Chapter 6
Antenna Basics

Dipoles, Ground-planes, and Wires

Directional Antennas

Feed Lines

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Some General Rules

- Bigger is better. (Most of the time)
- Higher is better. (Most of the time)
- Lower SWR is better. (Most of the time)
- Coax is better than twin-lead. (Some of the time)
- Ladder-Line is better than coax. (Some of the time)
- Antenna tuners do not change the performance of an antenna.
- Tuners may allow the transmitter to work better.
- Improve antennas first – then improve power.

Antenna Vocabulary

- Elements – conducting and radiating parts of an antenna
- Feedpoint and Feedline
- Polarization – Orientation of the Electric field
- Impedance – Feedpoint voltage / Feedpoint current
- Radiation pattern – graph of signal strengths on a polar plot
  - Elevation, Azimuth, Lobes, Nulls
- Isotropic radiator – same strength in all directions
- Directional – more strength in one or more directions
- Gain – ratio of strengths expressed in db
  - dbi – gain compared to isotropic
  - dbd – gain compared to a dipole
  - Front-to-back gain
  - Front-to-side gain

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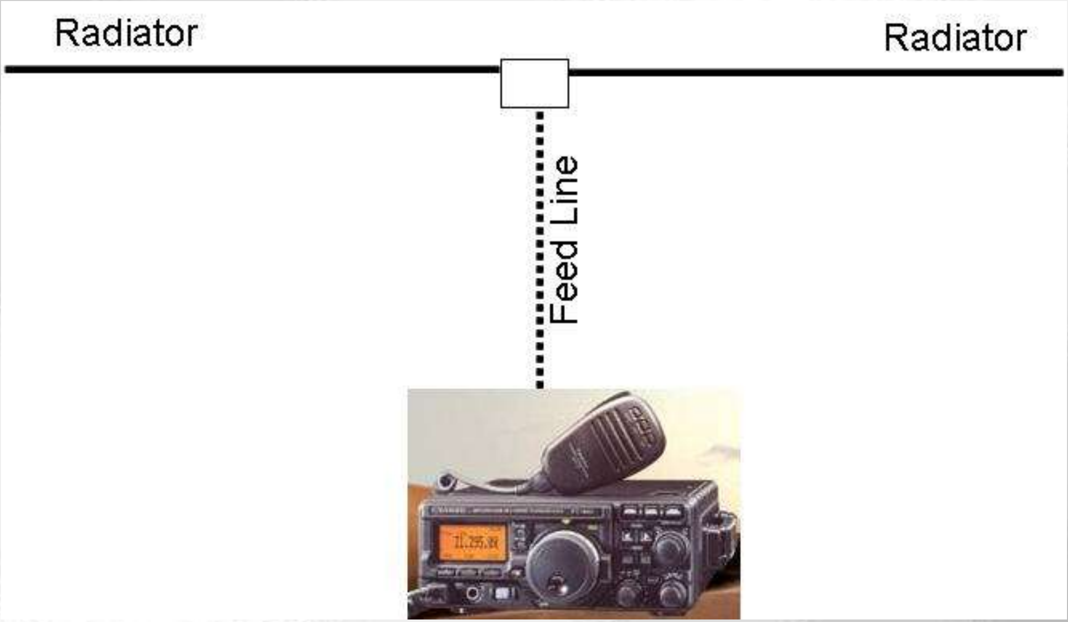
Dipole Antenna



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Half Wavelength Dipole

Basic building block of most antennas. It has two poles – di-pole.

- Length is a physical ½ wavelength of frequency.
  - A 20-meter half-wave dipole would be about 10 meters long.
  - An 80-meter half-wave dipole would be about 40 meters long.
- Polarization – E field – is parallel to dipole

Length of a ½ Wave Dipole

$$Length_{ft} = \frac{492}{f_{MHz}} = \frac{492}{f} = 1/2\,\lambda$$

- Freespace wavelength is 984 feet per MHz.
- Freespace half wave is 492 feet per MHz.
- This length is for free space and thin wire. Near earth, the resonant length will be shorter. 468 vs. 492

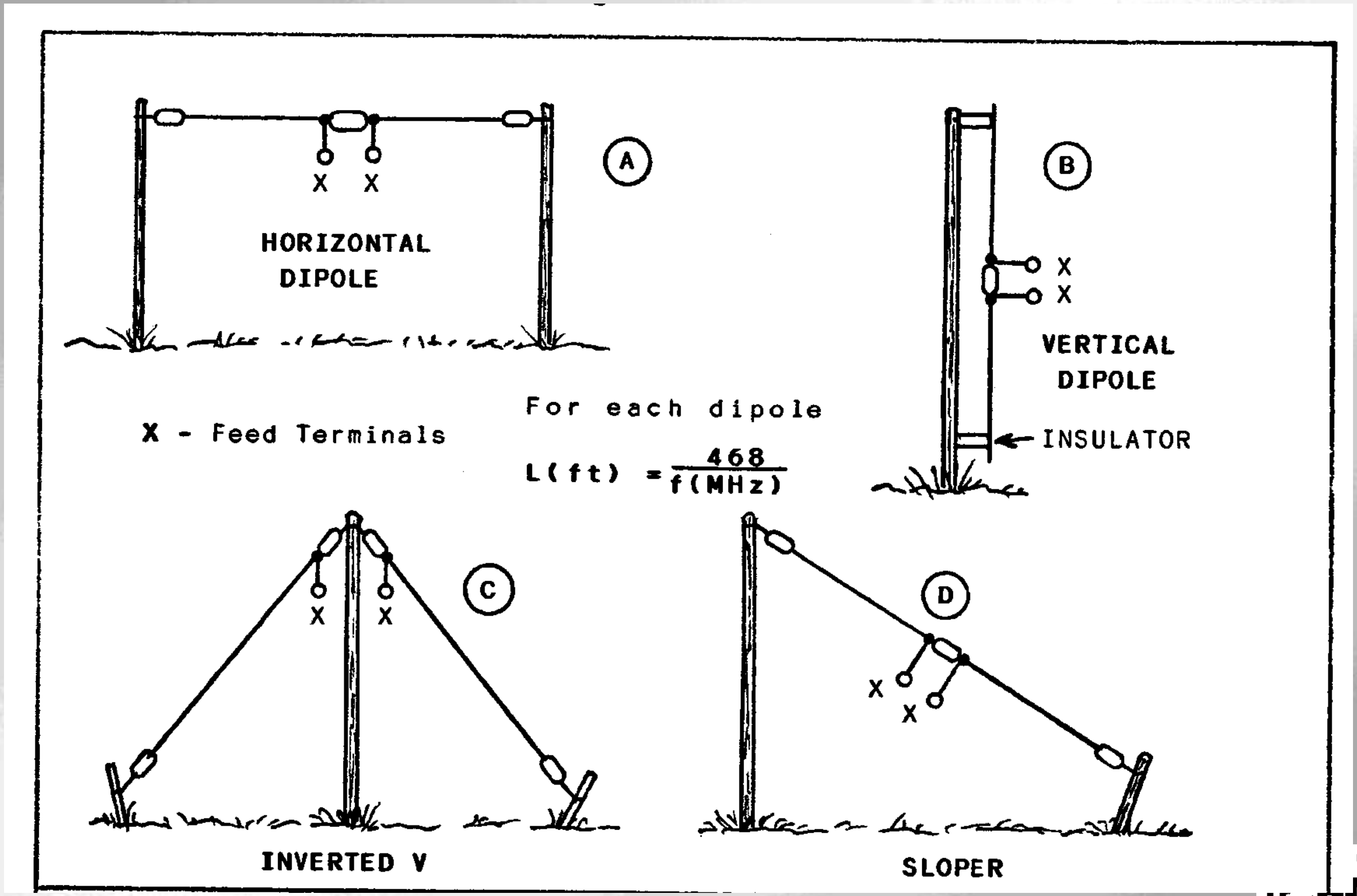
- Calculate the length in feet of a ½ wave dipole for:
  - 14.200 MHz
  - 3550 kHz
  - 146.52 MHz
  - 10.05 MHz
  - 7.150 MHz
  - 440 MHz

Length of a ½ Wave Dipole

$$Length_{ft} = \frac{492}{f_{MHz}} = \frac{492}{f} = 1/2\,\lambda$$

- Calculate the length in feet of a ½ wave dipole for:
  - 14.200 MHz = 34.6 ft.
  - 3550 kHz = 138.6 ft.
  - 146.52 MHz = 3.36 ft.
  - 10.05 MHz = 49 ft.
  - 7.150 MHz = 68.8 ft.
  - 440 MHz = 1.12 ft.

Dipole Configurations



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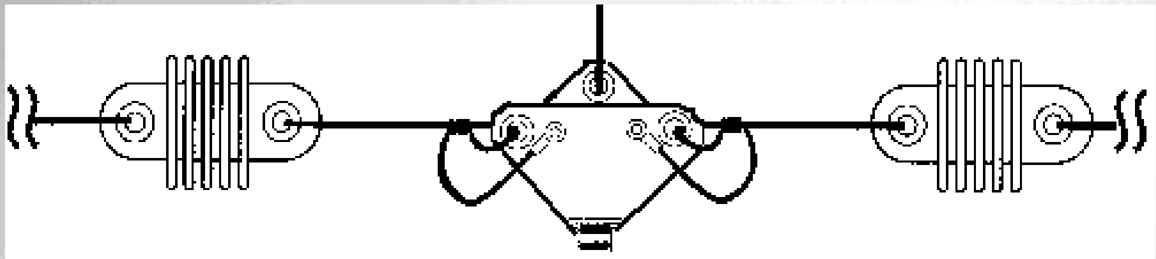
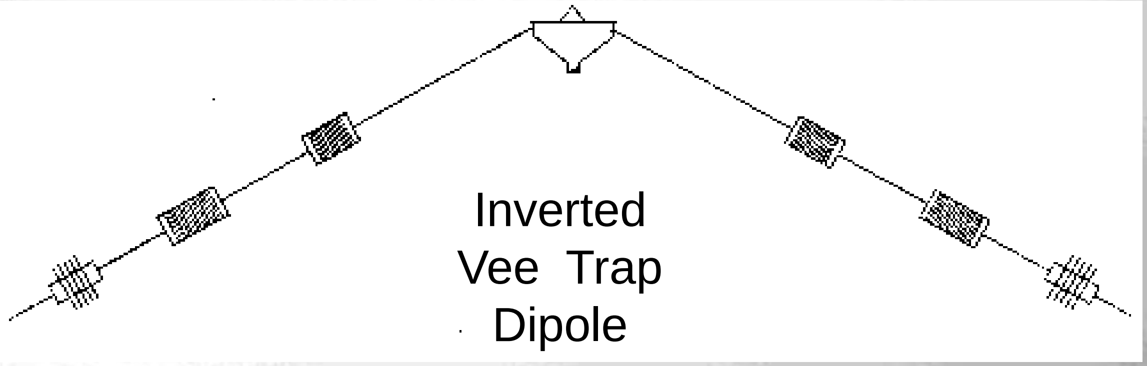
Dipole Detail





Inverted Vee Trap Dipole

Dipole Kit

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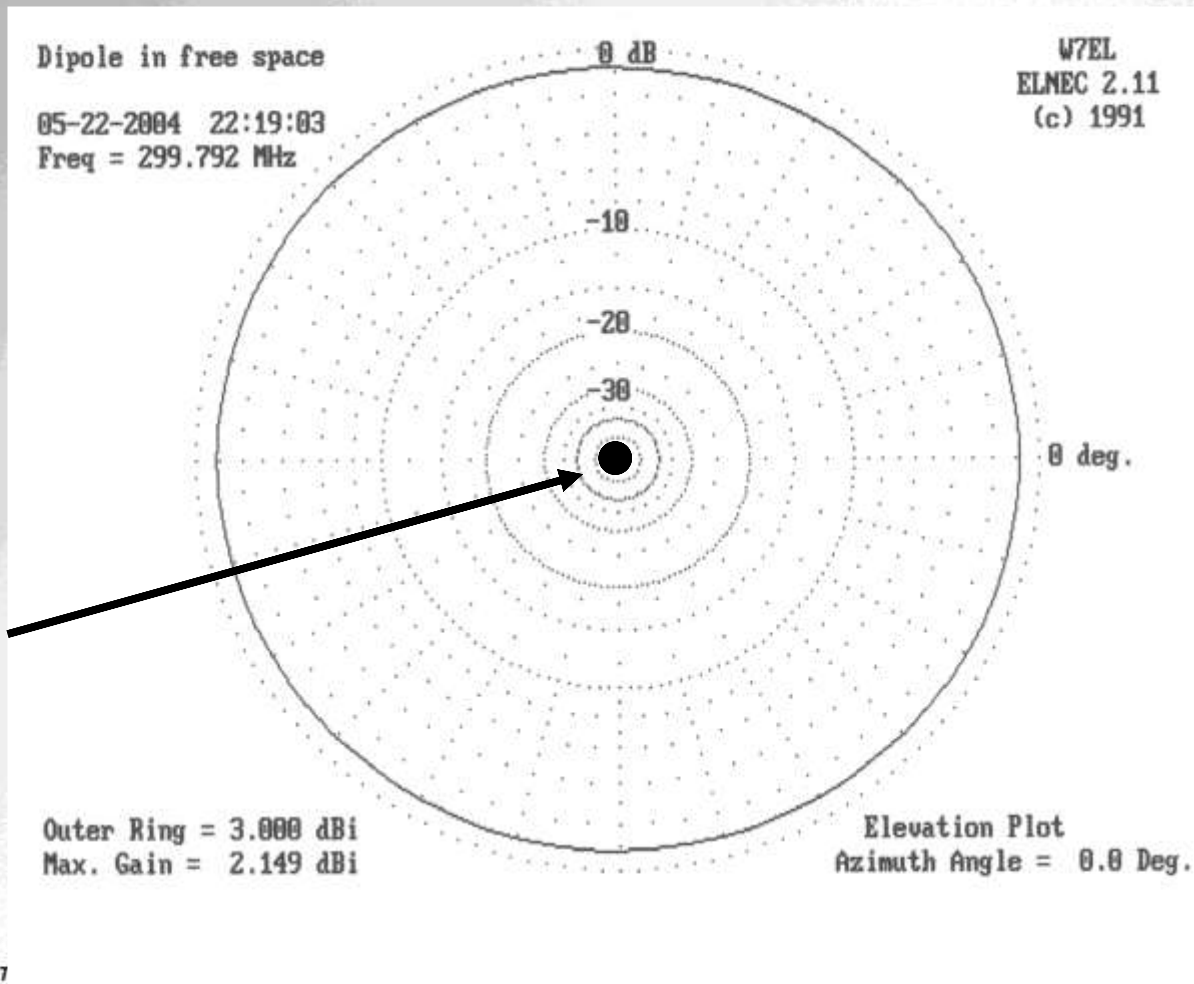
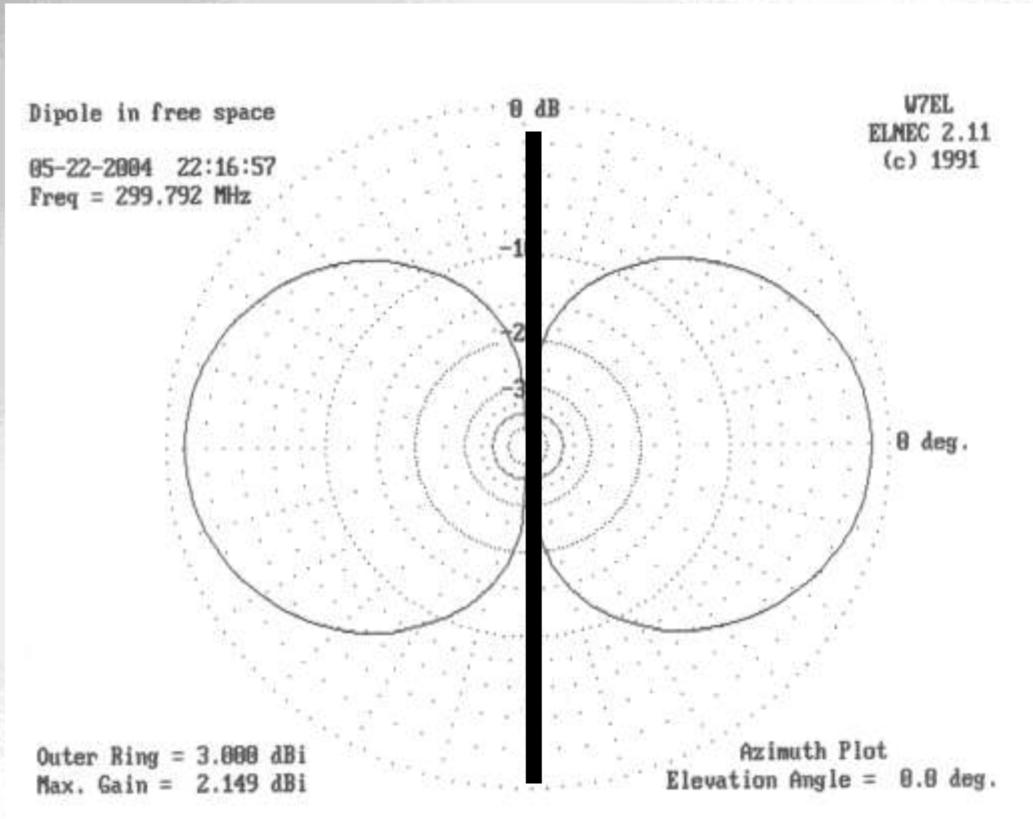
Dipoles in Free Space

Elevation Plot



Looking into wire end

Dipoles in Free Space
Azimuth Plot



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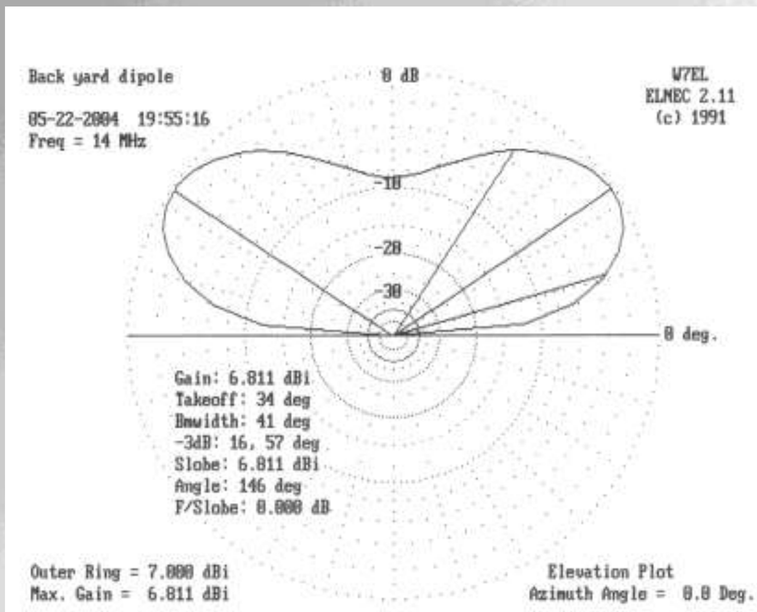
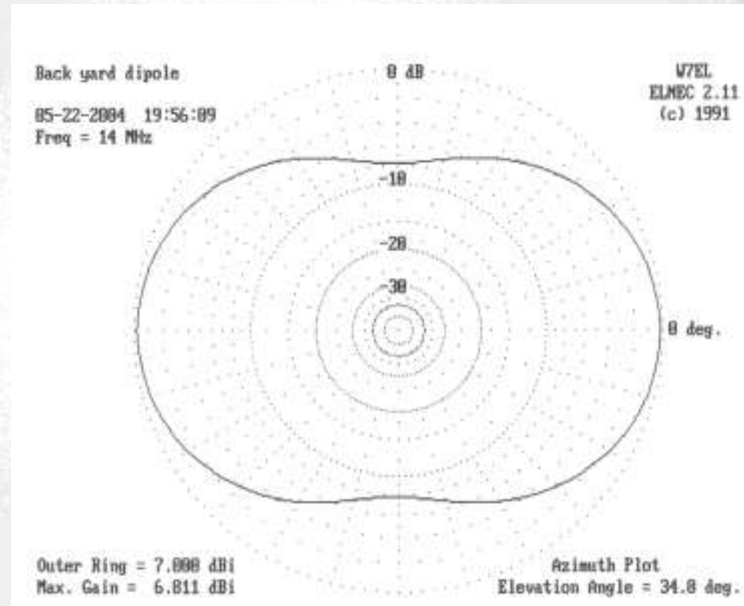
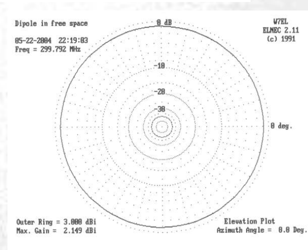
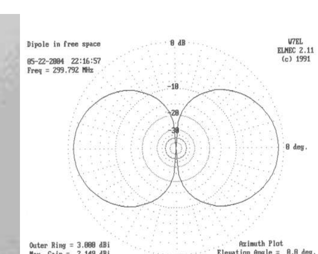
Horizontal Dipoles Over Real Ground









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Quarter-Wave Vertical Antennas

Radiating element is perpendicular to ground and ¼ wavelength long.

- Uses ground currents for other half of dipole
- Good choice when you do not have room for a dipole or beam and the usual antenna for mobile operations (whip).
- Vertical polarization.
- Omni-directional pattern with minimal signal straight up.
- Low angle of radiation, good for DX.

Ground Mounted Verticals

For a vertical to work effectively, it needs a highly conductive ground since the ground acts as the other half of the antenna.

- Wires called radials are laid out around the antenna.
- Lots of radials are sometimes needed.
- Radials should be placed on the surface of the ground or buried a few inches below the ground.
- Paradox: Adding radials can make SWR higher.

Ground Radials

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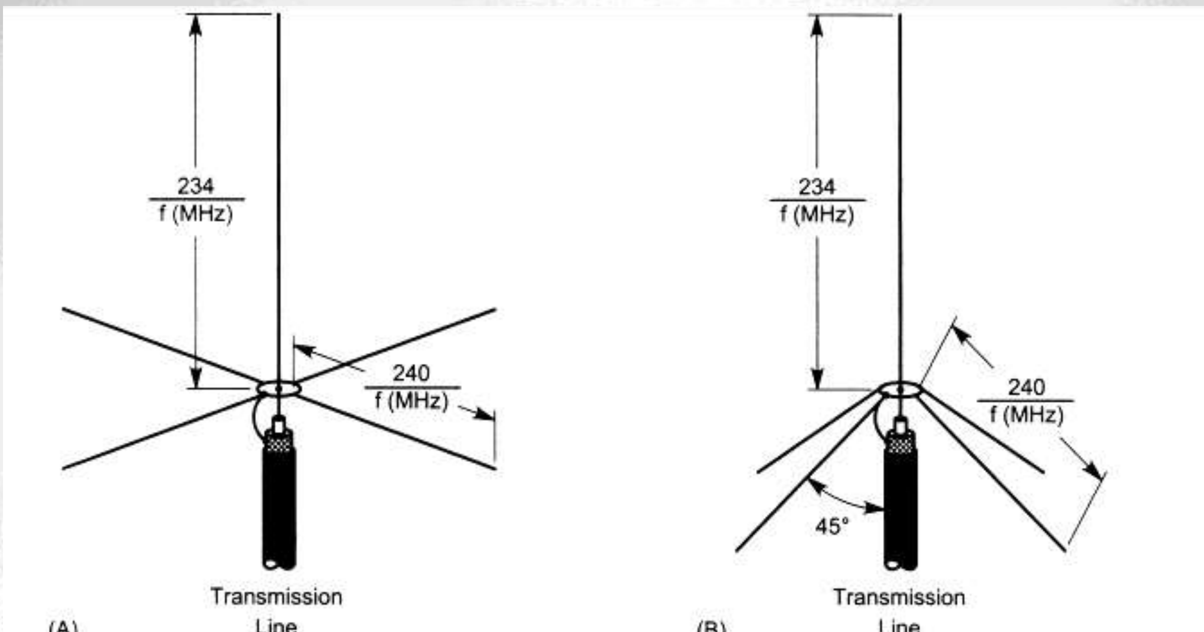
Quarter Wave Verticals Above Ground

A **Ground Plane Antenna is a**n elevated vertical antenna with radials**.**

- If the radials are changed from horizontal to downward sloping, the feed point impedance can be made closer to 50 ohms to match 50 Ohm Coax.



Length of a Quarter Wave Vertical

$$Length_{ft} = \frac{234}{f_{MHz}} = \frac{234}{f} = 1/4\,\lambda$$

234 accounts for shortening effects of ground. For Free space length, use 246.

- Calculate the following Vertical ¼ wave antenna lengths:
  - 14.200 MHz =
  - 3550 kHz =
  - 146.52 MHz =
  - 10.05 MHz =
  - 7.150 MHz =
  - 440 MHz =

Length of a Quarter Wave Vertical

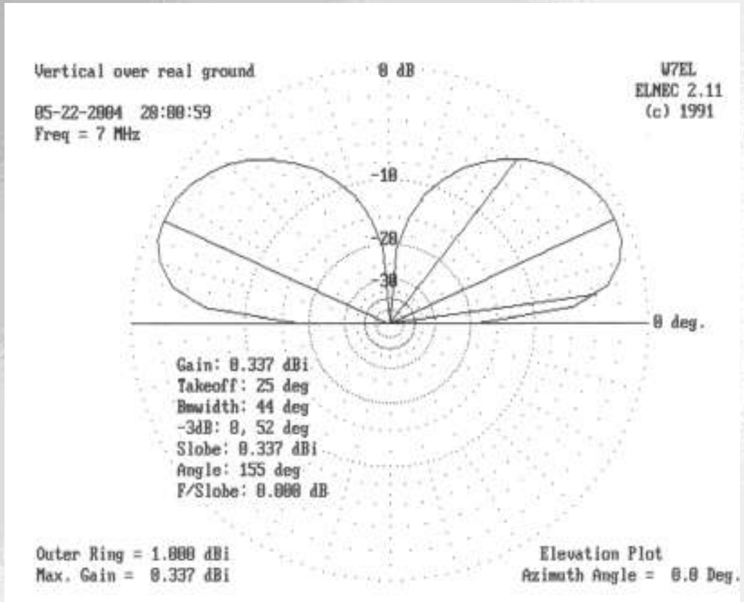
$$Length_{ft} = \frac{234}{f_{MHz}} = \frac{234}{f} = 1/4\,\lambda$$

234 accounts for shortening effects of ground. For Free space length, use 246.

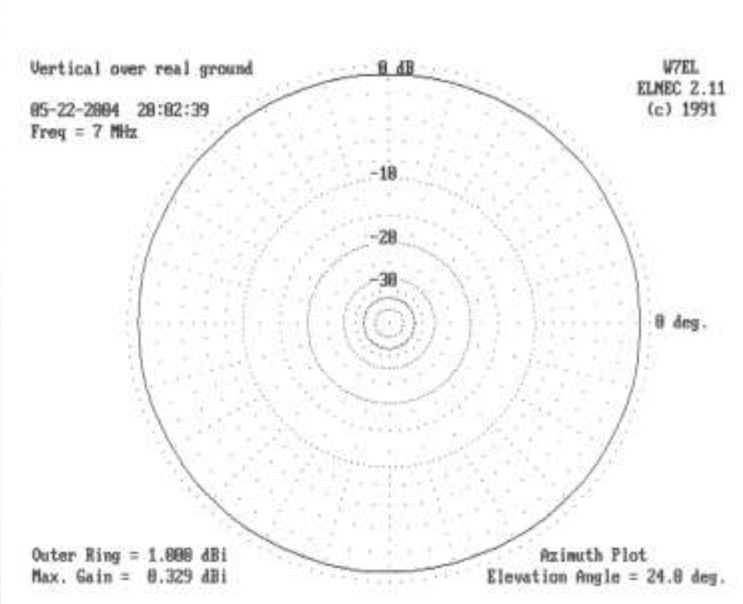
- Calculate the following Vertical ¼ wave antenna lengths:
  - 14.200 MHz = 16.5 ft
  - 3550 kHz = 65.9 ft
  - 146.52 MHz = 1.60 ft
  - 10.05 MHz = 23.3 ft.
  - 7.150 MHz = 32.7 ft.
  - 440 MHz = 0.53 ft.

Vertical Antenna Radiation Patterns

Elevation Pattern



Azimuth Pattern



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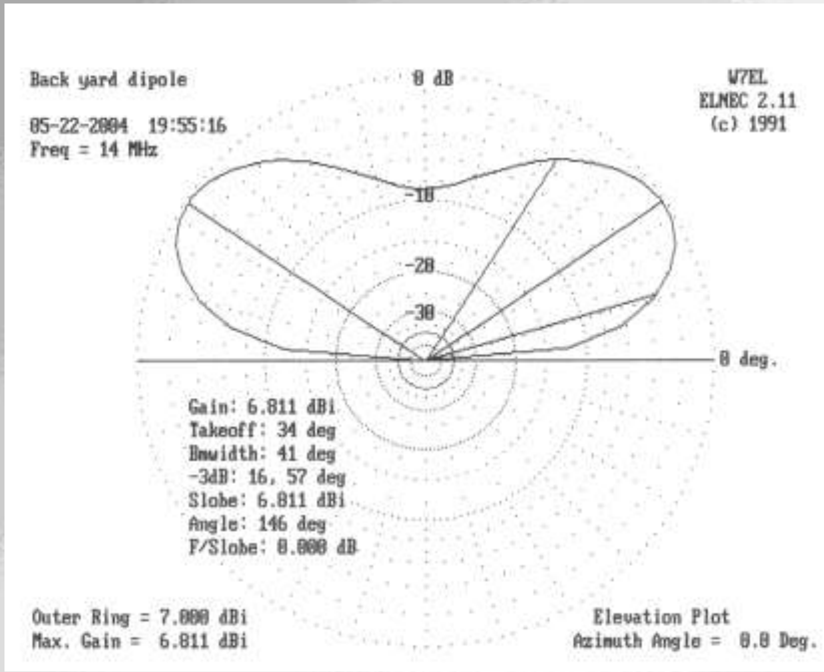
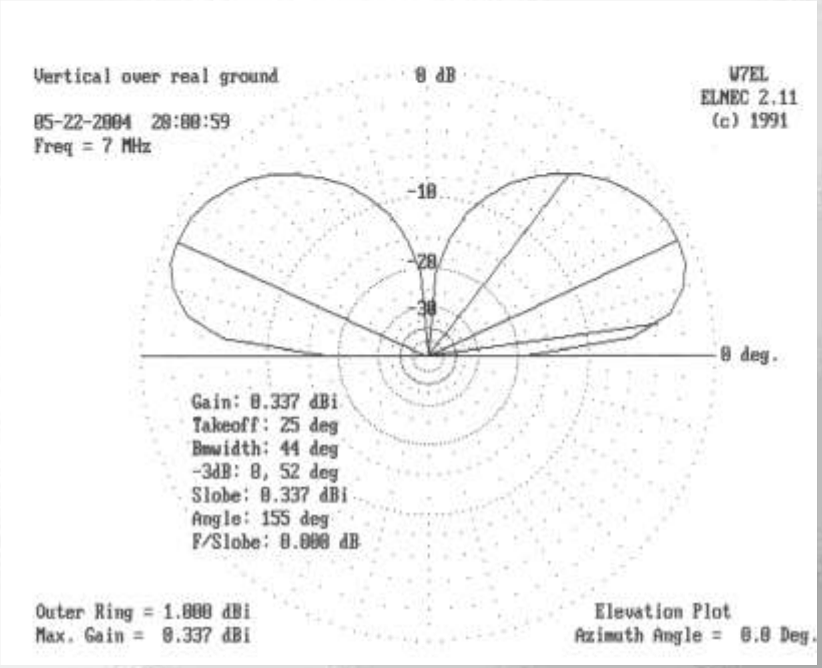
Dipole vs. Vertical

Dipole



Takeoff Angle = 34º

Vertical



Takeoff Angle = 25º

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Short and Random Length Antennas

Dipole antennas shorter or longer than multiples of ½ wavelength (1/4 wave for verticals) are *non-resonant* and can be “*loaded*” to achieve resonance.

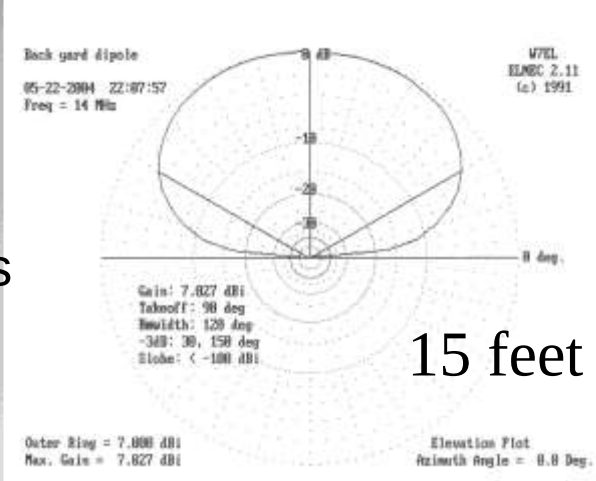
- Loading for short antennas is usually an inductance
- Loading for long antennas is usually a capacitance
- The operating bandwidth without retuning is small.

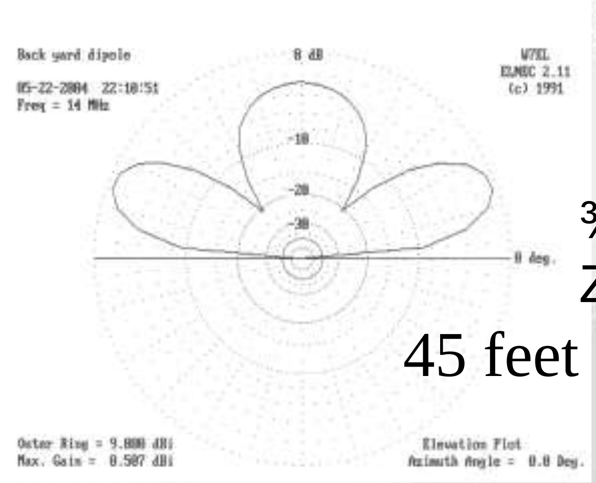
Random length wires are sometimes end-fed

- Needs a tuner at the radio
- High RF voltages can cause “RF Burns”

Effect of Dipole Height Above Ground

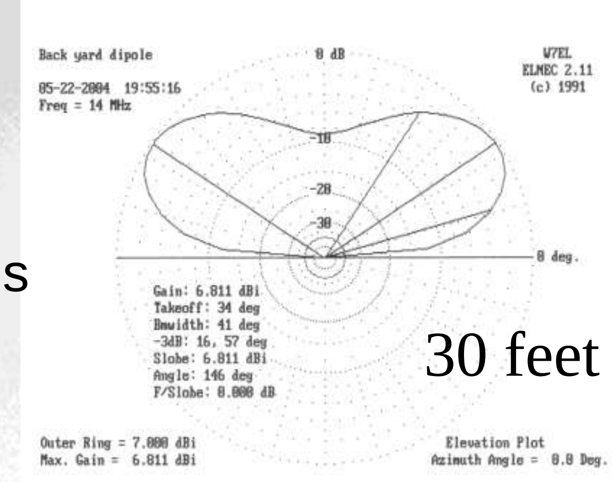
1/4 Wave
Z ~ 80 Ohms

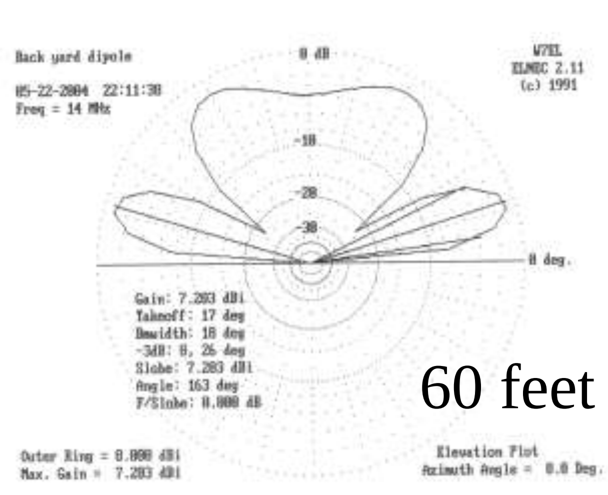




¾ Wave
Z ~ 75 Ohms

½ Wave
Z ~ 70 Ohms





1 Wave
Z ~ 72 Ohms

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Directional Antennas

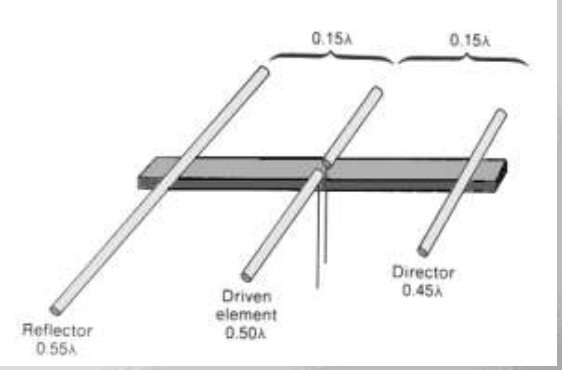
Take available power and focus the power in a desired direction. When power is focused, it appears that the signal strength has increased.

- This apparent increase in strength or power is called **gain**.
- To increase power in one direction, it is reduced in other directions producing nulls
- Sometimes nulls are useful to reduce interfering signals.

Yagi Antennas

An *array* of parallel dipole elements spaced from 0.1 to 0.2 wavelengths apart. One element is *driven*, other elements are *parasitic*.

- Reflector element is longer than driven element.
- Director elements are shorter than driven element.
- Lobe of gain in direction of directors.
- One or more nulls of gain to back and sides
- Elevation gain high at low angles.



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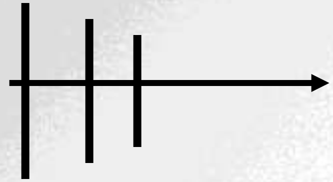
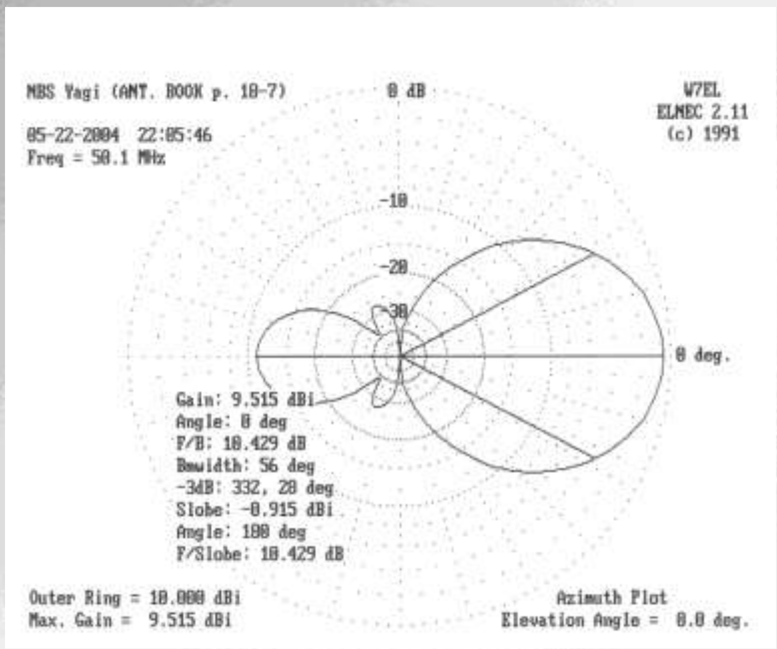
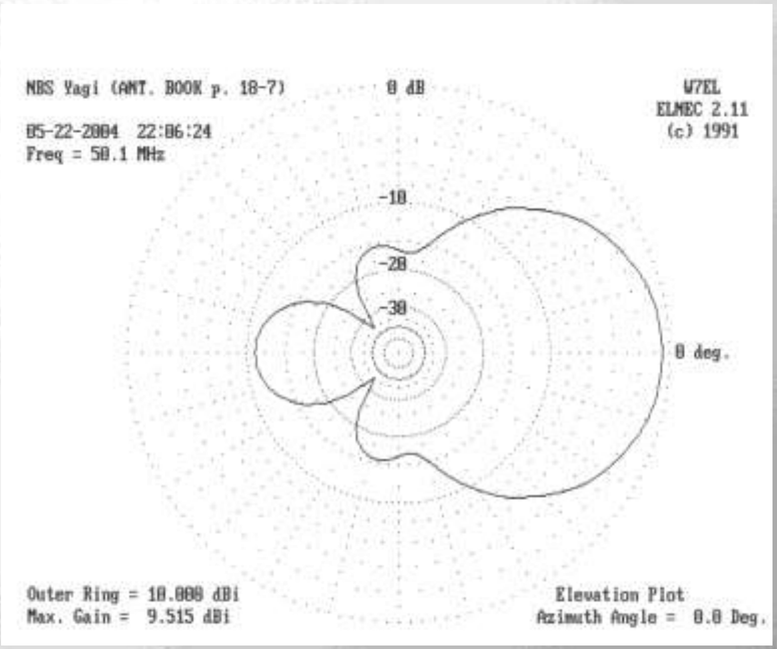
Yagi Antenna Gain





Azimuth



Elevation

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Yagi Antenna

Parasitic elements affect the direction pattern of a Yagi by re-radiating RF so that it is in phase with the field of the driven element.

- Lengths and spacing of the parasitics are adjusted for correct phase
- Many tradeoffs between number of elements and length of boom for maximum gain and bandwidth
- Two elements => 7 dbi gain and 15 db front to back
- Three elements => 9.7 dbi, 30 db front to back
- Elements with larger diameter increase the operating bandwidth

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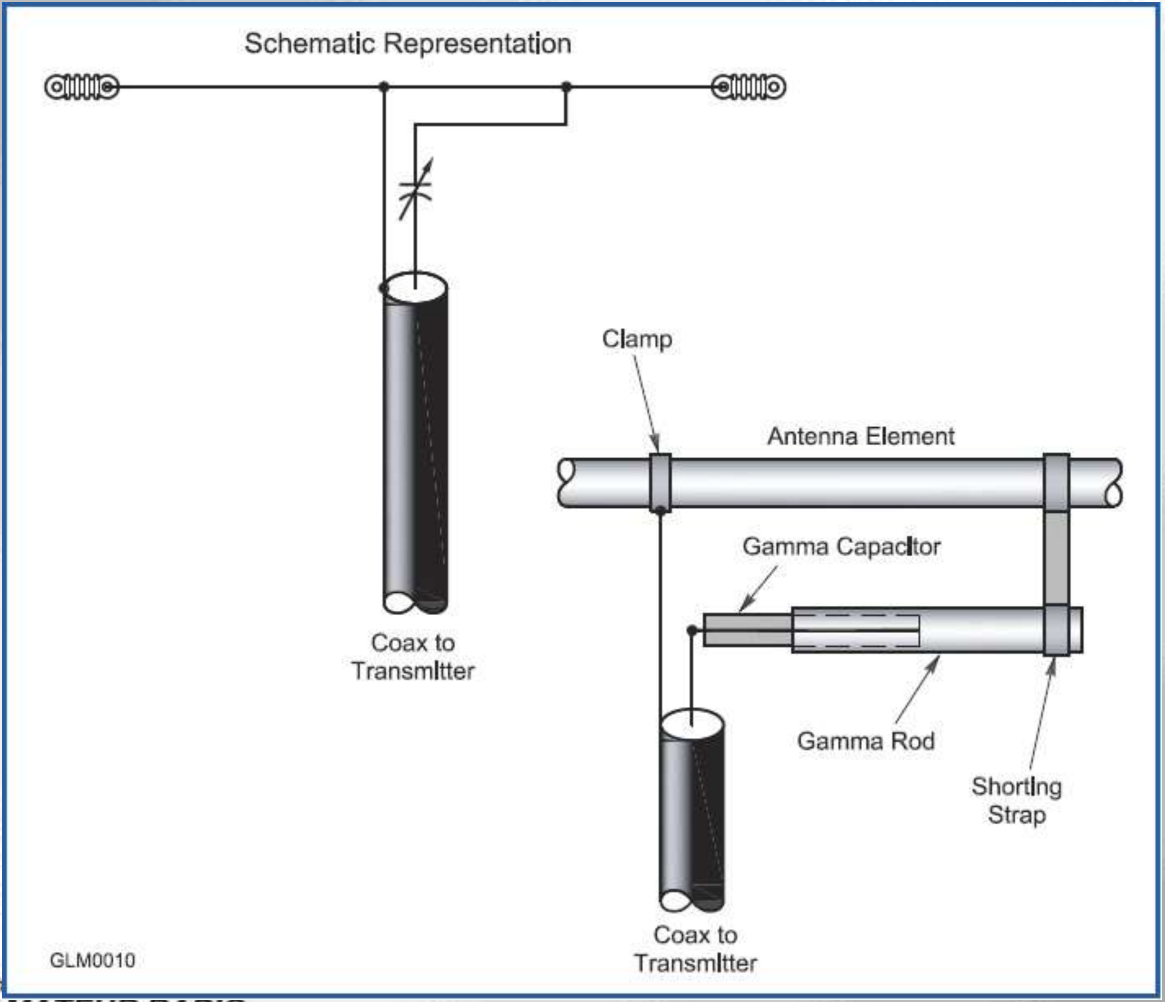
Yagi Antenna Impedance

Impedance of the driven element is reduced by loading of the parasitics, typically to 20 Ohms. A matching device is used to raise Z to 50 Ohms

- Gamma match allows the driven element to be electrically connected to the boom with no center insulator.
- The gamma match capacitor can be a telescoping rod inside a tube.

Gamma Match



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Loop Antennas

Large loop antennas for transmitting are usually one wavelength or larger in circumference. (Loop antennas used for direction finding are much less than 0.10 wave)

- May be circular, square, triangular, or random shape
- May be horizontal or vertical
- Currents and voltages vary from minimum to maximum at ¼ wave intervals around the loop
- At resonance, feedpoint Z is about 100 Ohms

Loop Antenna Configurations

- Horizontal square loop
  - Has a pattern of lobes and nulls and high angles
  - Useable on harmonic frequencies
- Vertical delta loop – triangular, apex up or down
  - Bi-Directional gain
  - Combination of horizontal and vertical polarization
- Quad and Delta Beams
  - Using loops for Yagi elements
  - Reflector loop is longer, Director loop is shorter
  - Gain is similar to a Yagi

Specialized Antennas

NVIS antennas – a dipole 0.1 to 0.25 waves high – good for short skip below critical Freq.

Stacked antennas

- Vertical stacking lowers take off angle
- Horizontal stacking reduces azimuth beamwidth
- Doubling the antennas can give up to 3 db gain

Log Periodics

- Logarithmic variation of element length and spacing
- Wide operating range but less gain than a Yagi

Specialized Antennas

Beverage – A low wire several wavelengths long
- For receive only; best in direction of the wire
- Signal to Noise radio is improved by reducing noise
- Needs high gain preamp in receiver

Multiband – fan dipoles, trap dipoles, loaded
- Fan – two or more dipoles on one feedline
- Trap dipoles – parallel LC circuits in series
- Linear loading – transmission line stubs
- G5RV – designed for 20 Meters; stub matching
- Harmonic – dipole used on odd harmonics

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Feed Lines

Characteristic Impedance – Z_0

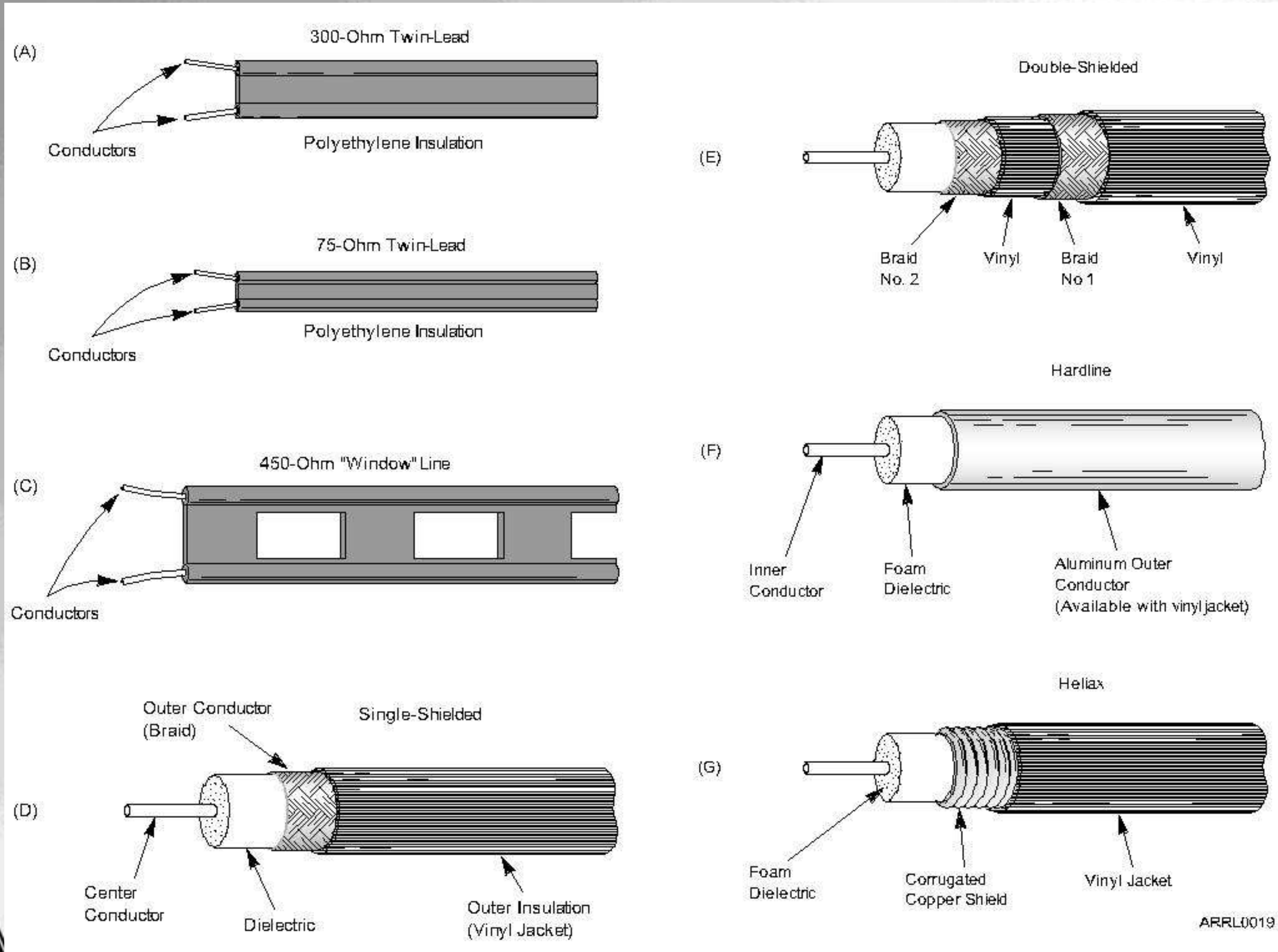
- Function of conductor size and spacing and dielectric
- Ratio of line voltage to line current at a point

Parallel wires – Z_0 from 300 to 600 Ohms

- Open wire using spreader insulators
- Window line using polyethylene insulation
- Twin Lead

Coaxial Cable – Z_0 from 50 to 100 Ohms

- Center conductor and outer conductor (shield)
- Dielectric may be air, polyethelene, teflon, foam



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Forward and Reflected Power

If the load resistance matches the characteristic impedance:

- All the power is absorbed at the load.
- Voltage on the line is constant

When the load is mismatched:

- a voltage wave is reflected.
- Voltage on the line will have minimums and maximums called a *voltage standing wave*

Power in the line can be resolved into a forward power and a reflected power.

Voltage Standing Wave Ratio

- VSWR (or just SWR) is the ratio of the maximum voltage to the minimum voltage on the line.
  - Equal to the ratio of Z_L to Z_0 or Z_0 to Z_L , whichever is greater than or equal to 1:1
  - 1:1 means the line is matched and no standing wave
  - Higher than 1:1 means some power is reflected
  - SWR will be the same at all points on the line
- Effects of high SWR
  - Greater than 2 => Reductions of transmitter output
  - Extra losses in feedline; Breakdown of components

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SWR Calculation from Power

Some meters will read the Forward Power and Reflected Power (watts), or voltages. This data can be used to calculate the SWR.

$$VSWR = \frac{1 + \sqrt{\frac{\text{Reflected Power}}{\text{Forward Power}}}}{1 - \sqrt{\frac{\text{Reflected Power}}{\text{Forward Power}}}}$$

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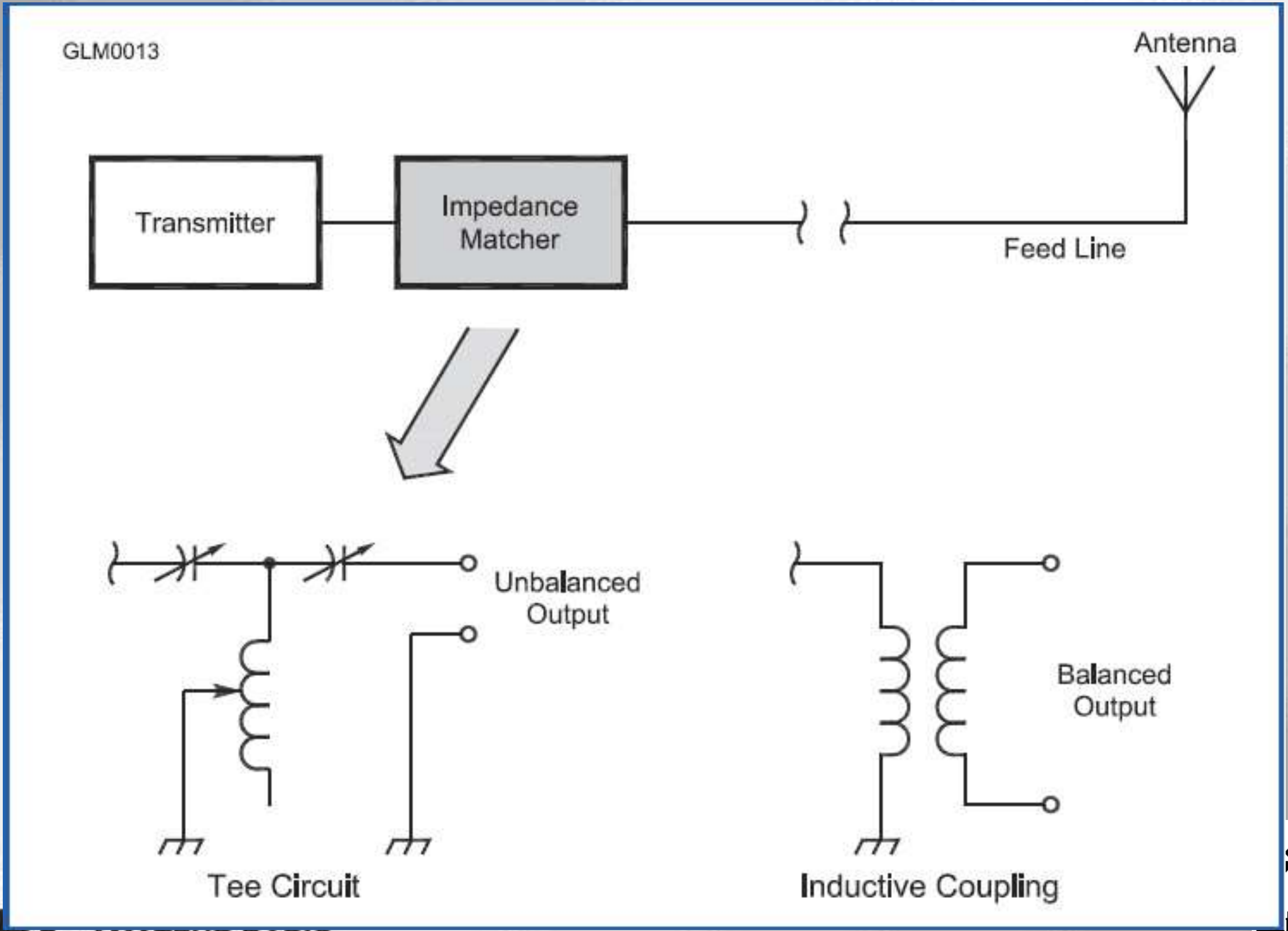
SWR Calculations

$$SWR = \left(\frac{Z_{Feedline}}{Z_{Load}}, \frac{Z_{Load}}{Z_{Feedline}}\right) \ni (SWR > 1)$$

Feed line	Load	SWR
50	50	?
50	?	2.0
?	300	6.0

Impedance Matching



Antenna Tuners

A Tuner doesn't tune the antenna.

- It transforms the impedance at the input of the feedline to the impedance needed for the transmitter.
- It does not change the impedance of the feed line, the impedance of the antenna, or the impedance of the transmitter.

If the feedline SWR is 5:1, it is still 5:1 even with an antenna tuner in line!

But the tuner allows the transmitter to operate under those conditions.

Losses in Feed Lines

Losses are heat and are due to:

- Resistance of conductors due to $I^2 * R$
- Losses in dielectric insulation

Attenuation due to losses is measured in db per 100 ft.

Losses increase with frequency

Type	Z	Diameter In.	Loss (30MHz db/100 ft.	Loss (150MHz) db/100 ft.
RG-58	50	0.25	2.47	5.63
RG-8X	50	0.375	1.96	4.53
RG-213	50	0.50	1.08	2.53

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