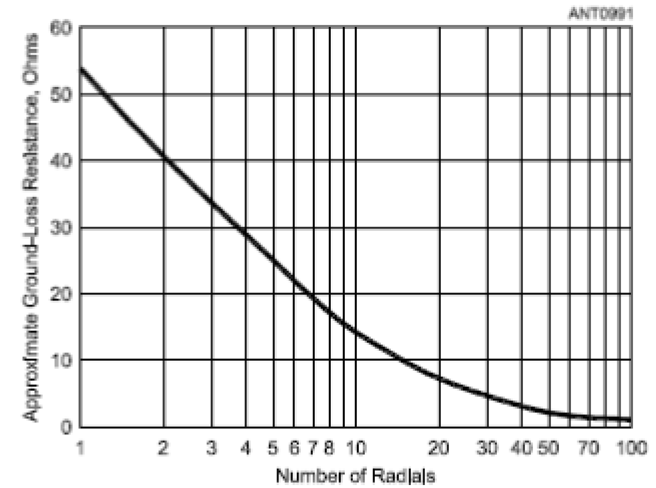


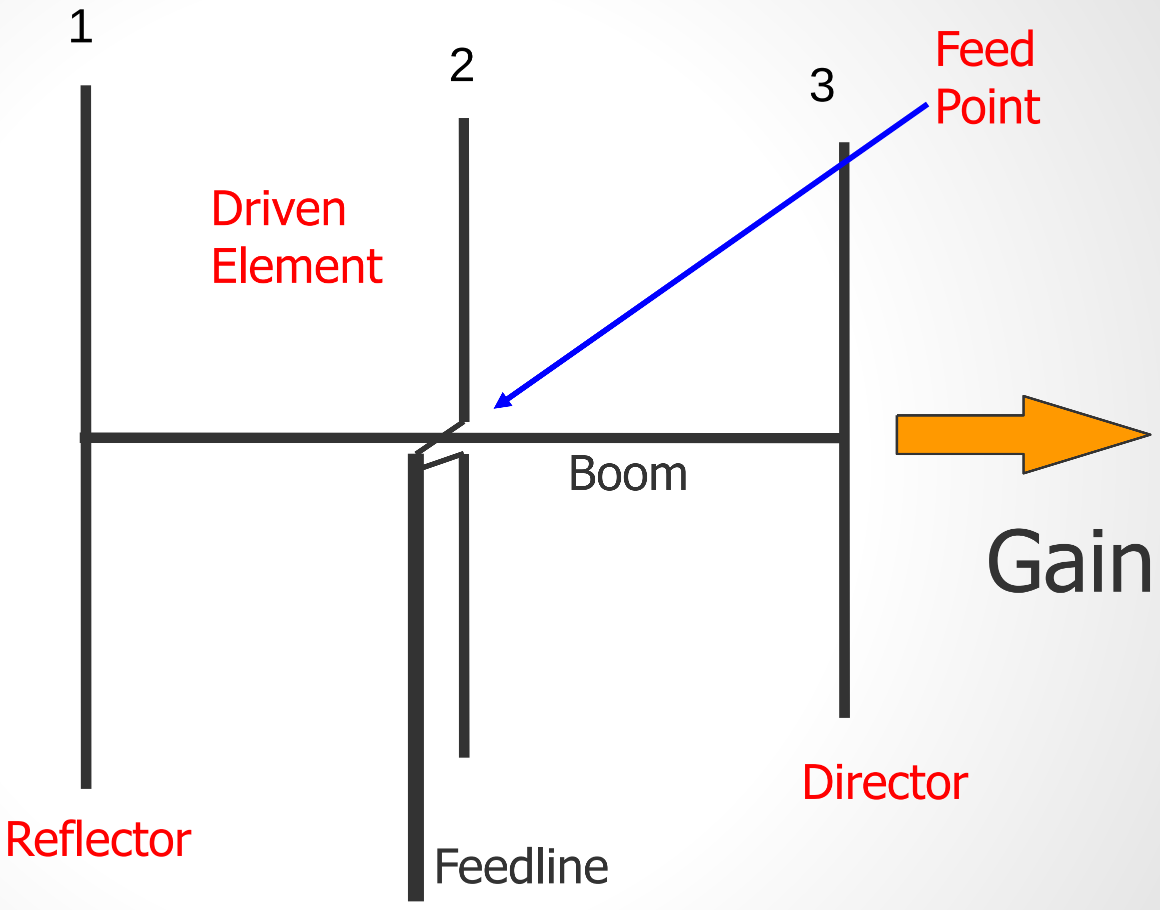
Fig 20—Approximate ground system loss resistance of a resonant λ/4 ground-mounted vertical element versus the number of radials, based on measurements by Jerry Sevick, W2FMI. Moderate length radials (0.2 to 0.4 λ) were used for the measurements. The exact resistance, especially for only a few radials, will depend on the nature of the soil under the antenna. Add 36 Ω for the approximate feed-point resistance of a thin resonant λ/4 vertical.

Number of Radials	*Loss Resistance, Ω*
4	29
8	18
16	9
Infinite	0

The ARRL Antenna Book, 21st edition, pg 8-23

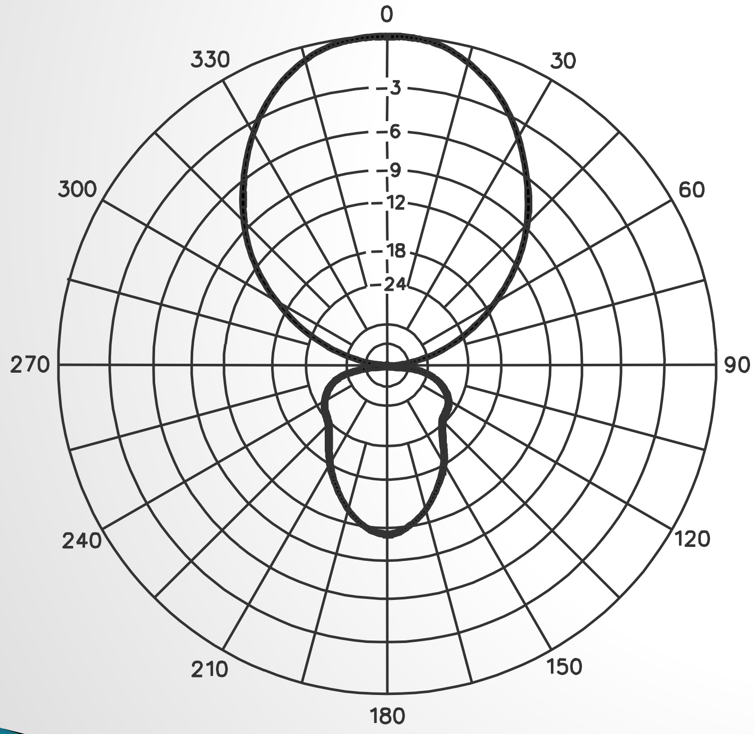
The Yagi

The Driven Element is approximately ½ wavelength long.



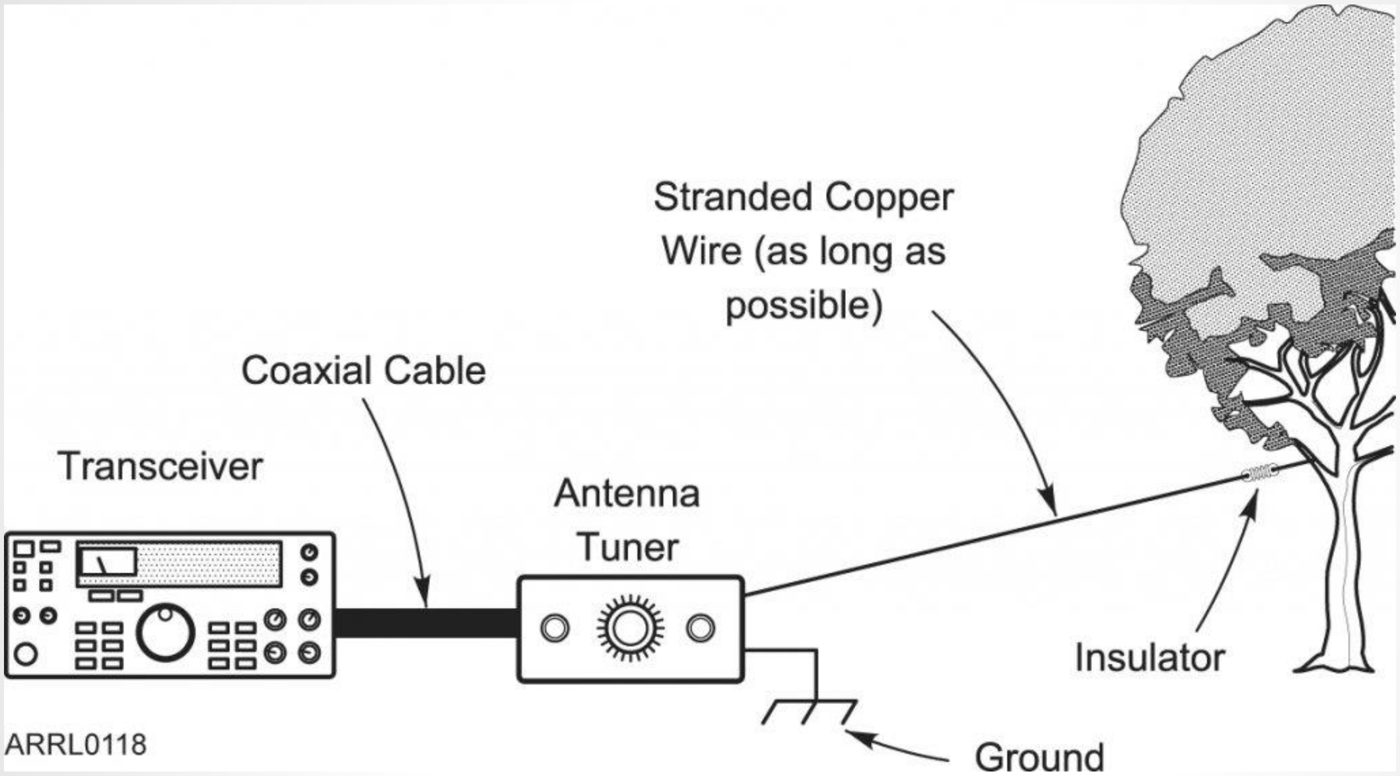
Coupled Impedance

The Yagi-Uda



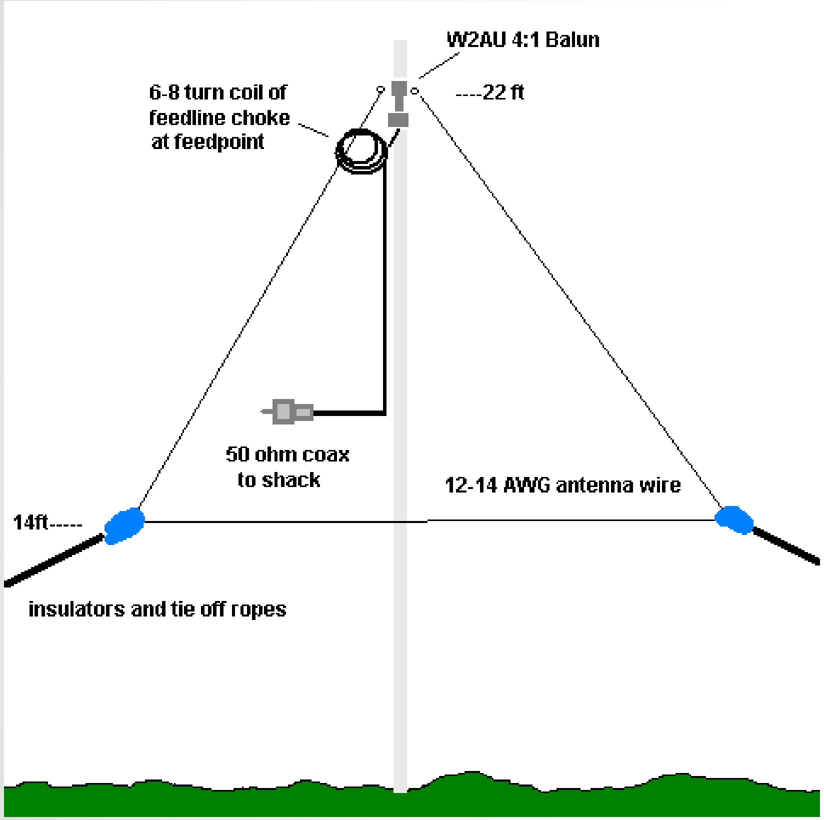
- The yagi antenna focuses RF energy in one direction
- This focus is called Antenna Gain.
- If an antenna has a gain of 3 dB the effective radiated power will <u>double</u>.

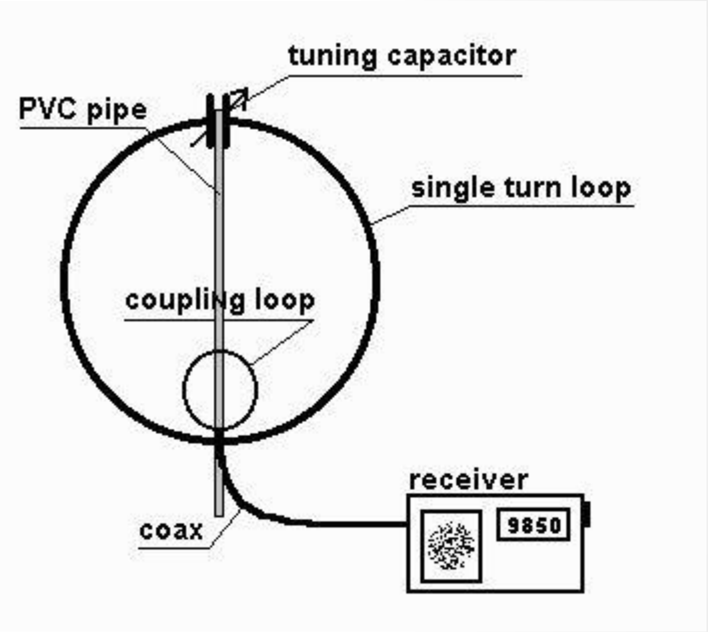
Random Wire



29 35.5 41 58 71 84 107 119 148 203 347 407 423

Loop

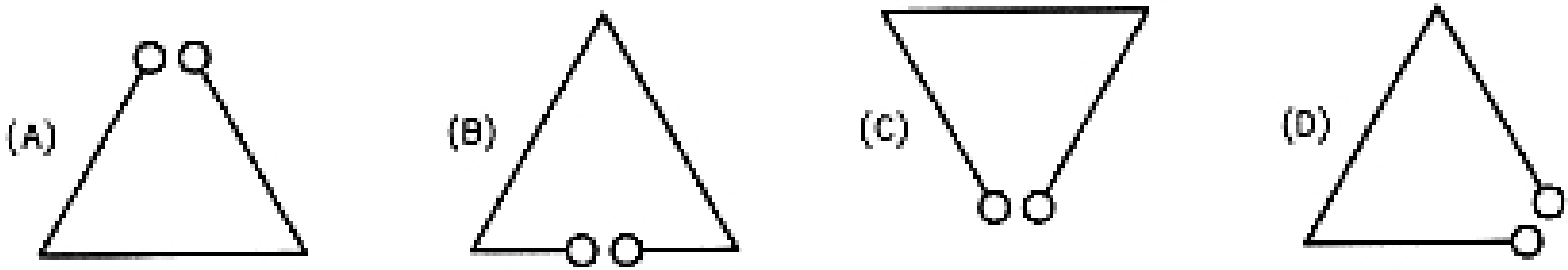




Full Size

Magnetic

Delta Loop



Apex Up
Apex Feed

Apex Up
Low - Side Feed

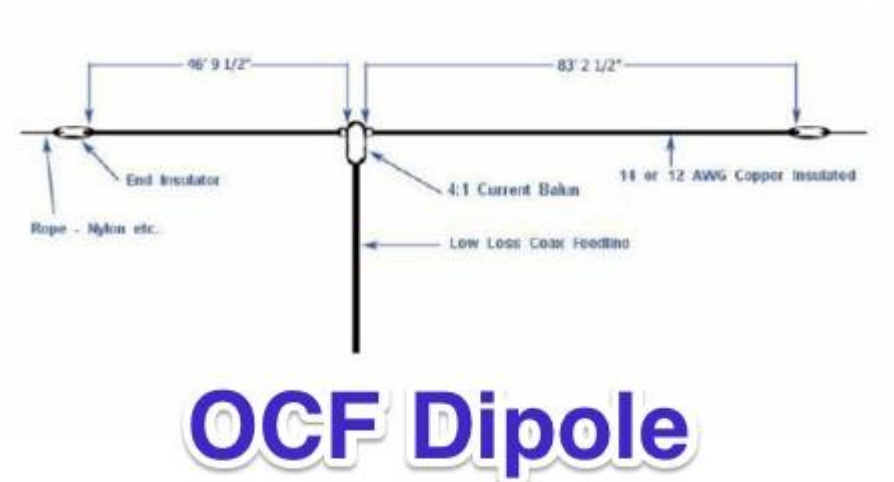
Apex Down
Apex Feed

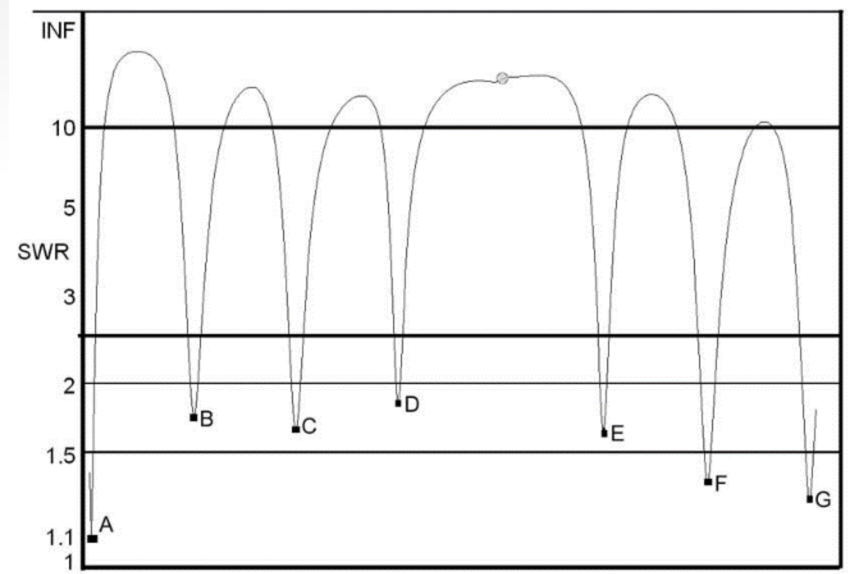
Apex Up
Corner Feed

	Polarization	Radiation Angle
A	Horizontal	Moderately High
B	Horizontal	High
C	Horizontal	Moderately High
D	Vertical	Low

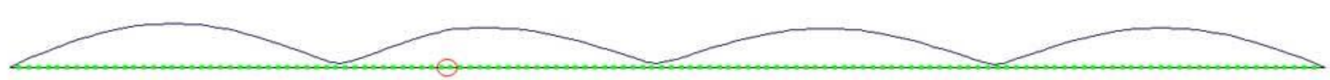
Feed Impedance ≈ 100 Ω

OCF Windom

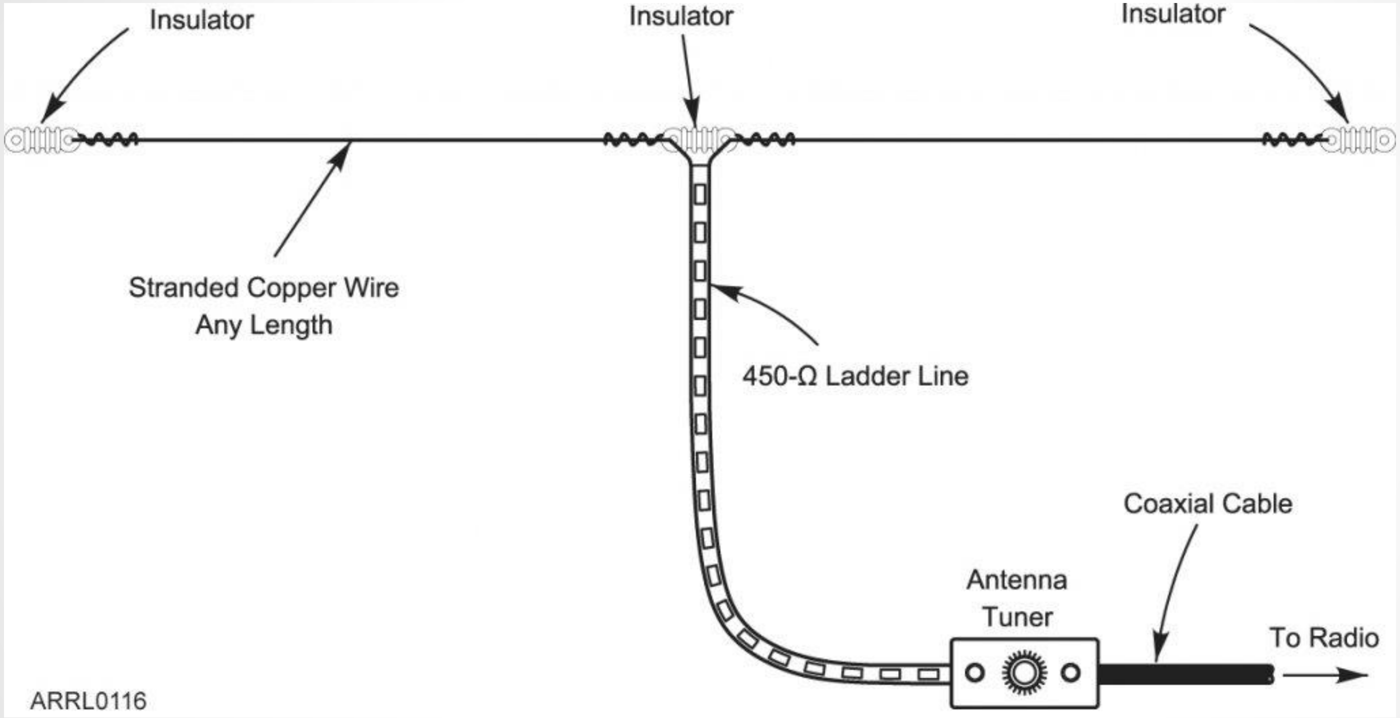




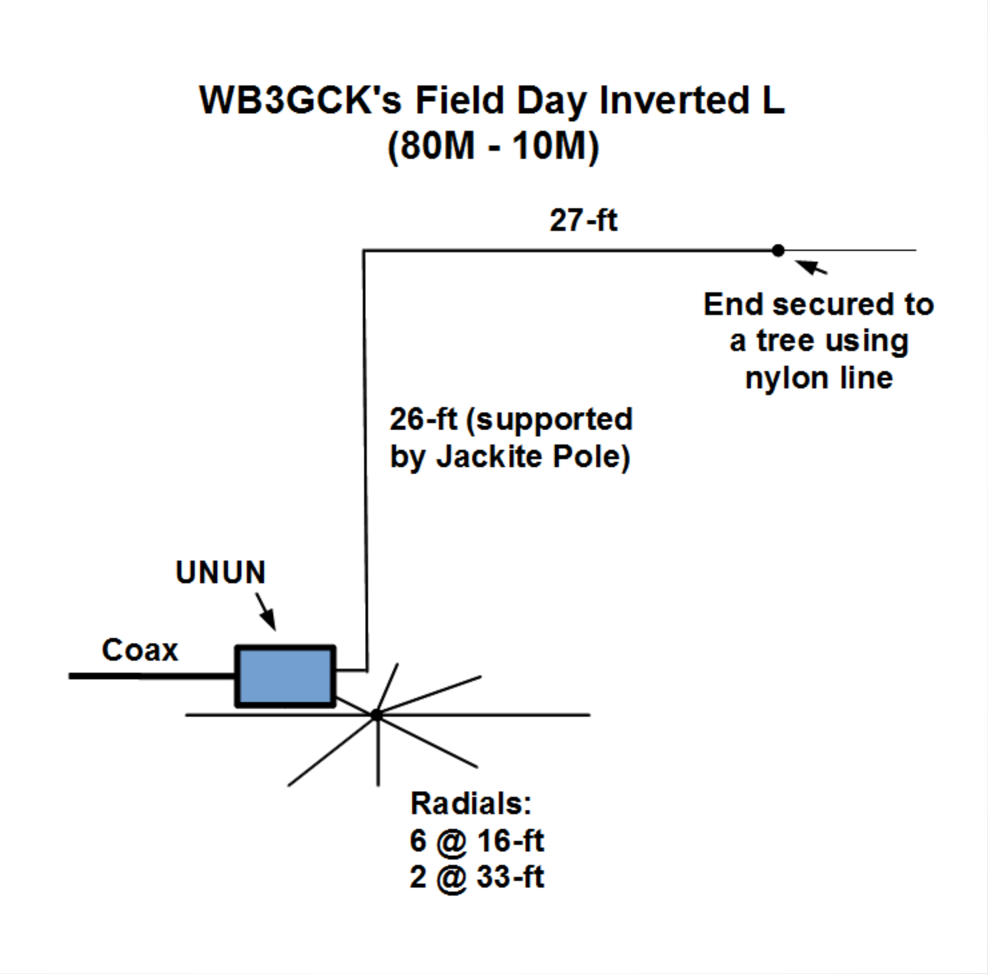
200 Ohm SWR Plot W8JI Windom


14 MHz OCF dipole (4th Harmonic)

Doublet

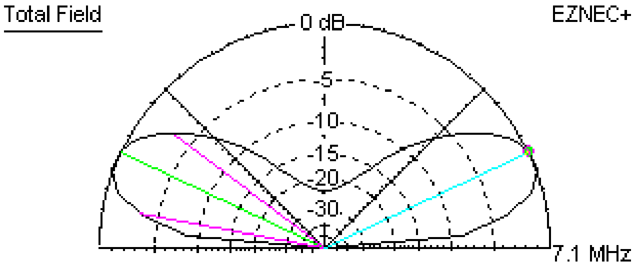

Insulator
Insulator
Insulator
Stranded Copper Wire
Any Length
450-Ω Ladder Line
Coaxial Cable
Antenna
Tuner
To Radio
ARRL0116

Inverted L

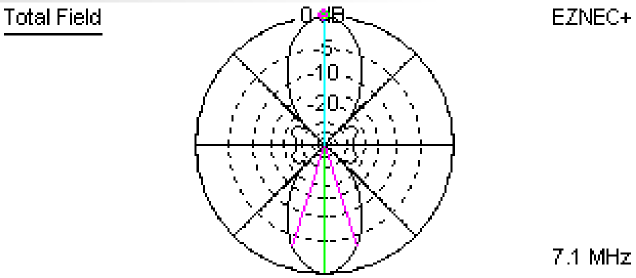


WB3GCK's Field Day Inverted L
(80M - 10M)
27-ft
End secured to a tree using nylon line
26-ft (supported by Jackite Pole)
UNUN
Coax
Radials:
6 @ 16-ft
2 @ 33-ft

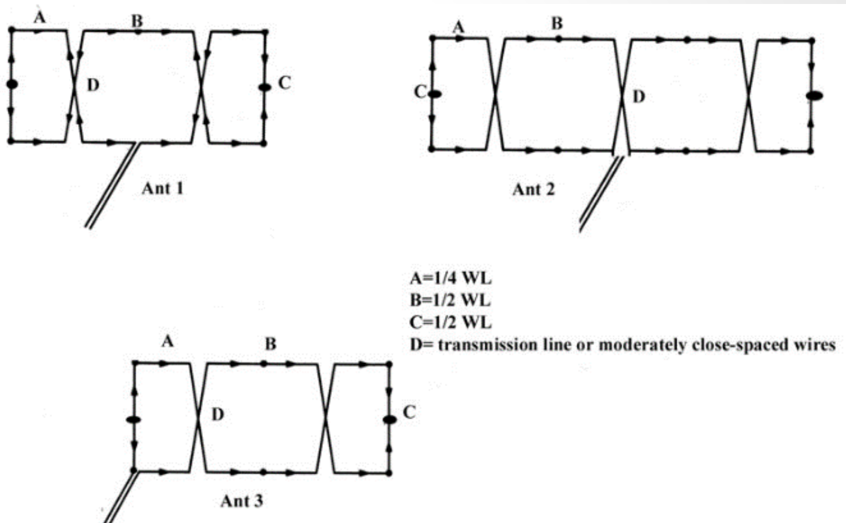
Sterba Curtain



Elevation Plot		Cursor Elev	25.0 deg.
Azimuth Angle	90.0 deg.	Gain	12.01 dBi
Outer Ring	12.01 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	12.01 dBi		
Slice Max Gain	12.01 dBi @ Elev Angle = 155.0 deg.		
Beamwidth	26.7 deg.; -3dB @ 142.5, 169.2 deg.		
Sidelobe Gain	12.01 dBi @ Elev Angle = 25.0 deg.		
Front/Sidelobe	0.0 dB		

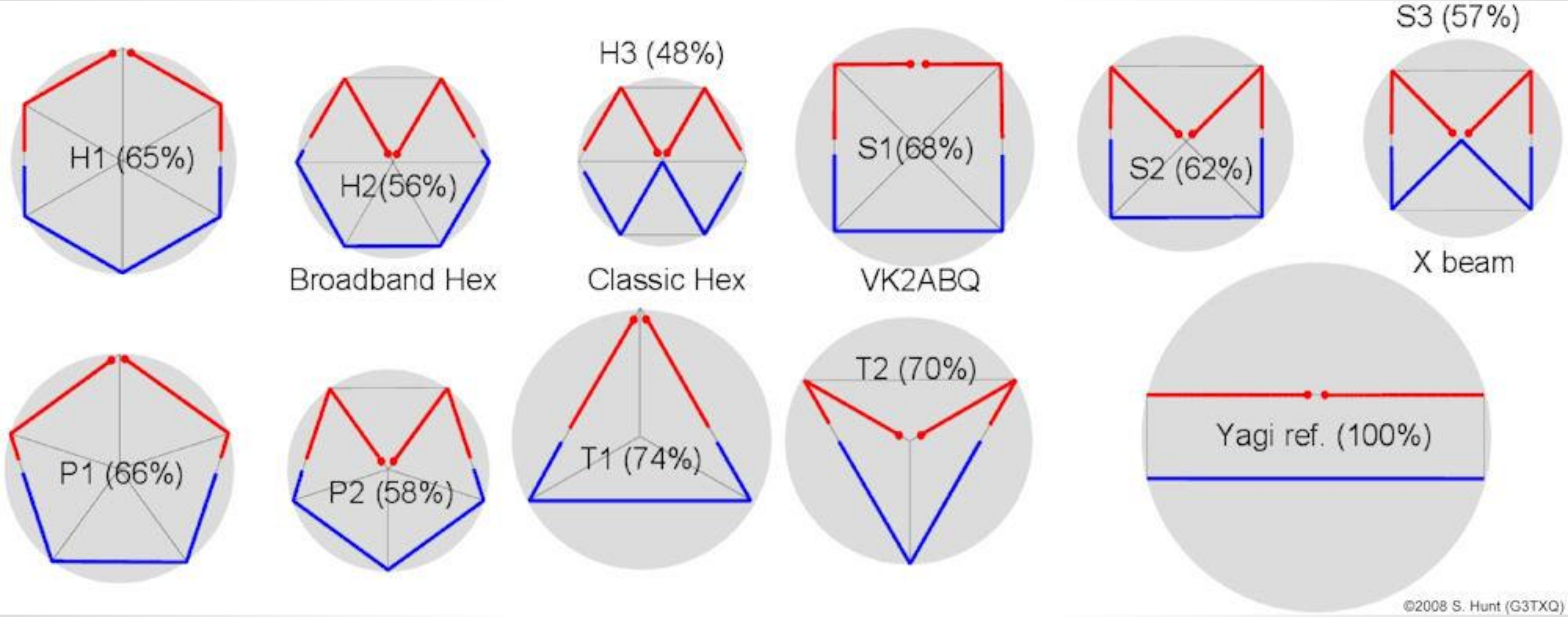


Azimuth Plot		Cursor Az	90.0 deg.
Elevation Angle	25.0 deg.	Gain	12.01 dBi
Outer Ring	12.01 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	12.01 dBi		
Slice Max Gain	12.01 dBi @ Az Angle = 270.0 deg.		
Front/Side	26.75 dB		
Beamwidth	34.8 deg.; -3dB @ 252.6, 287.4 deg.		
Sidelobe Gain	12.01 dBi @ Az Angle = 90.0 deg.		
Front/Sidelobe	0.0 dB		



Three forms of Sterba Curtains

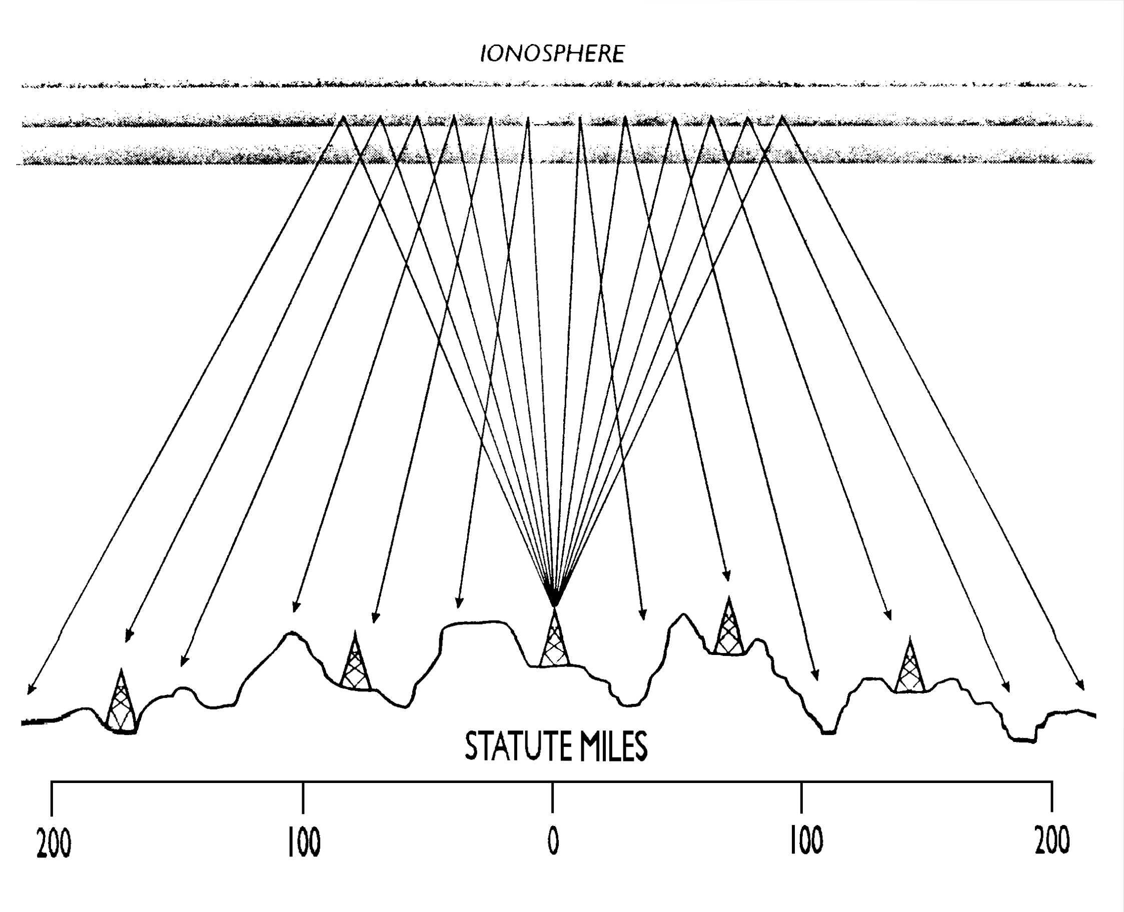
Wire Beams



http://www.karinya.net/g3txq/wire_beams/

Field Antennas

- Portability and Ease of Erection
- Efficiency and Size
- Take-off angle?
    - Some examples



AB0PC

Antenna Safety

- Do not put towers and antennas or feed lines near or where they can contact High Voltage lines.
  - 10 foot minimum safety margin of space.
- There are tower height restrictions near airports.
- Keep antennas away from places where they can be contacted during transmission.
  - Even low power can cause an RF burn.
- Do not work on a tower / antenna if storm possible
- Make sure tower & guys are in good condition.