Antenna Modeling

Presented by:

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Agenda

- **Introduction and background**
- **Basic antenna theory**
- **Simple antenna models**
- **More complex models**
- **Open discussion & conclusion**

Why Model Antennas?

- **Computer horse-power now available, even on PCs**
- **Significant resource ($) & time savings**
- **Improve accuracy & repeatability**
- **Easily perform “what if” analyses**
- **Learn a lot about antennas quickly**
- **It’s fun! … (warning - can become additive)**

Antenna Modeling History

- **Numerical Electromagnetics Code (NEC) developed for U.S. Navy**
  - **Produced by Lawrence Livermore Labs in 1970s**
  - **Written in FORTRAN for CDC and VAXs**
  - **Later made public**
  - **Basic modeling engine for all current modeling programs**

- **NEC-2 developed in 1981 (slimed down version of NEC)**
  - **Public Domain (no license required)**
  - **Ran on Mini's and later PCs**

- **NEC-3 ?**

- **NEC-4 developed in 1992**
  - **Requires user license**
  - **Several advanced features compared to NEC-2**

- **MININEC (date?)**
  - **Written in BASIC for PCs**
  - **Has some known flaws compared to NEC**

Antenna Modeling Products

(Sample)

Public Domain (Free)

- **4nec2 - Modeling and optimization program (Dutch)**
- **MMANA - By JE3HHT, Makoto (Mako) Mori (MININEC)**
- **EZNEC Demo 4.0 - By W7EL** (www.eznec.com)

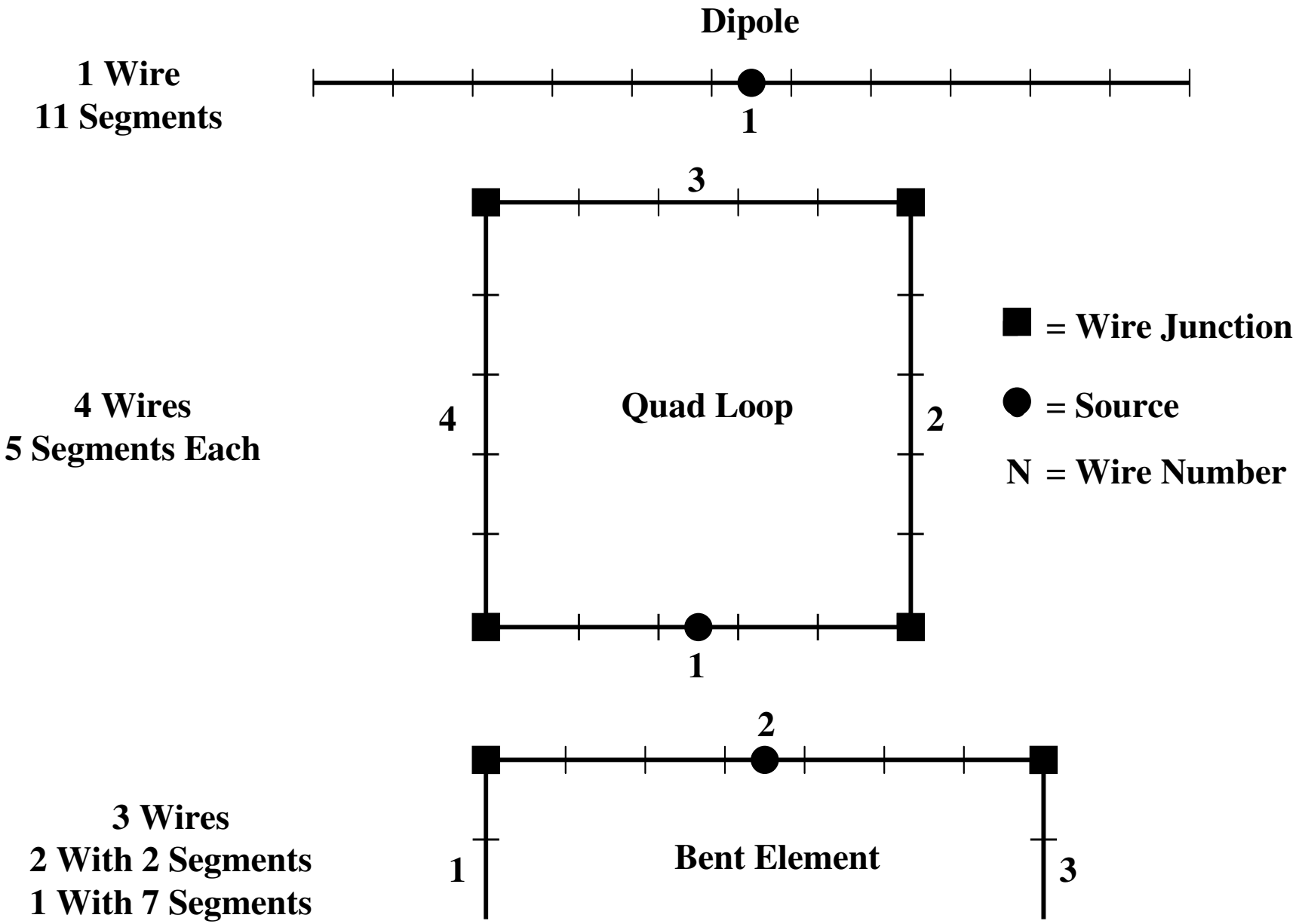
Commercial

- **Nec-Win Plus (similar to EZNEC)**
- **K6STI - Various modeling & optimization programs (MININEC)**
- **EZENEC 4.0, EZNEC + 4.0, EZNEC Pro (NEC-4)**

Antenna Modeling Terms

- ***Wire*** **- Basic antenna model building entity (linear, no bends)**
- ***Segment*** **- Sub-division of a wire**
- ***Source*** **- Feed point electrical specifics (Volts/Amps & Phase)**
- ***Load*** **- R, L, and C values alone or in any combination**
- ***Ground Type*** **- Free space, perfect and types of "real" ground**

Wires and Segments



Antenna Modeling Guidelines

- **A wire should have at least 9 segments per half-wavelength**
  (times 2 + 1 for impedance and SWR plots)

- **Segment length should be ≥ than 4 times wire diameter**

- **To extent possible, keep segment lengths equal**

What Can a Model Tell Us?

- **Antenna physical depiction (view)**

- **Far Field Pattern**
  - **2D plots (azimuth or elevation)**
  - **3D plots (both together)**

- **Antenna gain at any angle**

- **Front-to-back, front-to-side ratios, 1/2 power beamwidth etc.**

- **SWR vs. frequency**

- **Impedance (real & imaginary) vs. frequency**

- **Wire currents - magnitude and phase for each segment**

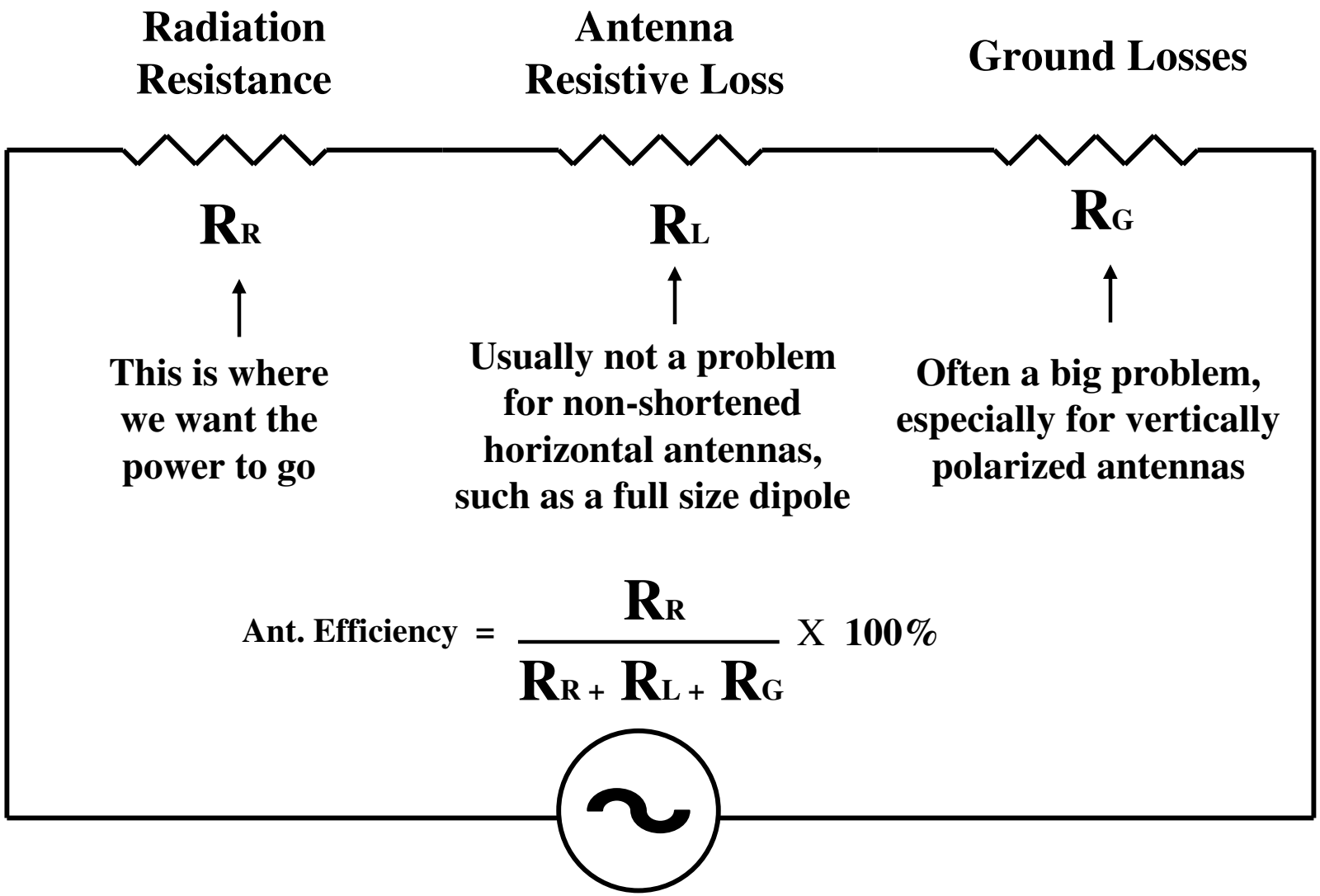
- **Other stuff**

Basic Antenna Concepts

- **Antenna gain is achieved by pattern alteration (directivity)**
- **All antennas are directive (except an isotropic source)**
- **Antenna gain = antenna directivity - antenna losses**
- **Gain is affected by antenna design, physical realization, & environment**
- **For antennas near earth, the pattern (directivity, gain) is greatly affected by reflections from the earth's surface (ground conductivity impact)**
- **Reflection of horizontally polarized signals is usually quite efficient**
- **Reflection of vertically polarized signals is often inefficient**
- **Theory of Reciprocity: Antennas behave the same transmitting & receiving**

Antenna Equivalent Circuit

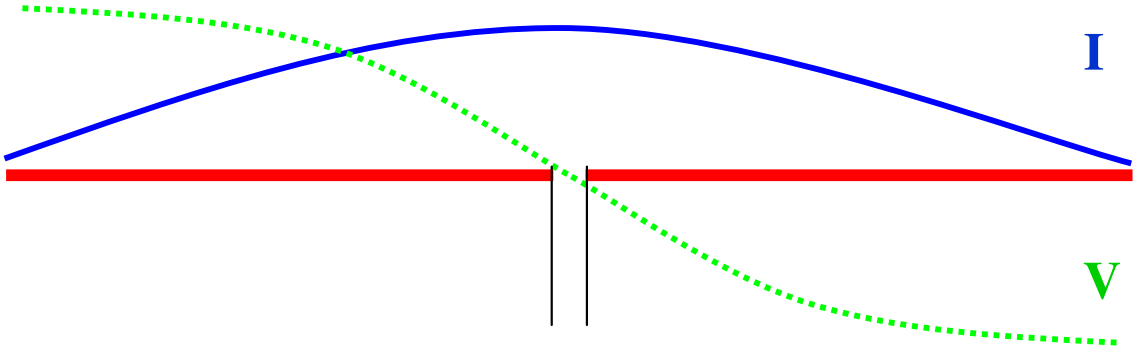
(Feedline Not Included)



$$\text{Ant. Efficiency} = \frac{R_R}{R_R + R_L + R_G} \times 100\%$$

Current Feed vs. Voltage Feed

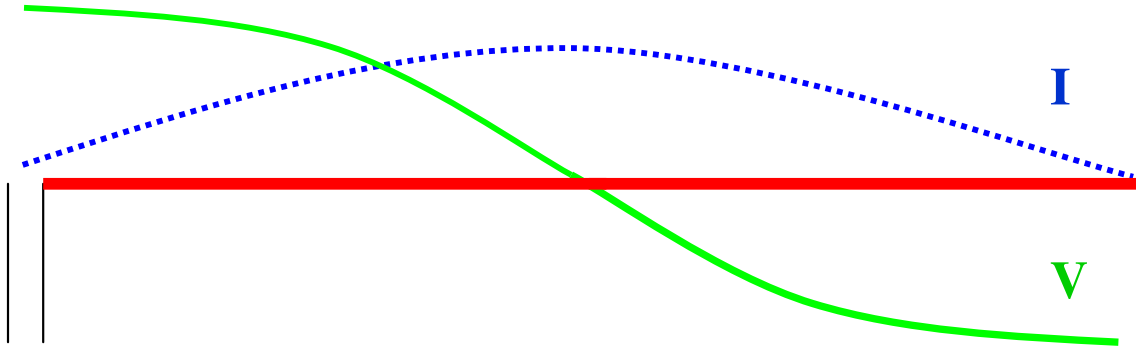
(for a λ /2 dipole, not all antennas)



Center Feed (Current Max.) = Current Feed

Zin is Low ~ 7 3 ohms in Free Space

Zin ~ R_R

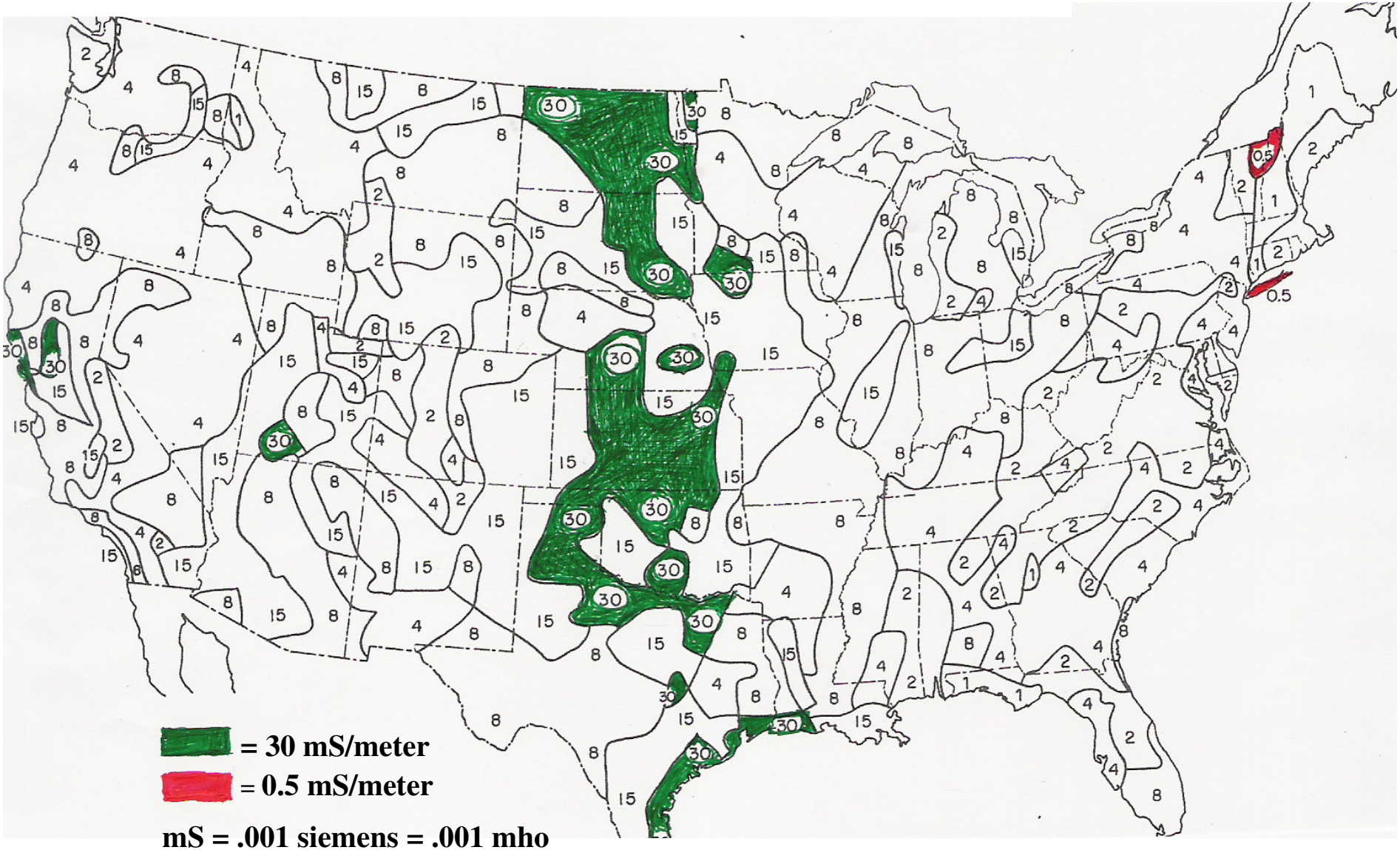


End Feed (Voltage Max.) = Voltage Feed

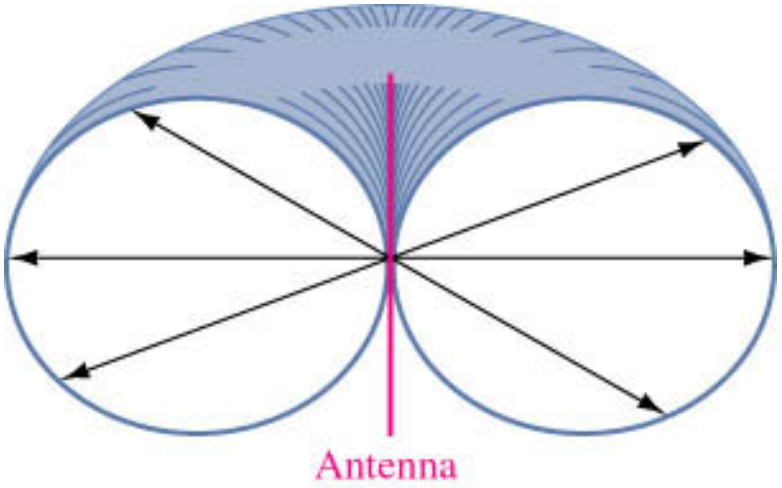
Zin is High - can range from 100s to 1000s of ohms

Zin >> R_R

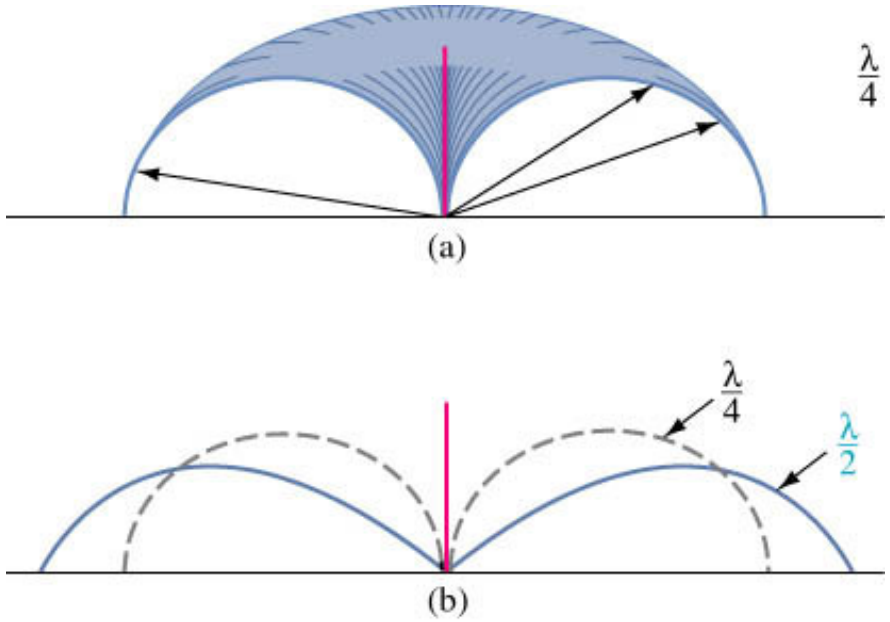
Estimated Ground Conductivity in the U.S.



Vertical Antenna Patterns

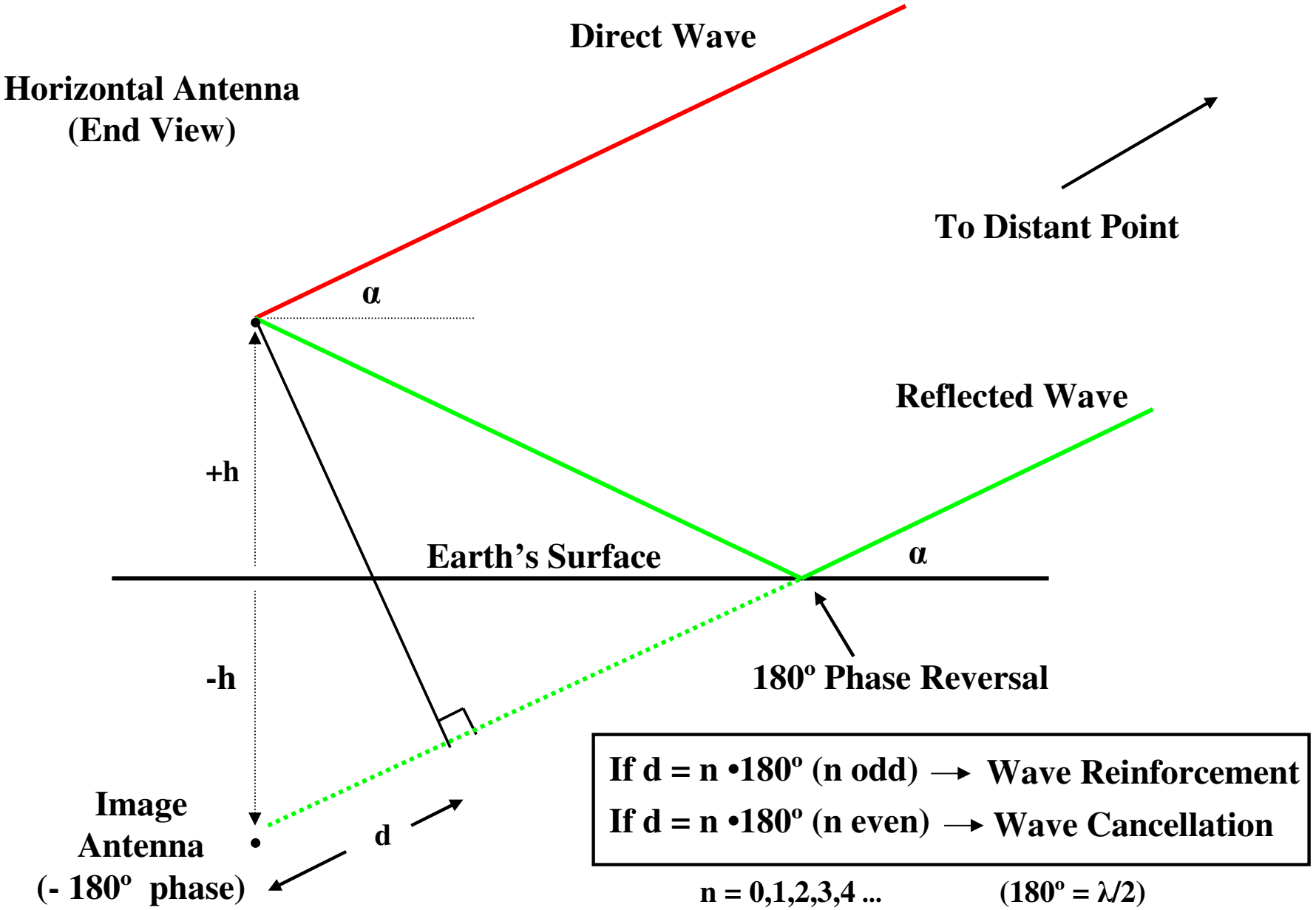


In Free Space
(Applies to λ /2 Dipole Also)



Above a Perfectly Conducting Surface

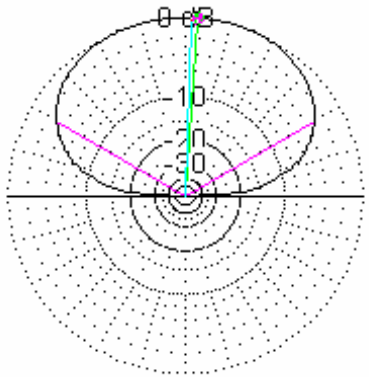
Horizontal Antenna Above Earth



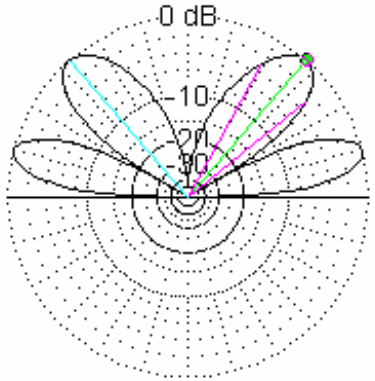
1/2 Wave Dipole Elevation Plots vs. Antenna Height

14 Mhz. - Perfect Ground

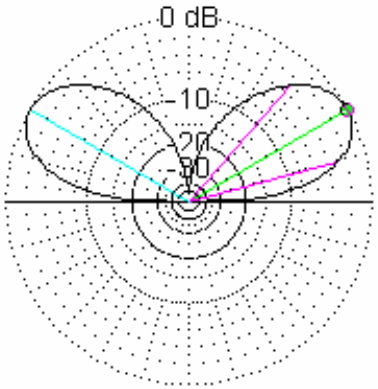
1/4 Wavelength (17.5 ft.)



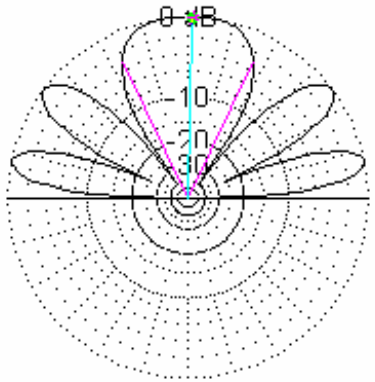
1 Wavelength (70 ft.)



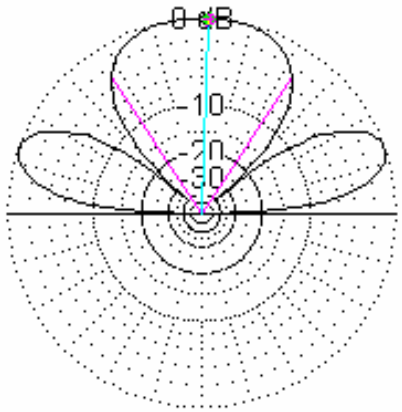
1/2 Wavelength (35 ft.)



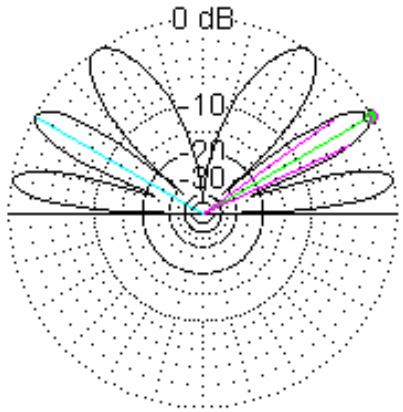
5/4 Wavelengths (87.5 ft.)

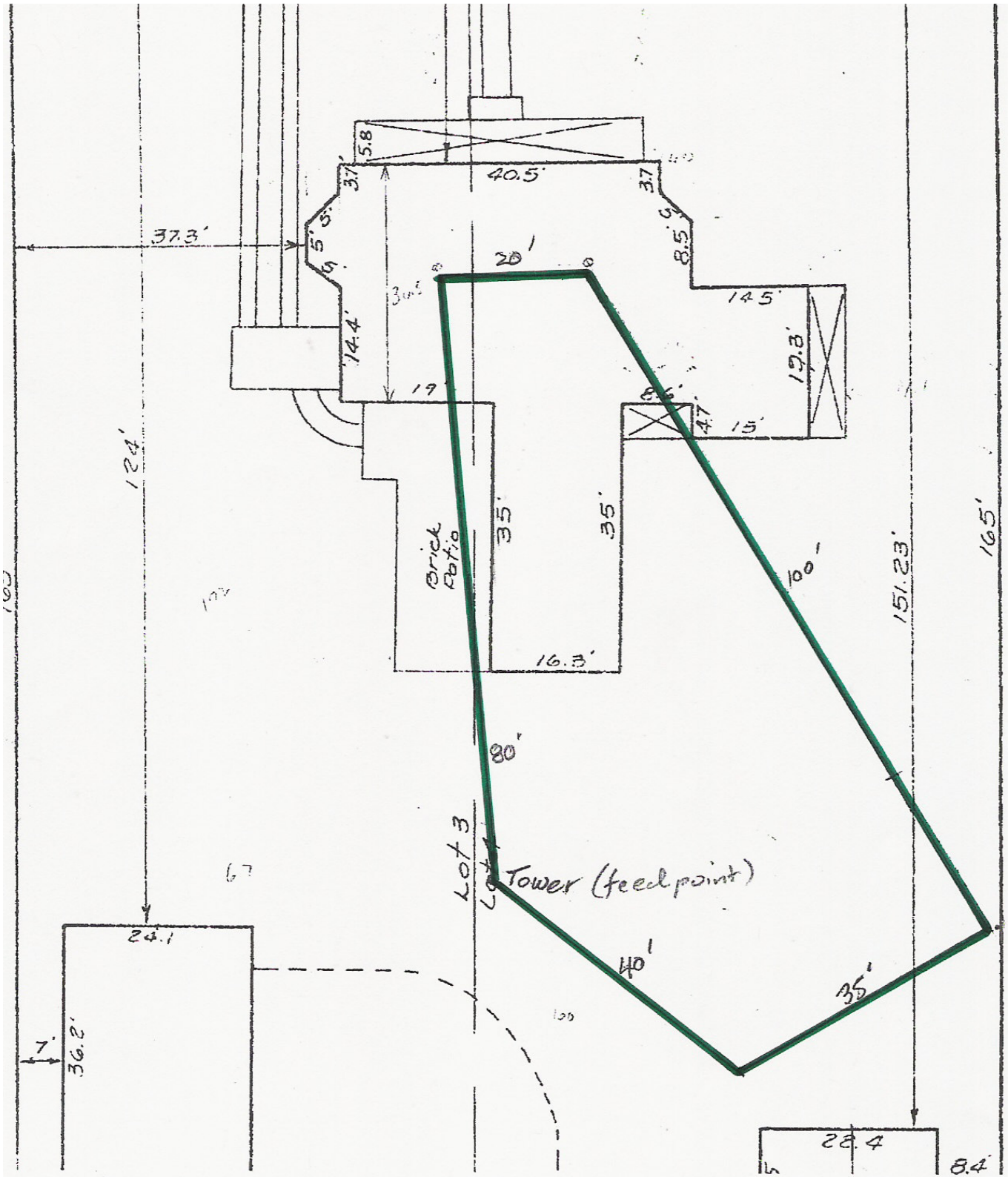


3/4 Wavelength 52.5 ft.



1 & 1/2 Wave-lengths (105 ft.)




5.8
40.5'
37.3'
37.3'
5.5'
5.5'
8.5'
8.5'
20'
145'
14.4'
19'
19.8'
4.7'
15'
124'
Brick Patio
35'
35'
16.3'
100'
151.23'
165'
80'
Lot 3
Tower (feedpoint)
40'
35'
24.1'
36.2'
1'
22.4'
8.4'