Short Vertical Antennas

Some thoughts for an 80m-Band Vertical

David A. Paul - AE5DA

ae5da@arrl.net

Additions to presentation given to SCARS group 9 Feb'08 appear in red.

Introduction

- Is there a need for short ***vertical*** 80m-band antennas?
  - **Dipole**:
    - $\lambda/2$ = 40m = **131 feet**
  - **Vertical Ground Plane**:
    - $\lambda/4$ = 20m = **65.6 feet**
  - **Short Vertical**:
    - $\lambda/10$ = 8m = **26.3 feet**

Topics of Discussion

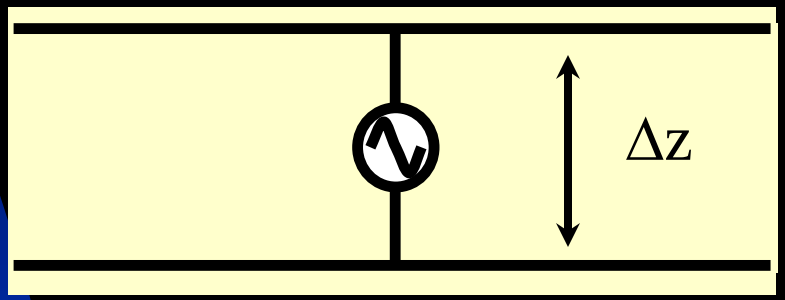
- Electrical Behavior of Short/Small Antennas
- Methods to Increase: Impedance, Bandwidth, Efficiency
- Proposed Antenna

Electrical Behavior of Small Antennas

- Radiation Resistance, Rr
  - Very small, very quickly
  - Decreases exponentially as radiating element size decreases
  - Leads to:
    - Very Narrow Bandwidth
    - Low Efficiency
- Demonstrate through simulations

Electrical Behavior of Small Antennas

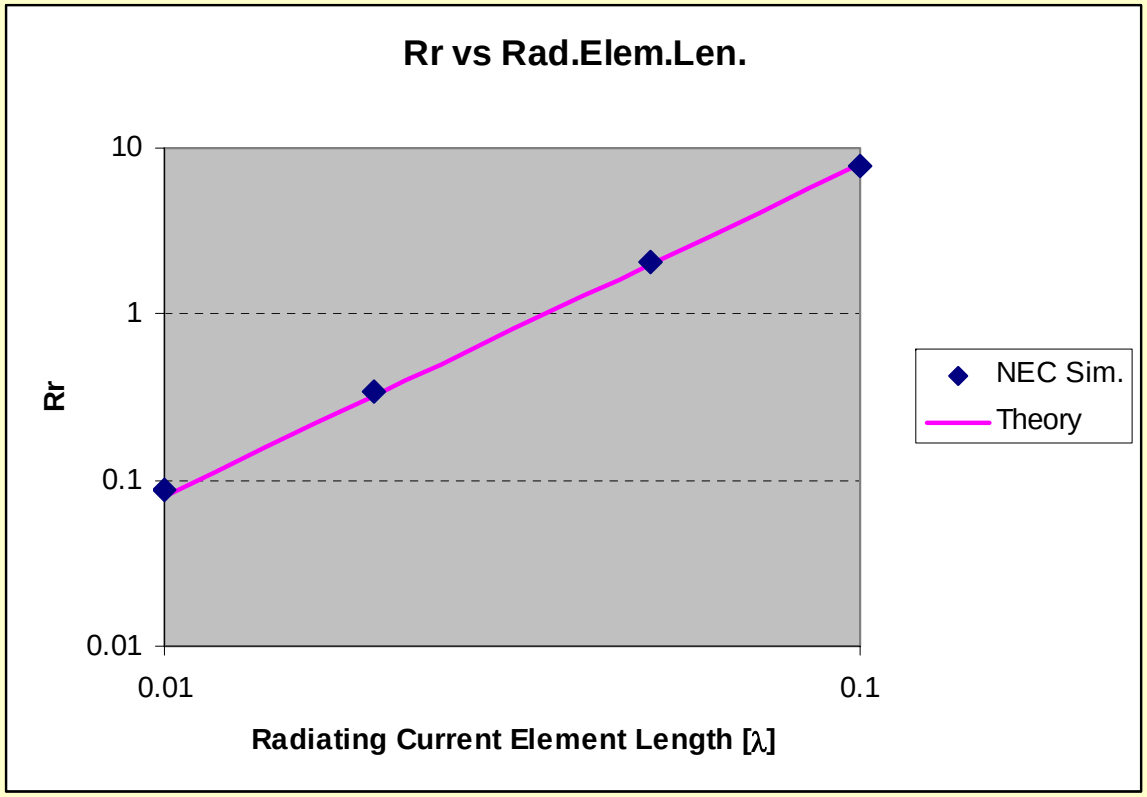
- Demonstrate through simulation of a double-loaded transmission-line antenna.



- Vertical Element
  - Primary Radiating Element
  - Length, Δz, small fraction of wavelength, i.e., $\Delta z << \lambda$
  - Uniform current

Electrical Behavior - Radiation Resistance

- Radiation resistance of a ***uniform*** current element



NEC Results

Δz/λ	Re(Zin)
0.1	7.9
0.05	2.082
0.02	0.345
0.01	0.087

Theory

$$R_r \cong 800\left(\frac{\Delta z}{\lambda}\right)^2$$

Electrical Behavior - Radiation Efficiency

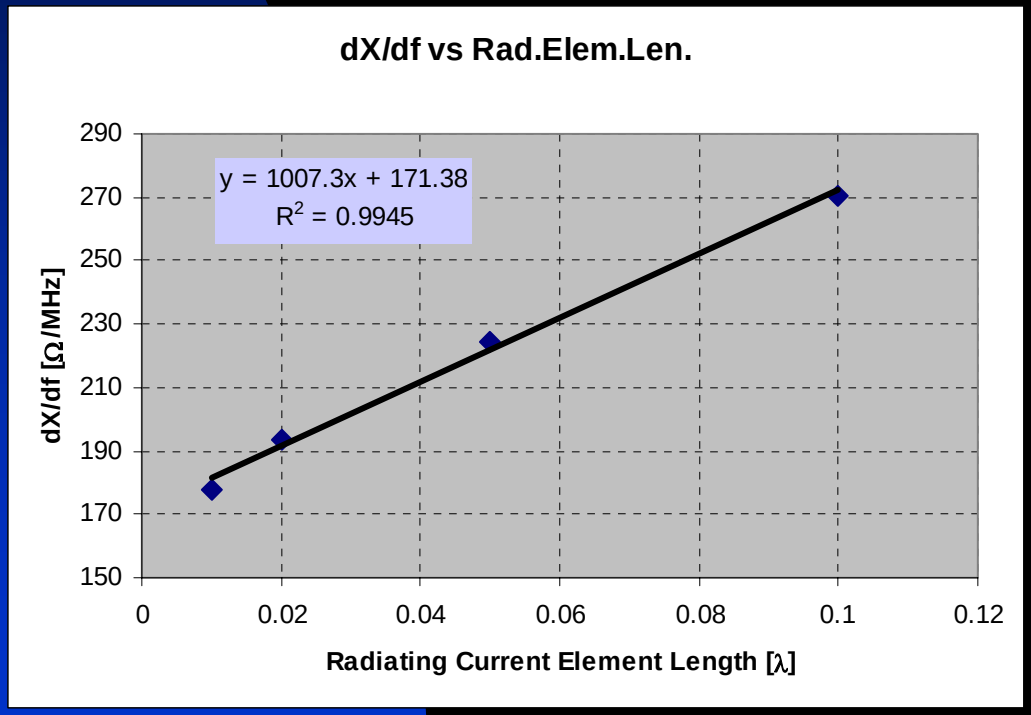
- Radiation efficiency

$$\eta = \frac{|I|^2 R_r}{|I|^2 R_{total}} = \frac{R_r}{R_r + R_l}$$

- **For sufficiently small element, Δz**
  - radiation resistance, Rr, becomes a small fraction of loss resistance, Rl
  - **Radiation efficiency decreases exponentially with decreasing element length, Δz**

Electrical Behavior – Reactance, X

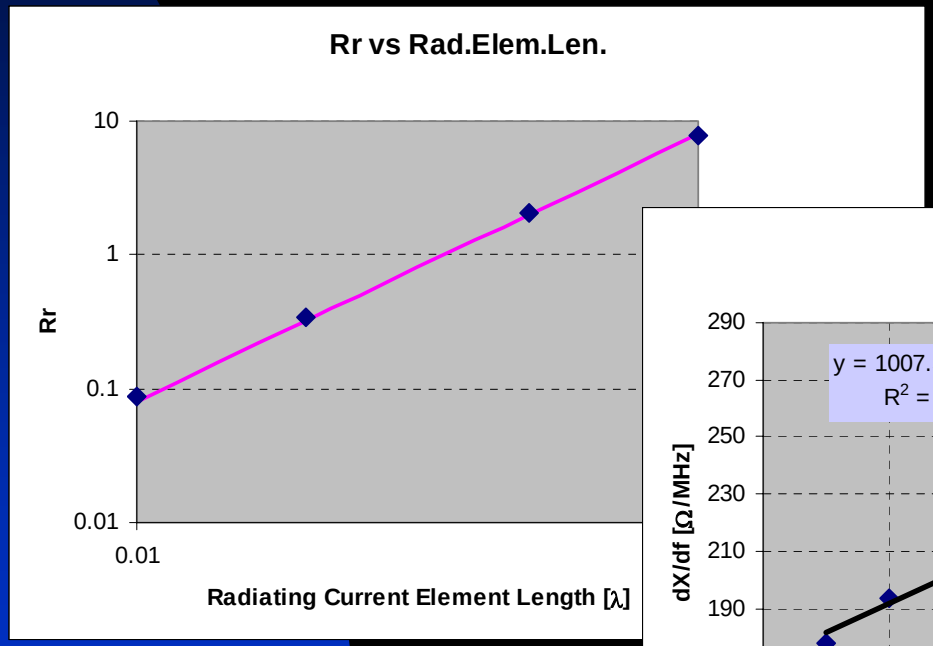
- Generally, the **reactance** (of a short, resonant antenna) **deviates greatly** in response to an **incremental frequency change**.

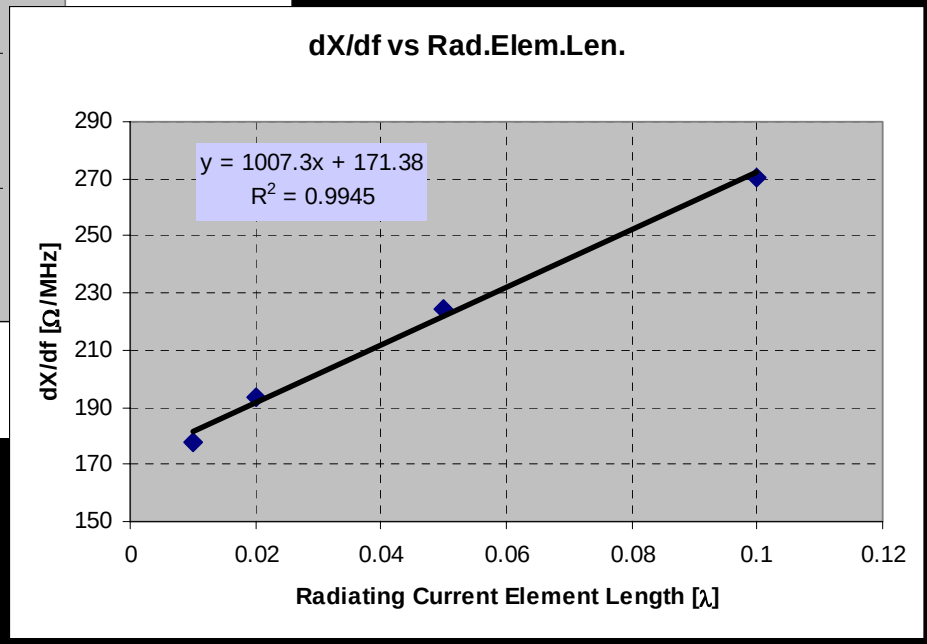


dX/df = ΔX/Δf : The change in reactance, X, divided by the corresponding change in frequency, f.

Electrical Behavior – Reactance, X (cont.)

- X deviates greatly - ***relative*** to Rr
  - Leads to NARROW Bandwidth





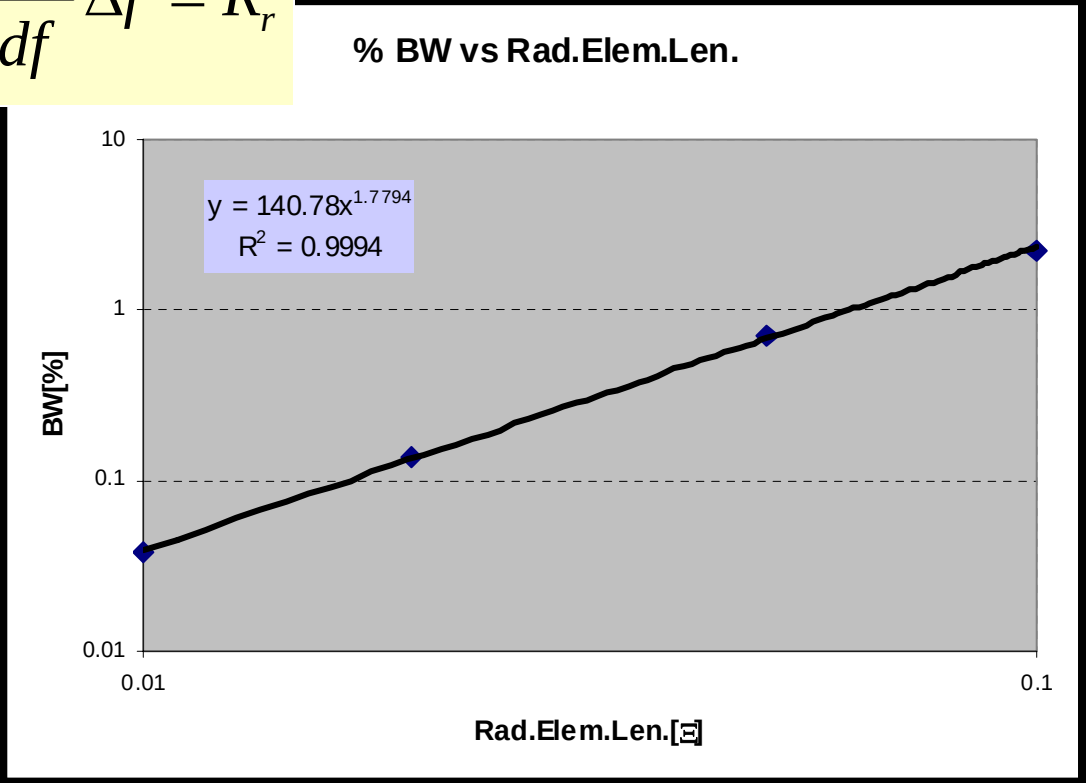
Electrical Behavior – Bandwidth

- Impedance Bandwidth

$$BW = 2\Delta f \quad \text{where} \quad \frac{dX}{df}\Delta f = R_r$$

BW @ VSWR~3

Band	Freq [MHz]	BW [%]
160m	1.8-2	10.5
80m	3.5-4	13.4
40m	7-7.3	4.2
10m	28 -29.7	5.9

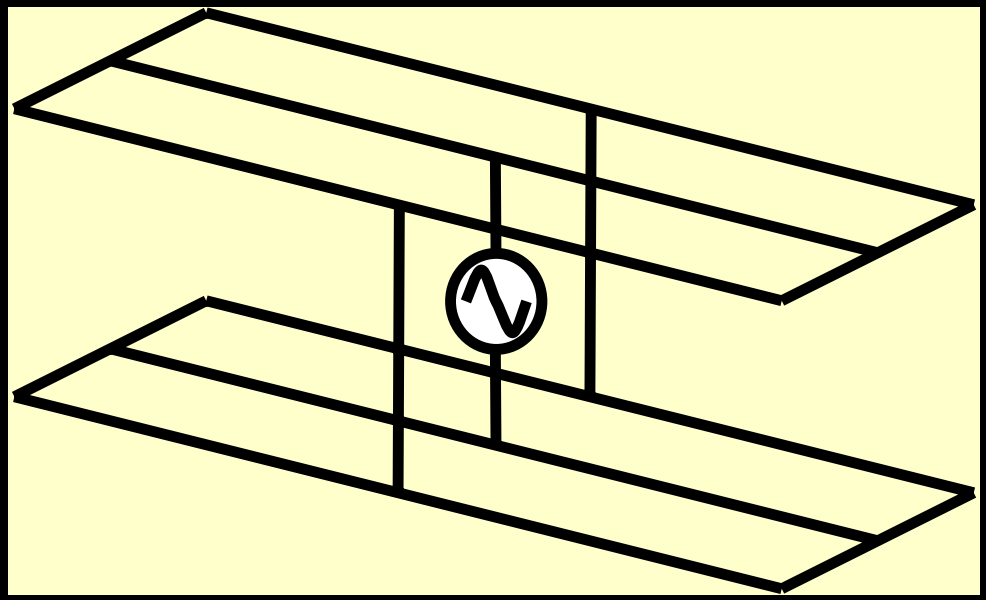


Methods to Improve Performance – Current Division

- Current Division Among Closely Spaced Elements
- "Folded Dipole" concept

$$Rrr = N^2 Rr$$

Example: Assume Rr=20Ω, N=3; then Rrr=9(20)=180Ω



Methods to Improve Performance – Current Division (cont.)

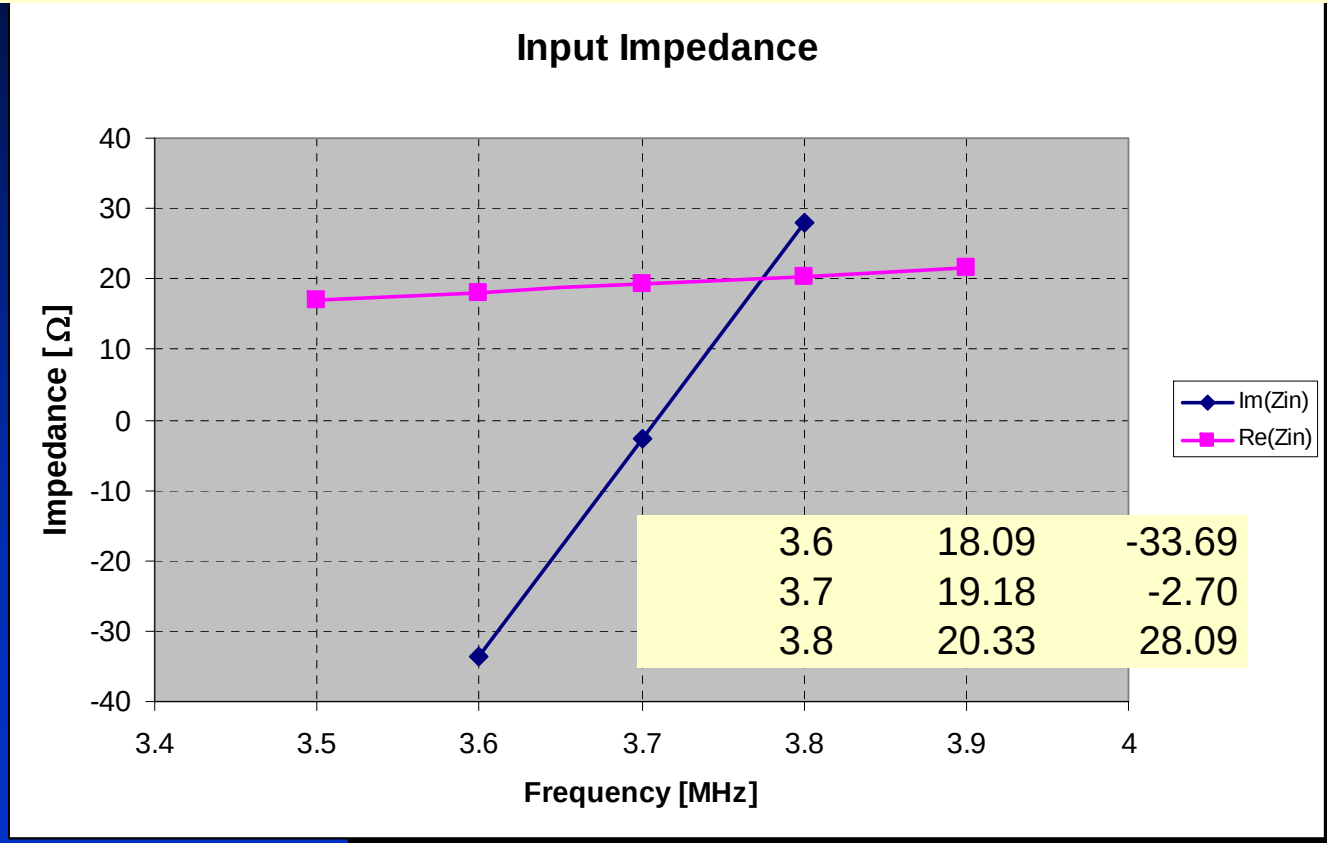
- Current Division improves
  - Efficiency
    - Increase no.elements
    - decrease current flow through each element
    - I^2R
  - Bandwidth – similar to folded-dipoles
  - Resonant impedance

Methods to Improve Performance – Earth as Ground Plane

- Analysis (“Method of Images”)
  - Vertical current element (our antenna)
    - close to ideal ground
  - Doubles radiation resistance
  - Due to “image” current on other side of ground
- Simulation
  - Real (avg.) ground
  - Very similar result

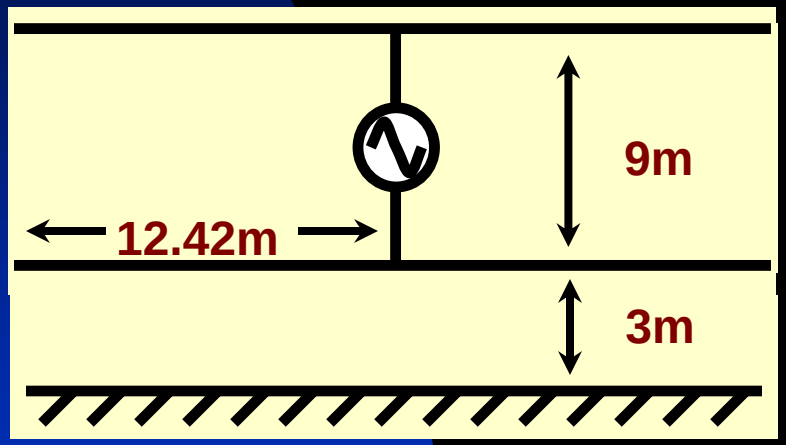
Methods to Improve Performance – Earth as Ground Plane (cont)

Impedance of "H" Antenna Above Ground – Details next slide.



Methods to Improve Performance – Earth as Ground Plane (cont)

Summary of "H" Antenna Above Ground



Single H element
- 3m above ground (bottom element)
- Vertical element: 9m tall, center fed
- Loading elements are 24.84m end-to-end

"Average" Ground
- σ = 0.005 S/m
- ε_r = 13

f_0=3.709MHz

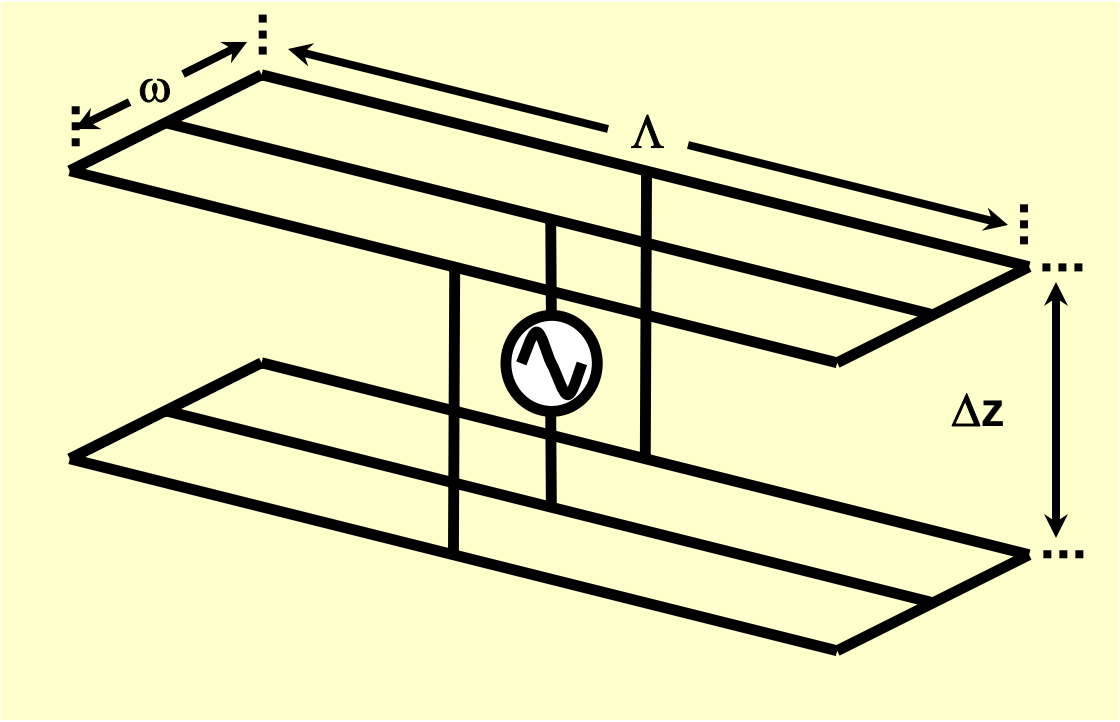
Antenna Mismatch & Transmission-line Losses

- How much mismatch can I tolerate?
  - Transmission-line losses
  - Impedance Matching Constraints

Proposed Antenna

- 3 “H” elements in parallel
- Mounted “close” to ground (10 feet)
- Zin ~ 9(19) = 171Ω

Proposed Antenna



Antenna Parameters
- ω = 2m
- Λ = 24.84m
- Δz = 9m

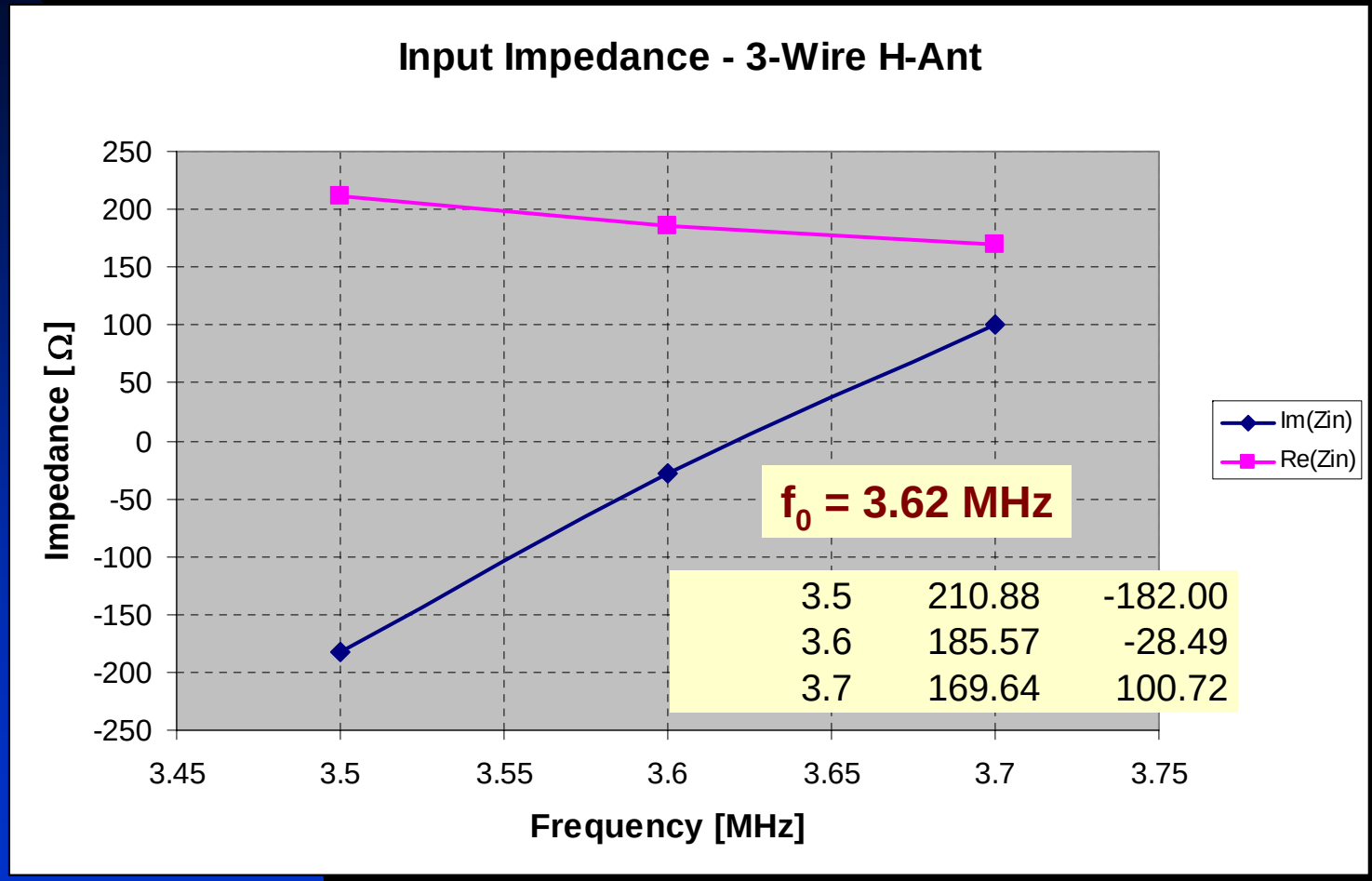
Center vertical element center-fed

3m above ground (bottom element)

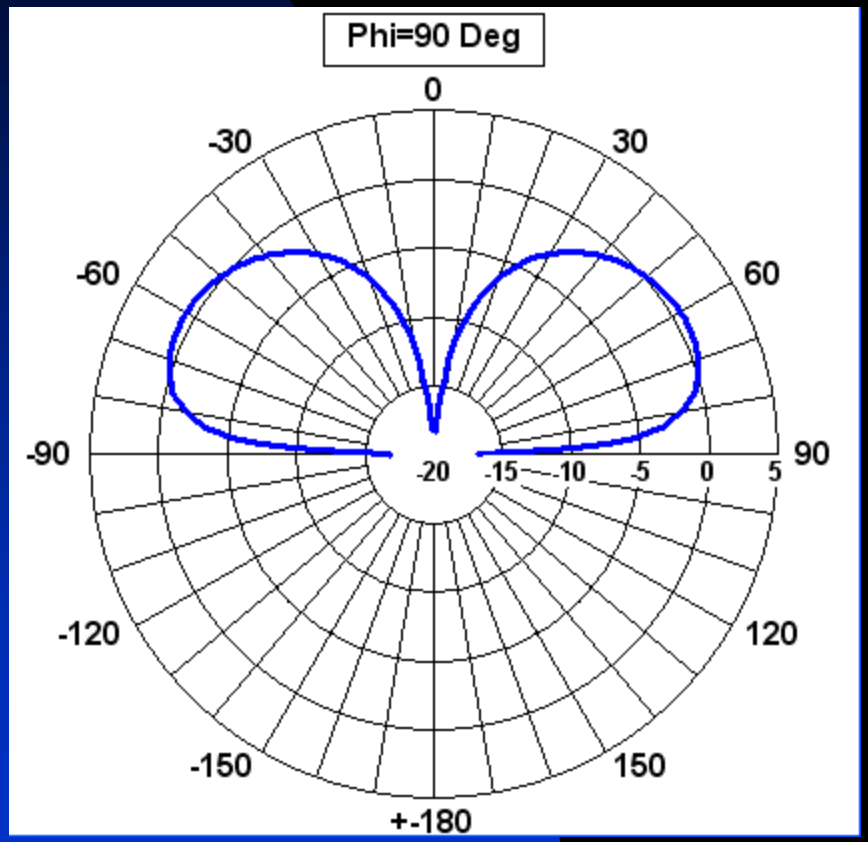
"Avg." Ground
- σ = 0.005 S/m
- ε_r = 13

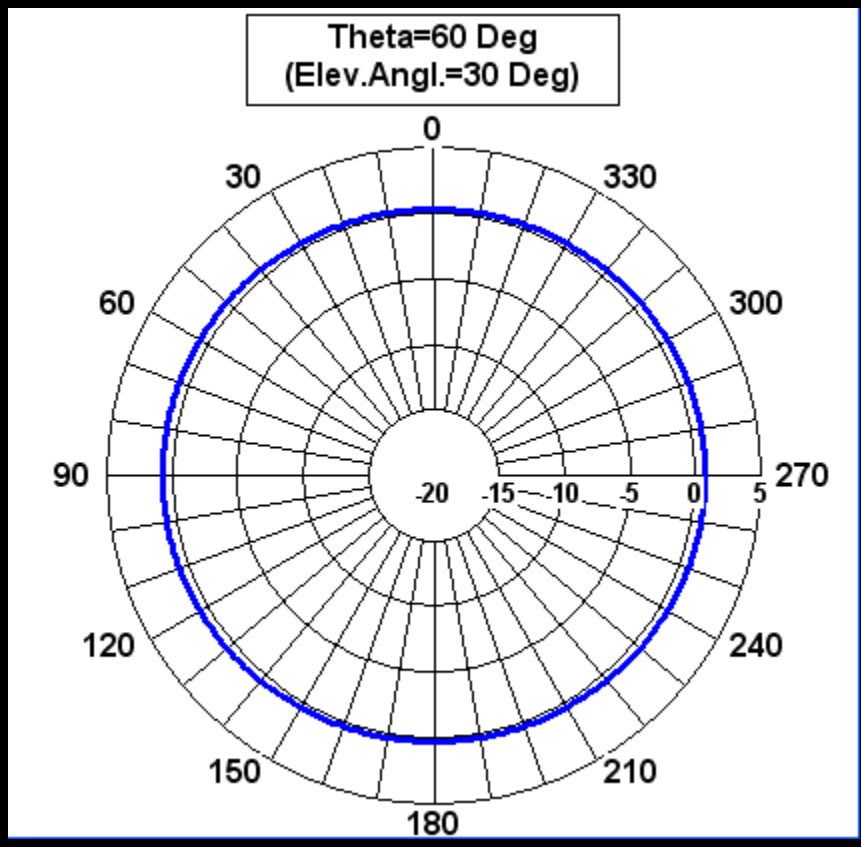
f_0 = 3.62 MHz

Proposed Antenna – Zin Near f0

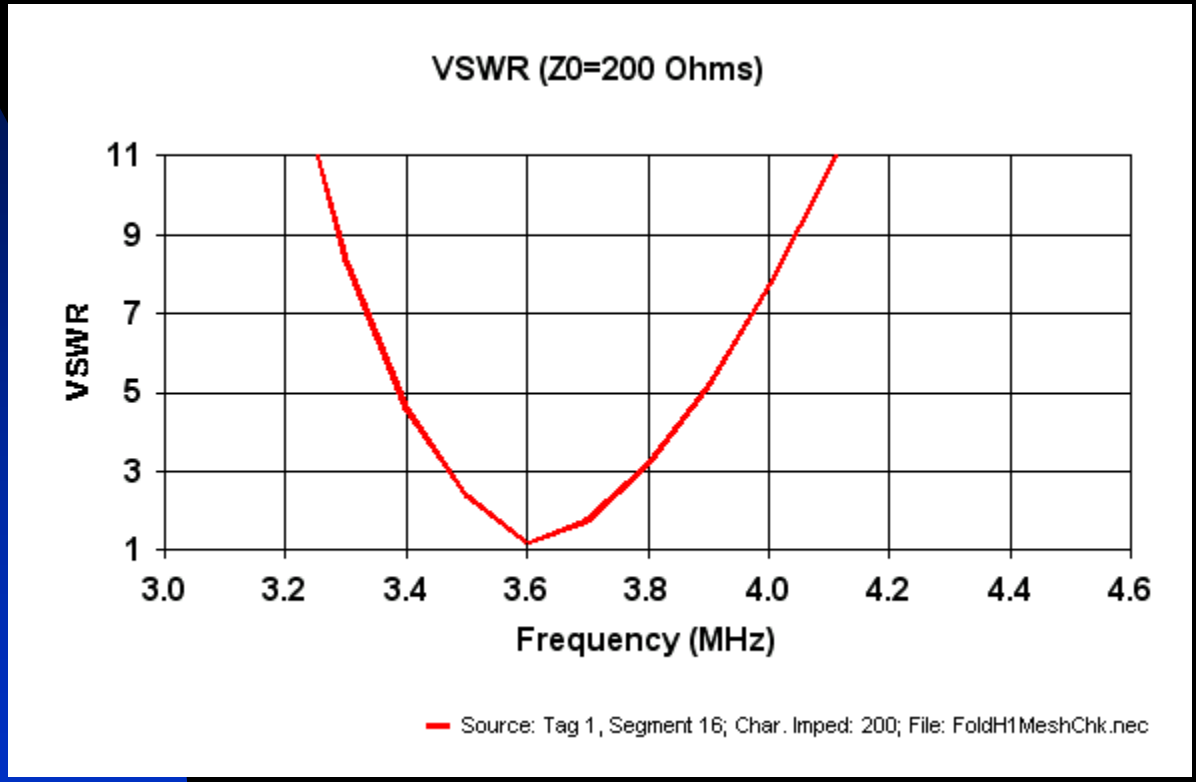


Proposed Antenna – Radiation Pattern

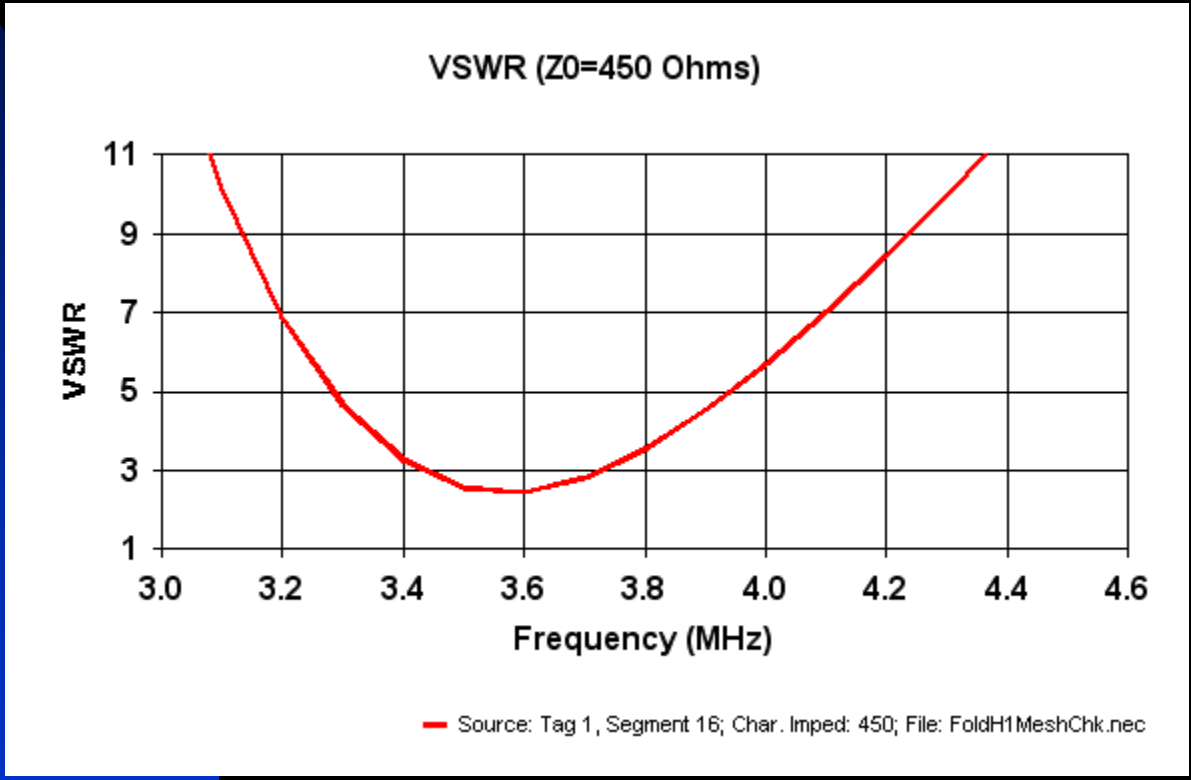




Proposed Antenna – VSWR (Z0=200)



Proposed Antenna – VSWR (Z0=450)



What This Means

- It’s possible to design a “reasonable” short antenna!