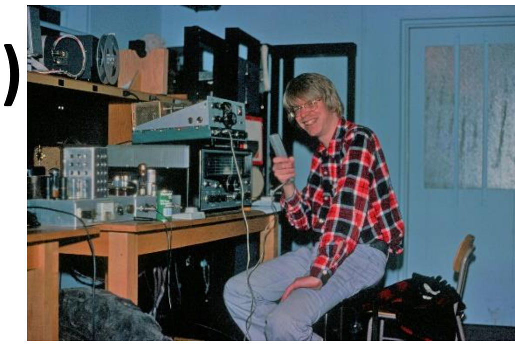
Some Practical and Useful Antenna Innovations for Amateur Radio

Professor Jim Breakall
WA3FET (K3CR, WP3R, KC3R)
Penn State University



Dayton Amateur Radio Association
February 5th, 2021

Dayton Hamvention®

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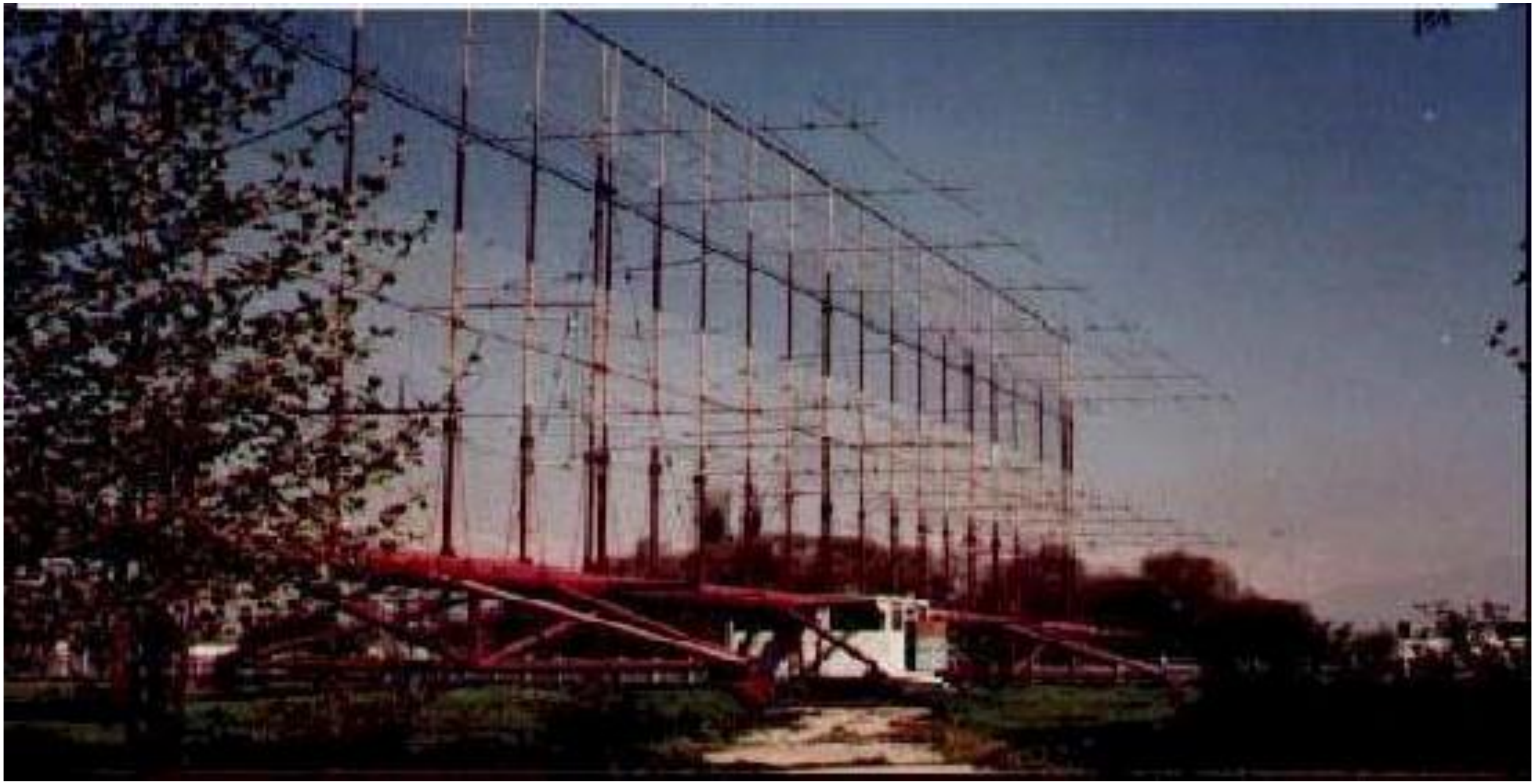
Big Gun Friendship Net (BGFN)

Ham Radio Contesting !!!

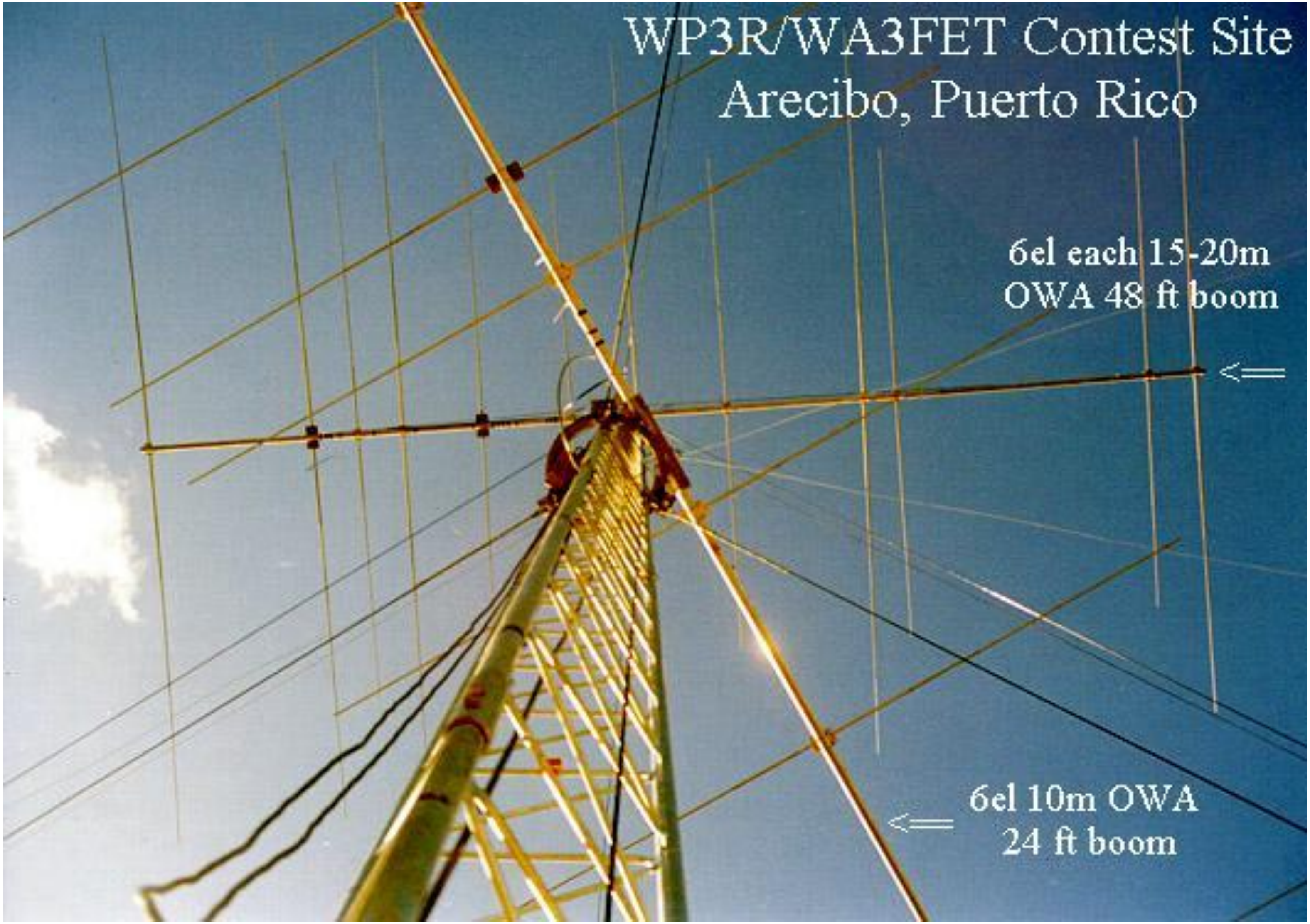


K3CR Contest Station at Penn State

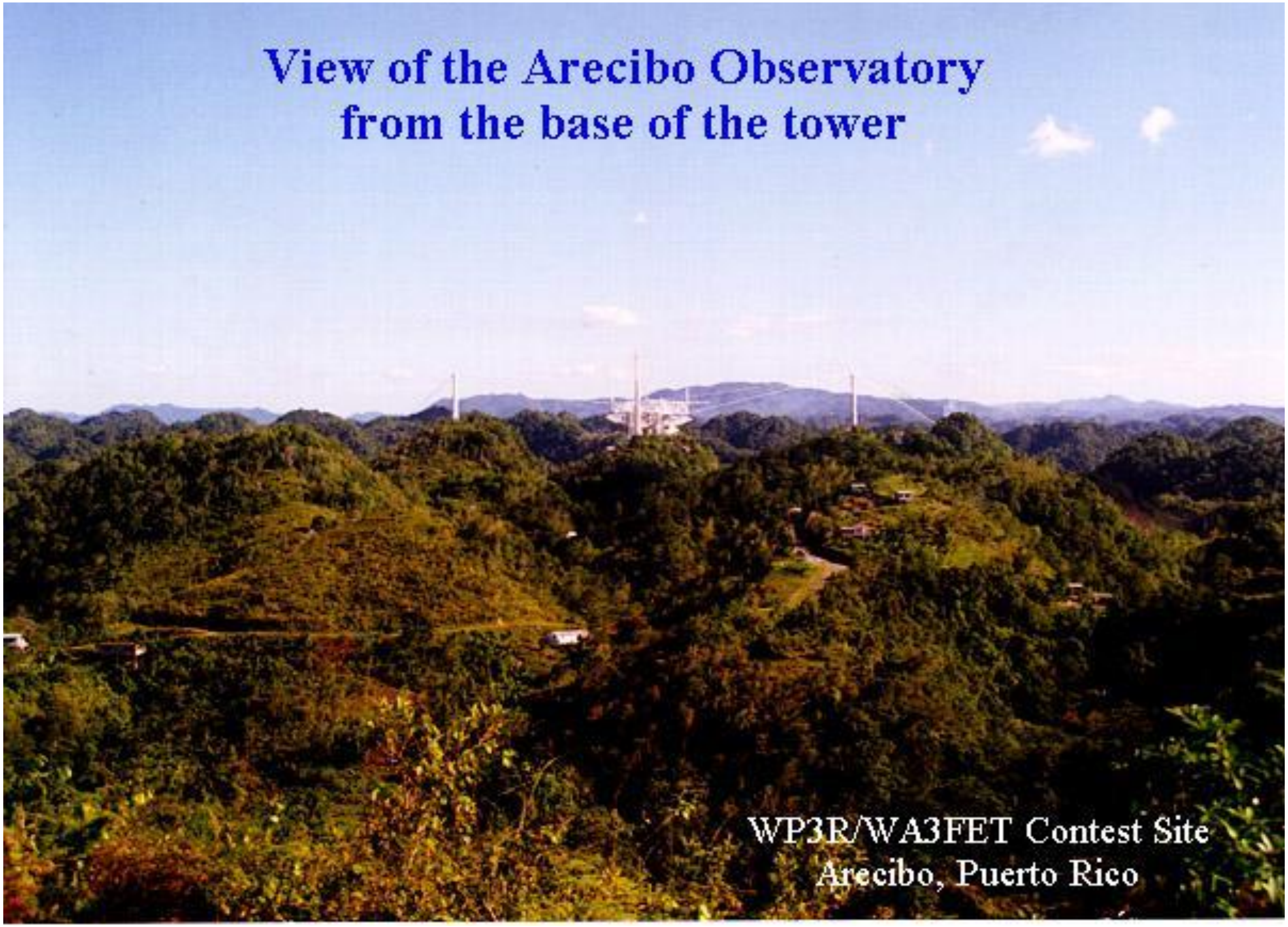
K3CR Contest Station at Penn State

WP3R/WA3FET Contest Station

WP3R/WA3FET Contest Station



WP3R/WA3FET Contest Station



Six Arecibo 100 kW HF Transmitters

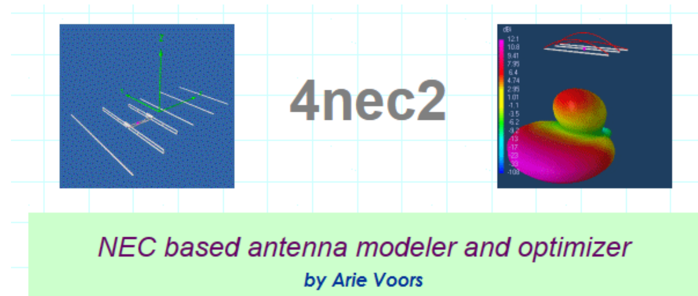
Future Contest Setup for WP3R for 160 to 10 meters??!!

Some Interesting Topics Covered Today

- How good are modeling codes really for analyzing and designing a dipole antenna?
- Does 468/frequency really work?
- How to use interpolation to get it tuned to resonance.
- A new method of designing a dipole that is independent of the diameter of the wire.
- The 43 foot vertical – is that really the best height?
- My old and trustworthy 80/40 (20) inverted-V fan dipole.
- My 40m 6 element Hamstick passive receive array
- Designing the SuperDARN HF log periodic array at the South Pole with new methods.

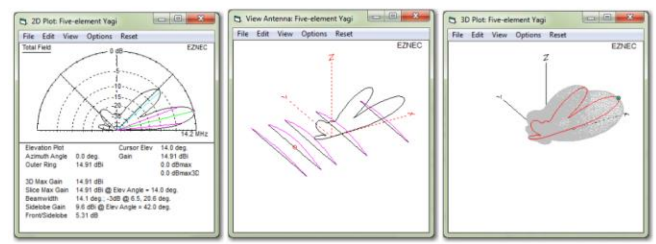
Various Antenna Modeling Codes based on NEC and MININEC

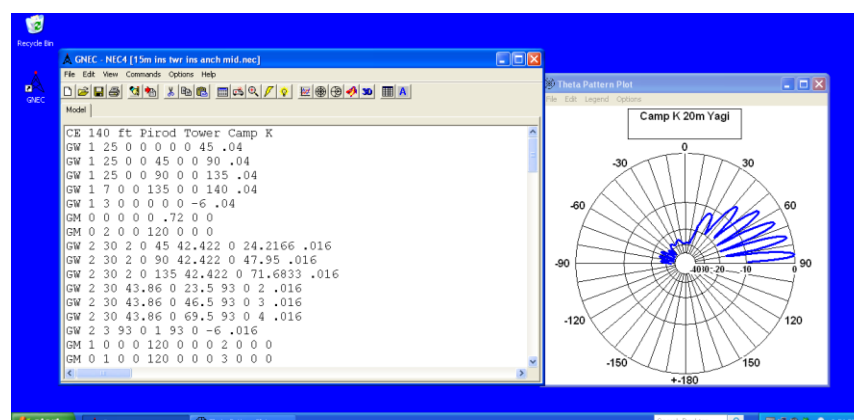
MMANA-GAL



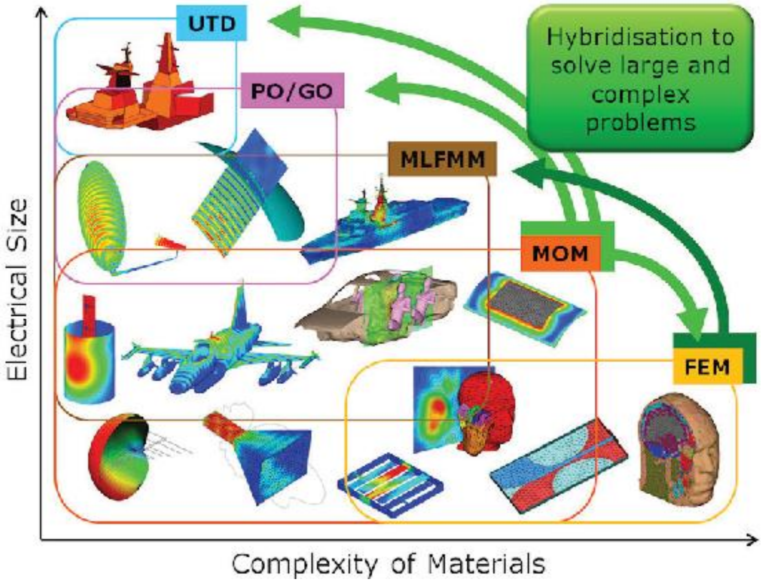
EZNEC Antenna Software by W7EL

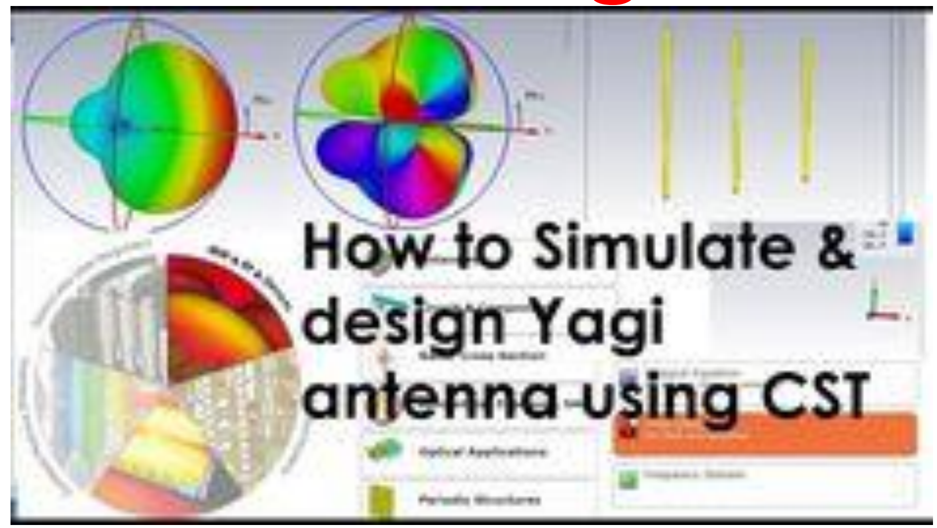
FREE - EZNEC Pro+ v. 7.0 is now available! - FREE



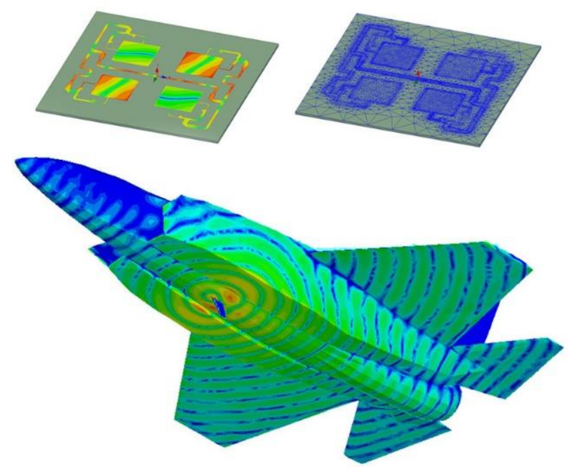


Some Modern State-of-the-Art Commercial Antenna Packages





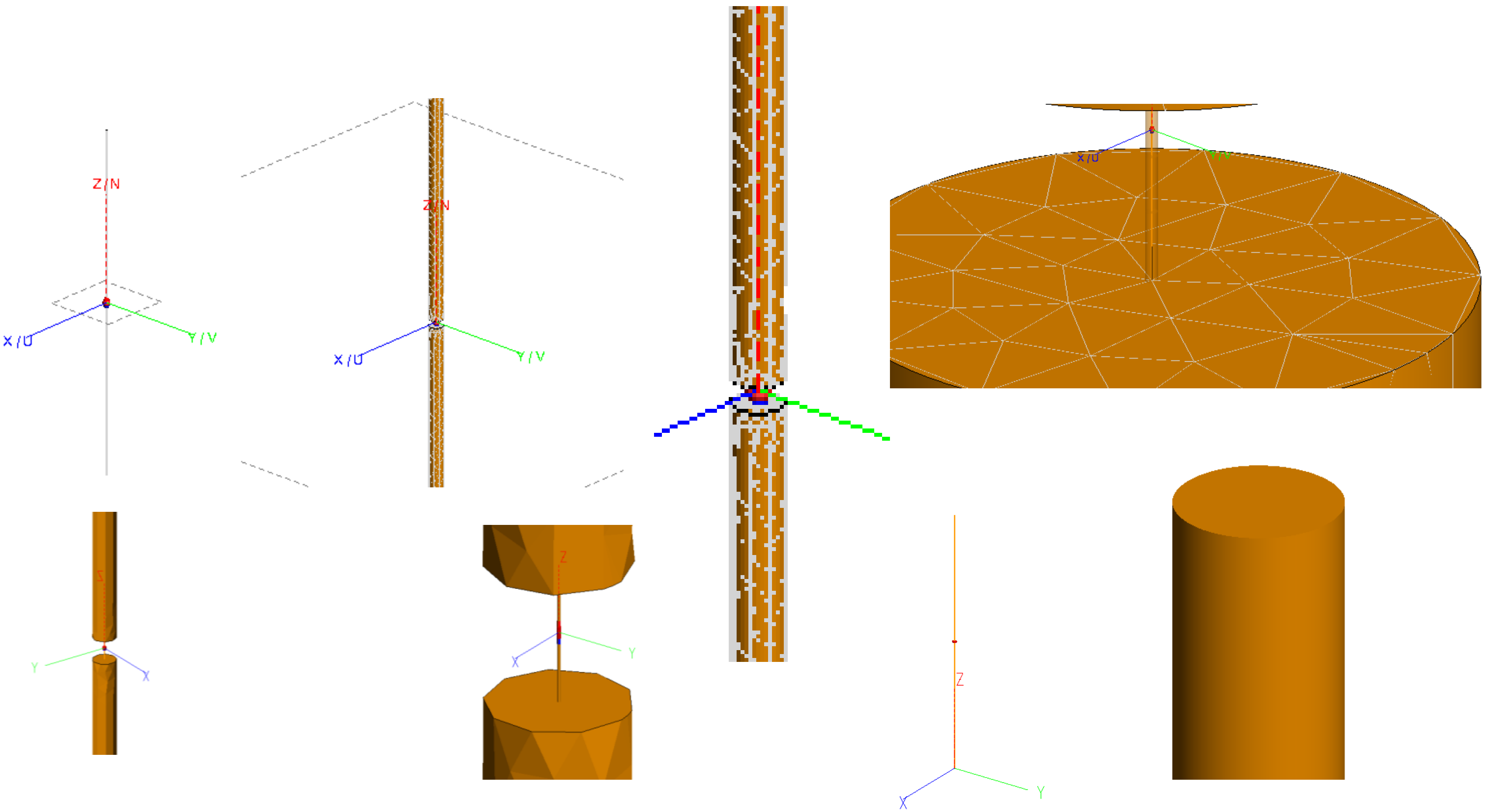
FEKO
Comprehensive Electromagnetic Solutions



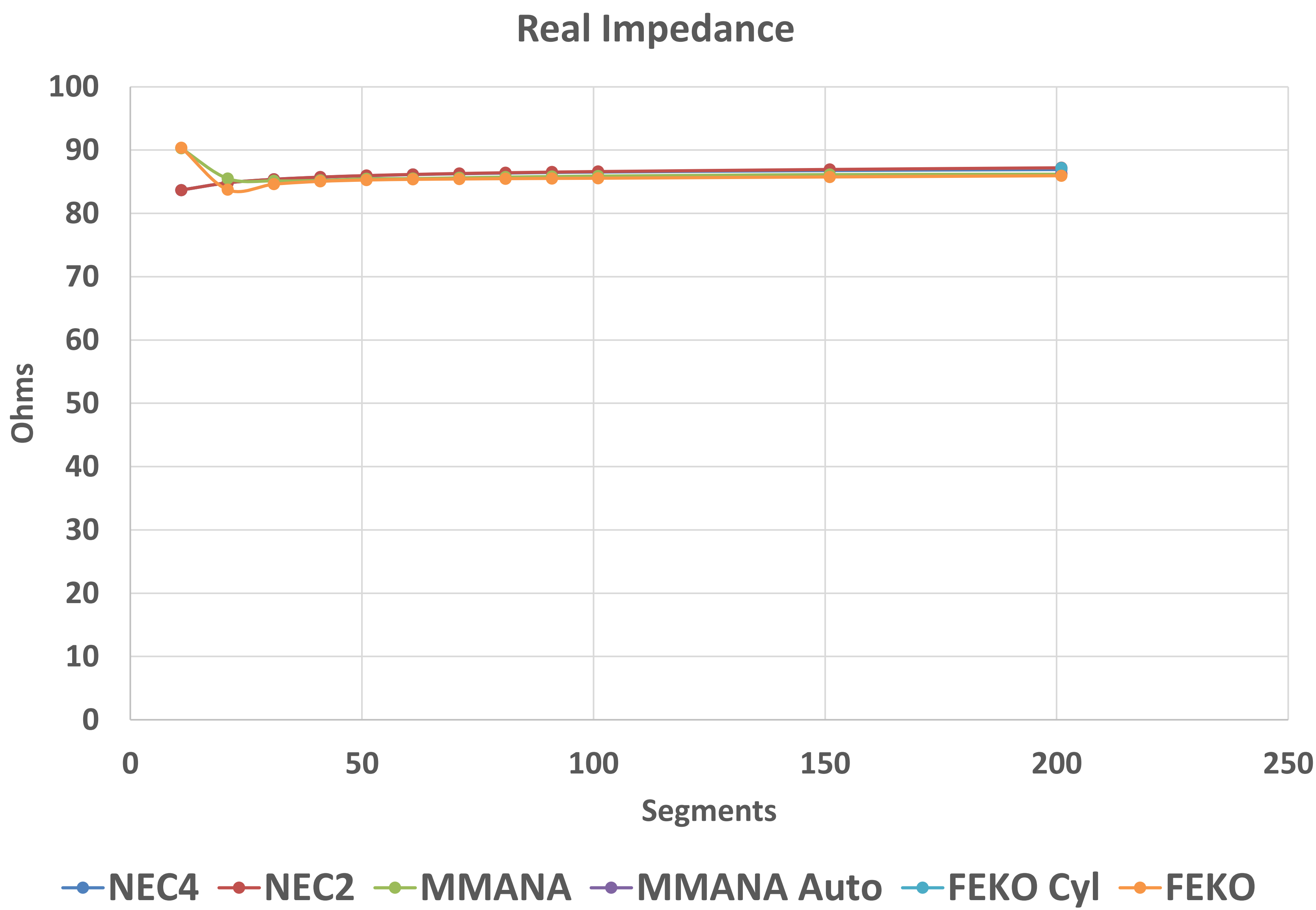
Ansys / HFSS

How do all the codes do with a half-wave dipole vs number of segments?

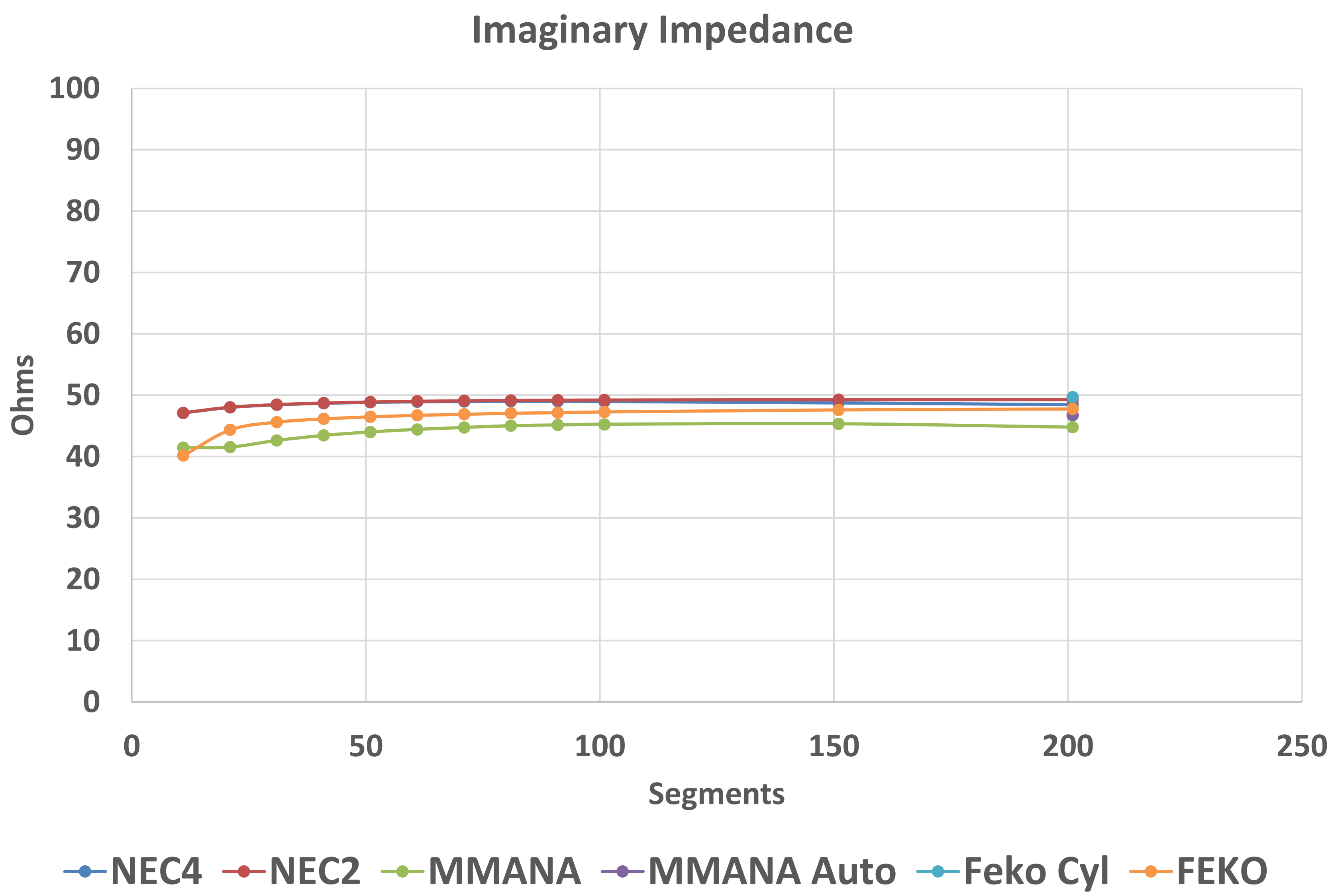
- **Half-wave dipole with radius = .001 wavelenths**
- **FEKO cylinder model as a reference**



Dipole Modeled with GNEC, MMANA-GAL, FEKO Wire and Cylinder



Dipole Modeled with GNEC, MMANA-GAL, FEKO Wire and Cylinder



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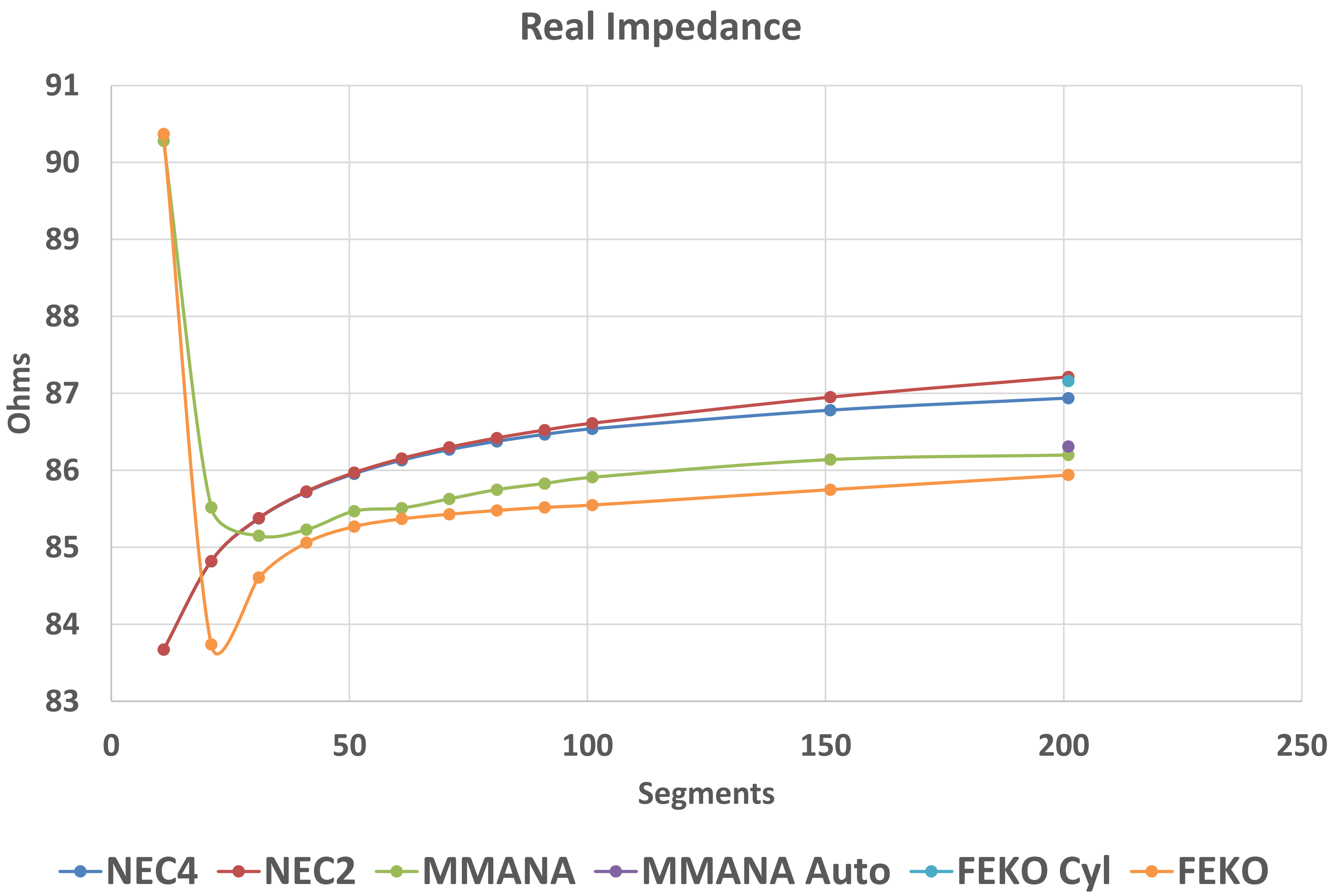
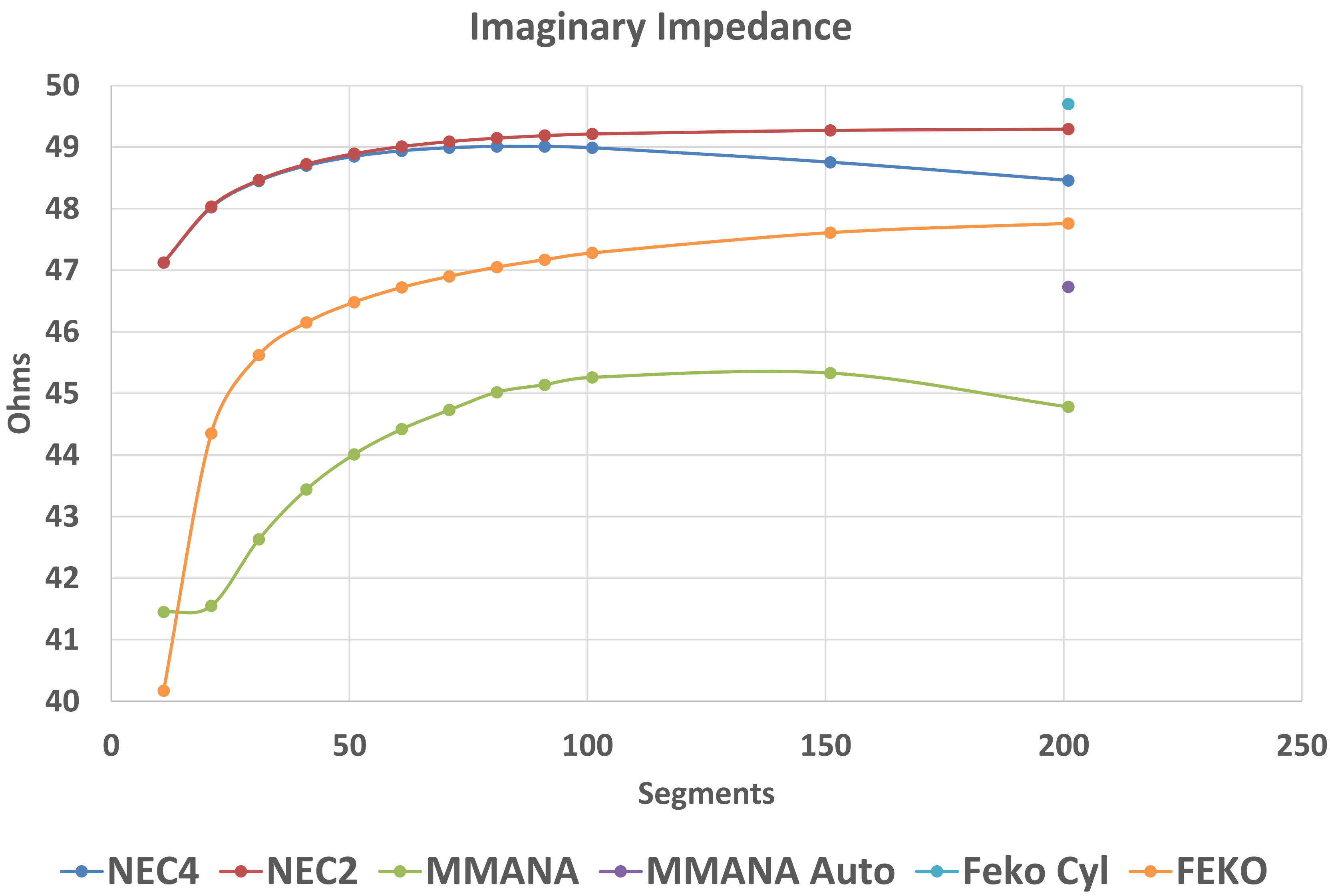


Dipole Modeled with GNEC, MMANA-GAL, FEKO Wire and Cylinder



WE ARE!

BIG 10

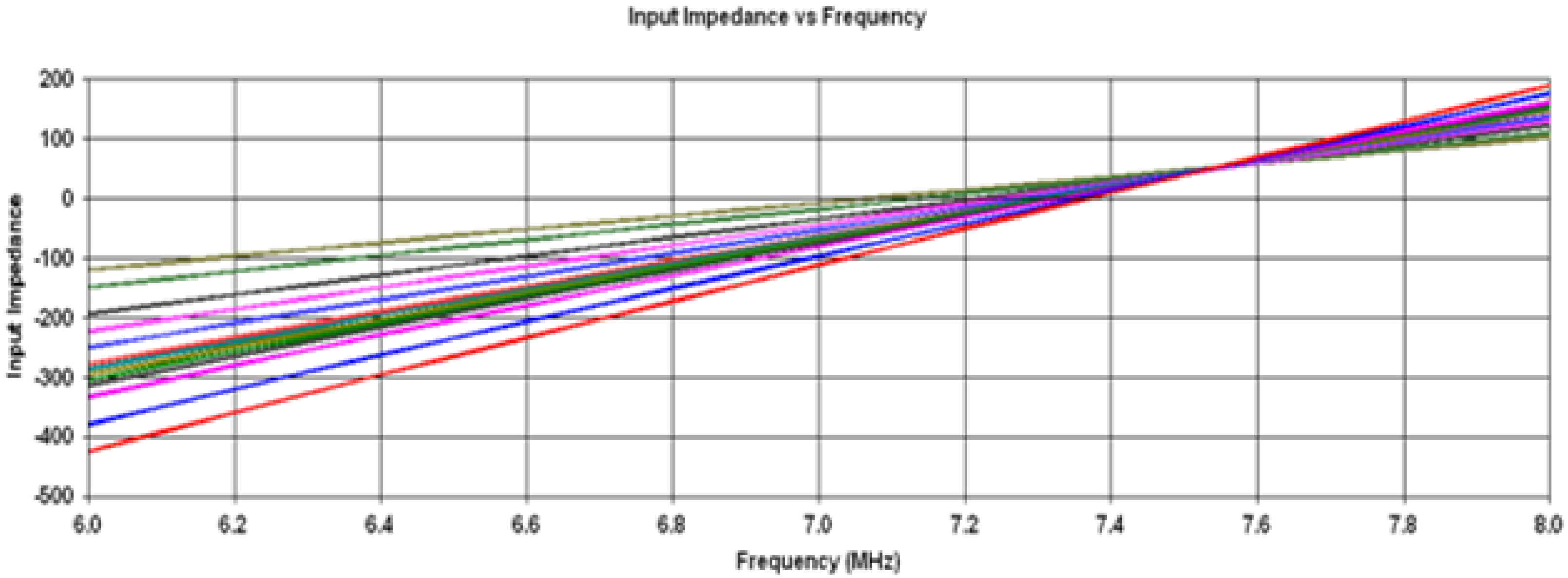
CHAMPS!

PENN STATE

What about 468/frequency (MHz) gives dipole length in feet?

- **Where does 468 come from?**
- **Ward Silver N0AX had an article in Eham.net in May, 2010.** [Where Does 468 Come From? (eham.net)]
- ***"Every ham is expected to memorize it... it's rarely correct."***
- **ARRL Antenna Book (initial edition 1939):** ***"the "end effect" due to the attachment of insulators at the ends of the antenna results in the approximately 5% reduction in length from the free-space 492/f to 468/f."***
- **ARRL Handbook (initial edition 1929):** ***"natural wavelength" and "(300 x 1.56)/f = 468/f"***
- **Ward's conclusion – No real background was ever found and trial and error and an antenna analyzer is best to adjust the dipole to resonance (imaginary part of impedance = 0 ohms.**

40m dipole modeled at 7.15 MHz with various diameters in free space
Formula varies from 458/f to 484/f – 93% to 98% of a halfwave (492/f)



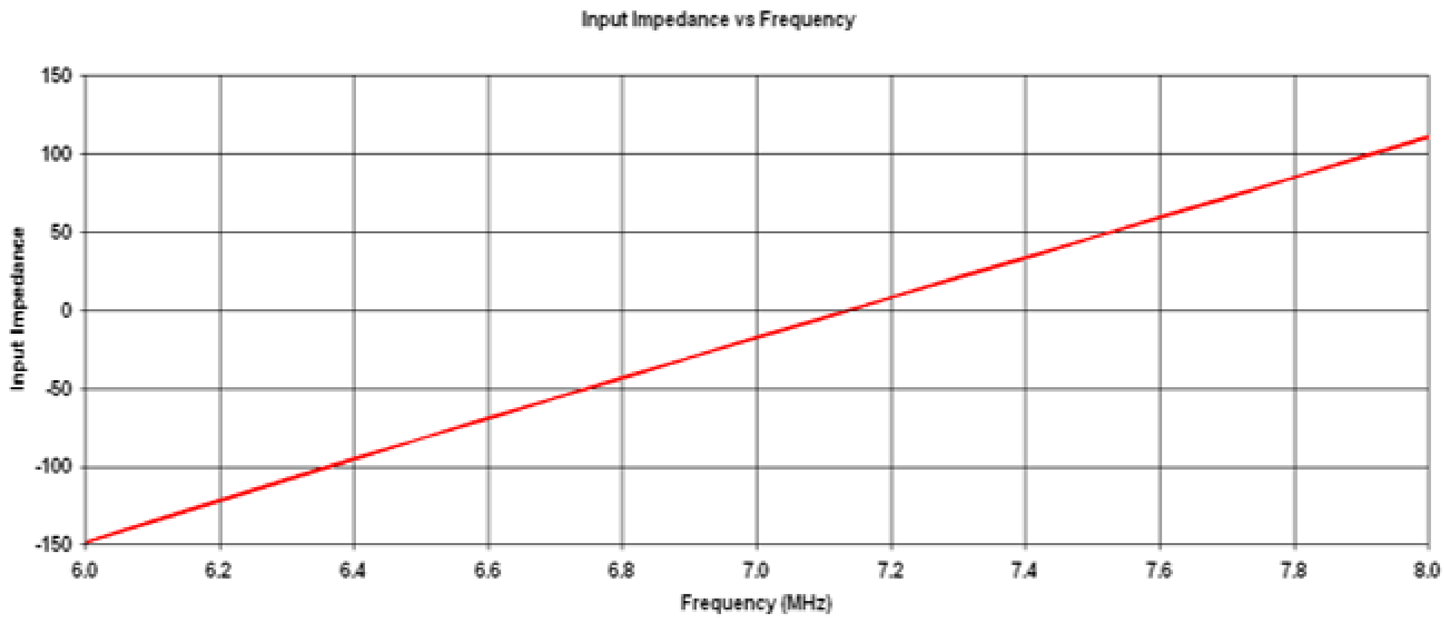
Imaginary Input Impedance of Dipole with formula 468/freq for 7.15 MHz – 65.454 ft in Free Space

Diameters – Gauges 40, 30, 20, 16, 14, 12, 10, and

1/8, ¼, ½, 1, 3, 6 inches

What diameter is closest to 468/f

- 468/7.15 = 65.454 ft

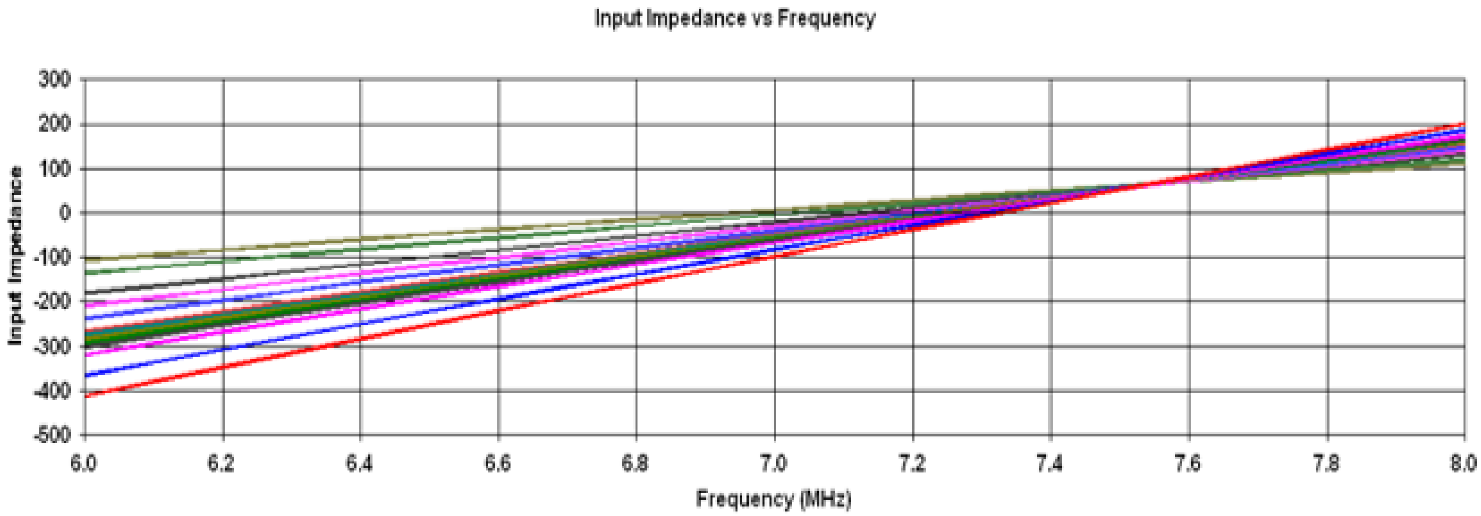


Diameter that is closest to desired resonant frequency is 3 inches in diameter

- 3 inches at 7.15 MHz is a radius of .0009 wavelengths

What about over ground at a height of 35 ft?

- Use average ground (relative dielectric constant = 13, conductivity = .005 S/m)

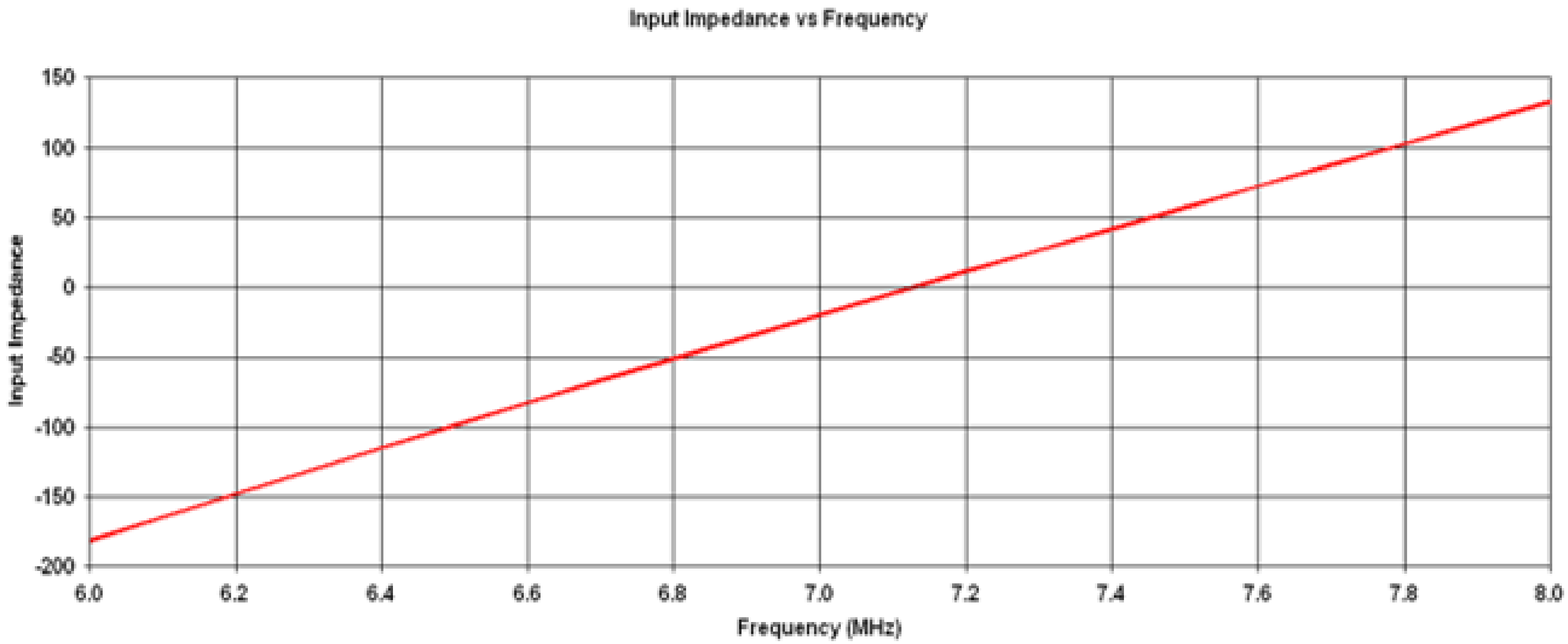


Imaginary Input Impedance of Dipole with formula 468/freq for 7.15 MHz – 65.454 ft over Average Ground (epsr = 13, sigma = .005 S/m) with Height = 35 ft

Diameters – Gauges 40, 30, 20, 16, 14, 12, 10, and

1/8, ¼, ½, 1, 3, 6 inches

What diameter is closest to 468/f over ground?

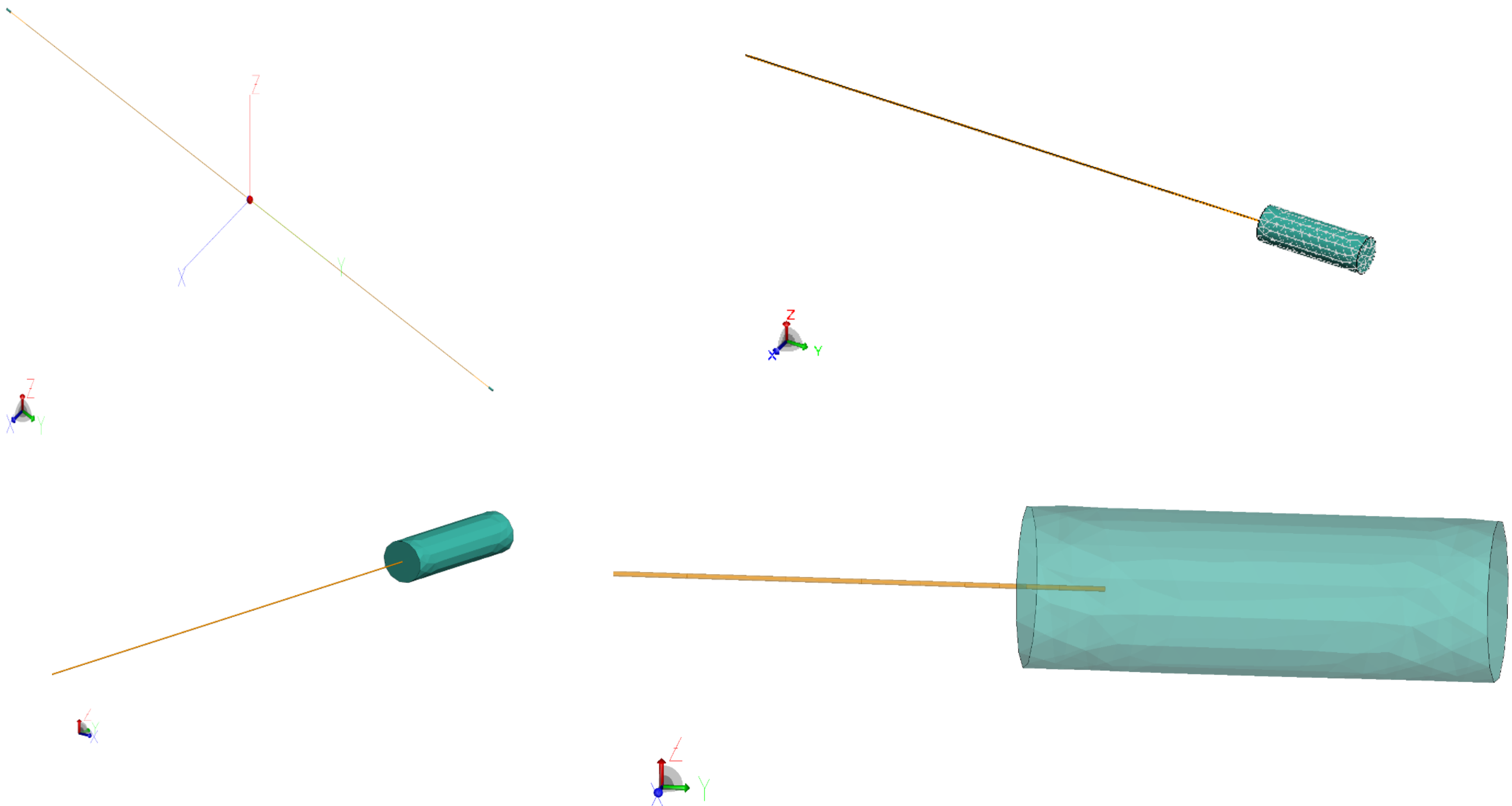


Diameter again that is closest to desired resonant frequency is 3 inches in diameter

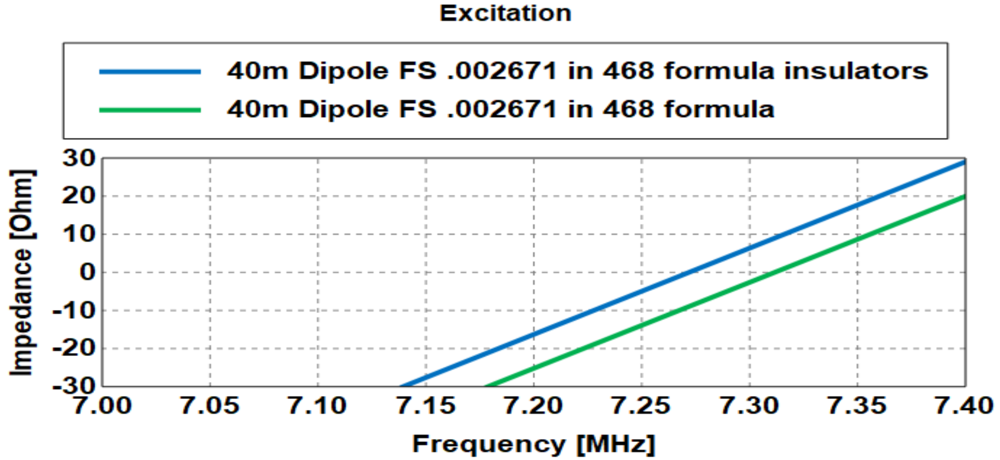
What about statements that it is the end insulators that causes a 5% decrease from a half-wavelength

(492 x .95)/f = 468/f

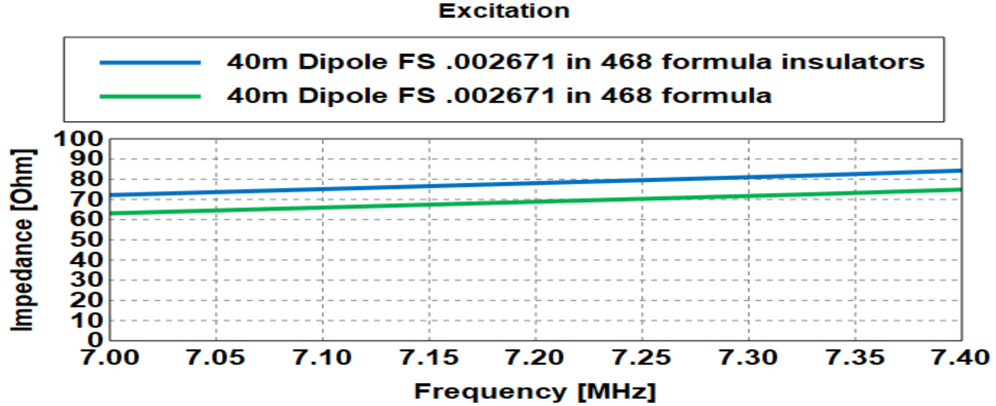
Insulator 2 inches x 6 inches



Shortening from end insulator effects
No Insulator – 478/f
Insulator – 476/f (Small Effect)



Imaginary Impedance

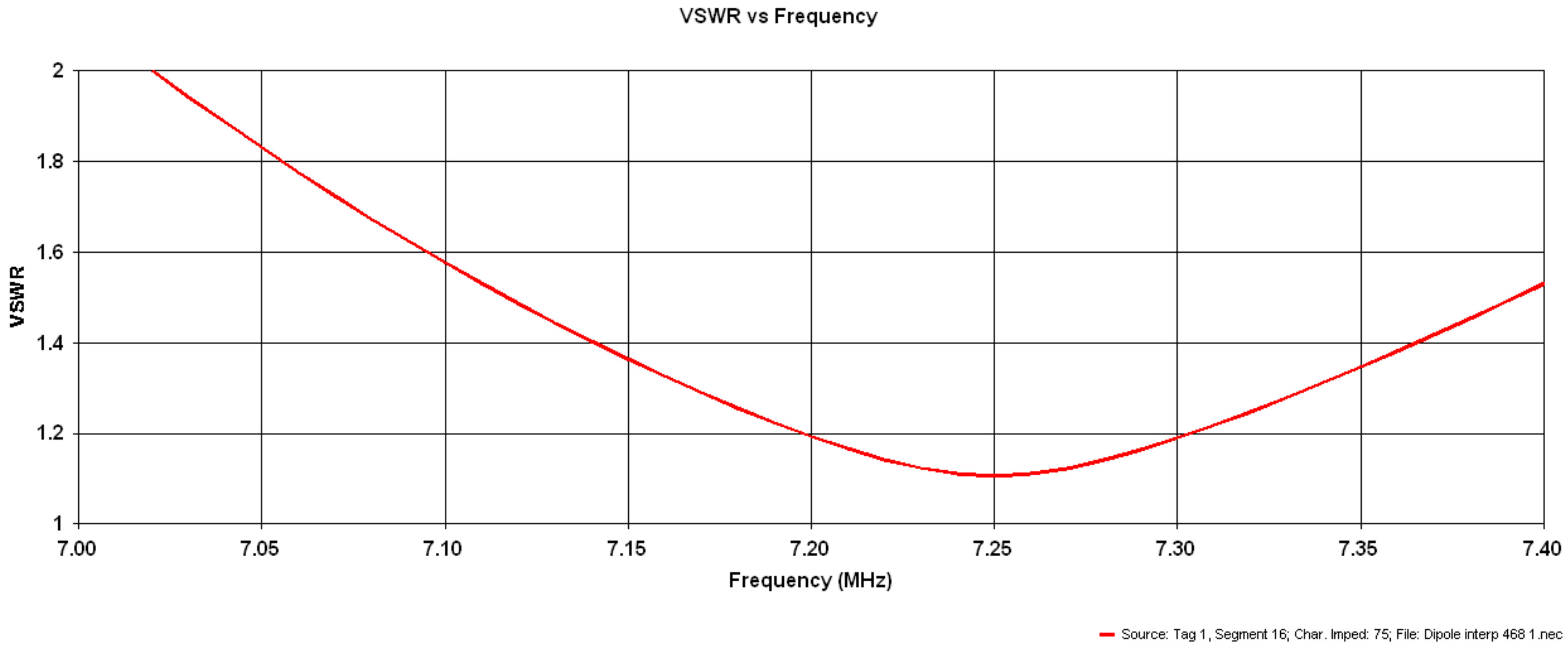


Real Impedance

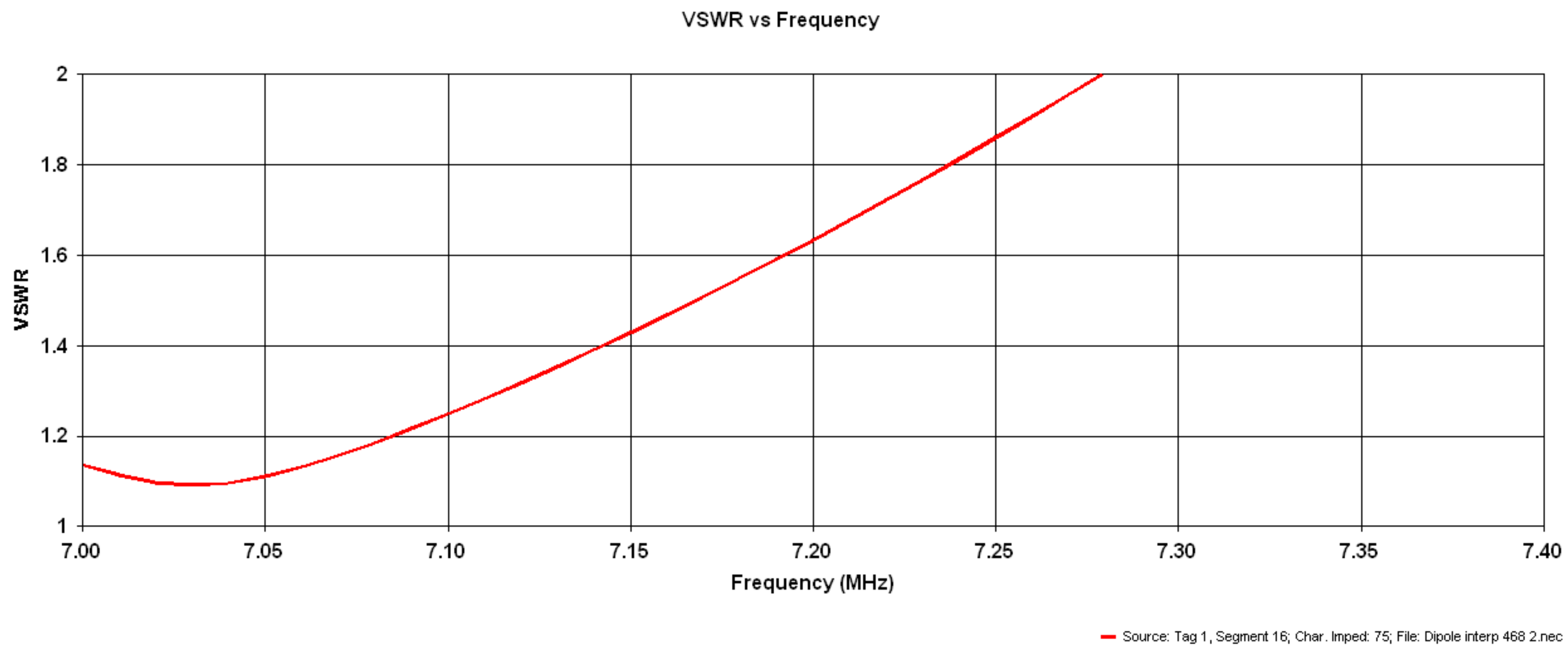
How to use the magic of interpolation to always get the correct length for a desired frequency

- Use 468/f to get length for a starting point
- Ex. F = 7.150 MHz → 468/7.15 = L1 = 65.454 ft
- Measure frequency of lowest SWR → F1
- F1 = 7.255 MHz (Not 7.15 MHz) for #14 wire
- Add 2 ft → L2 = 67.454 ft
- Measure new frequency for lowest SWR → F2
- F2 = 7.035 MHz
- **L = (L2-L1)/(F2-F1) x (F-F1) + L1**
- L = (67.454-65.454)/(7.035-7.255) x (7.15-7.255) + 32.727 = 66.4 ft (Correct length)

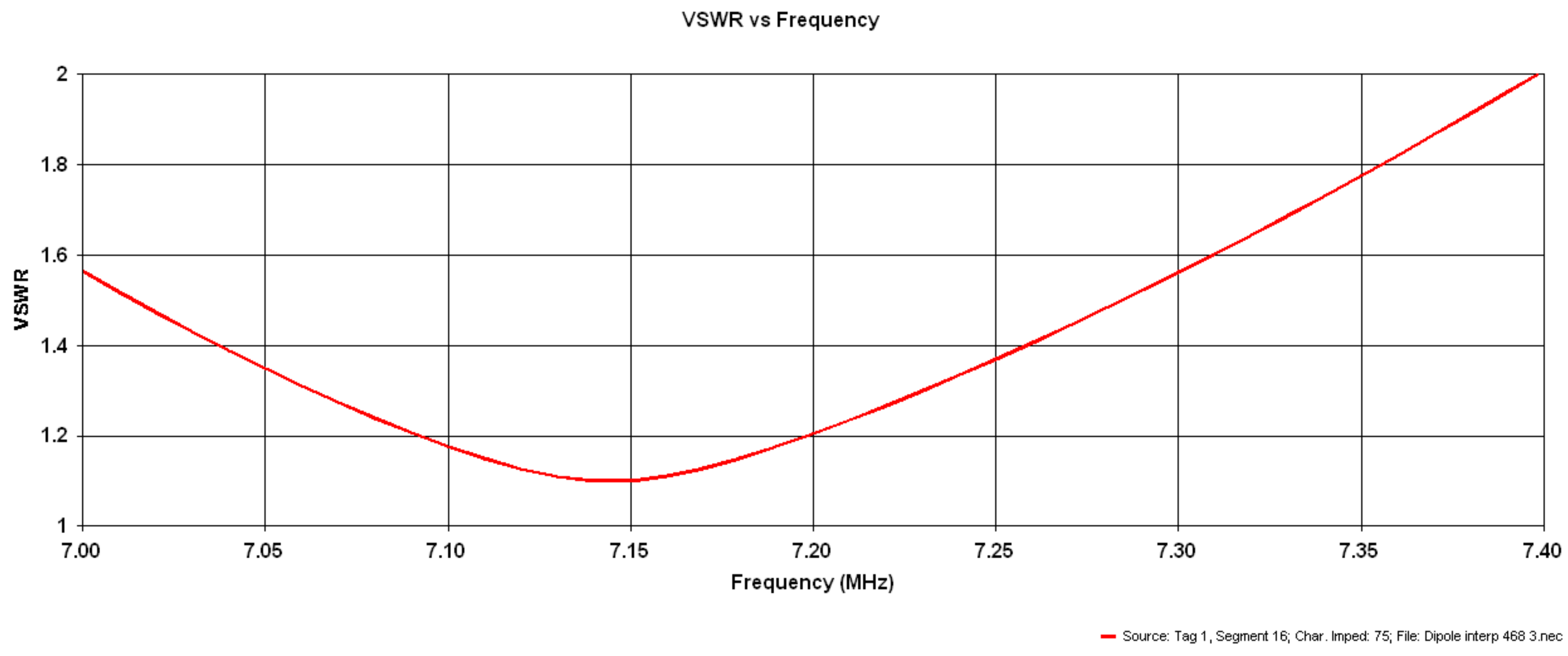
L1 = 65.454 ft, F1 = 7.255 MHz
Reference Impedance = 75 ohms



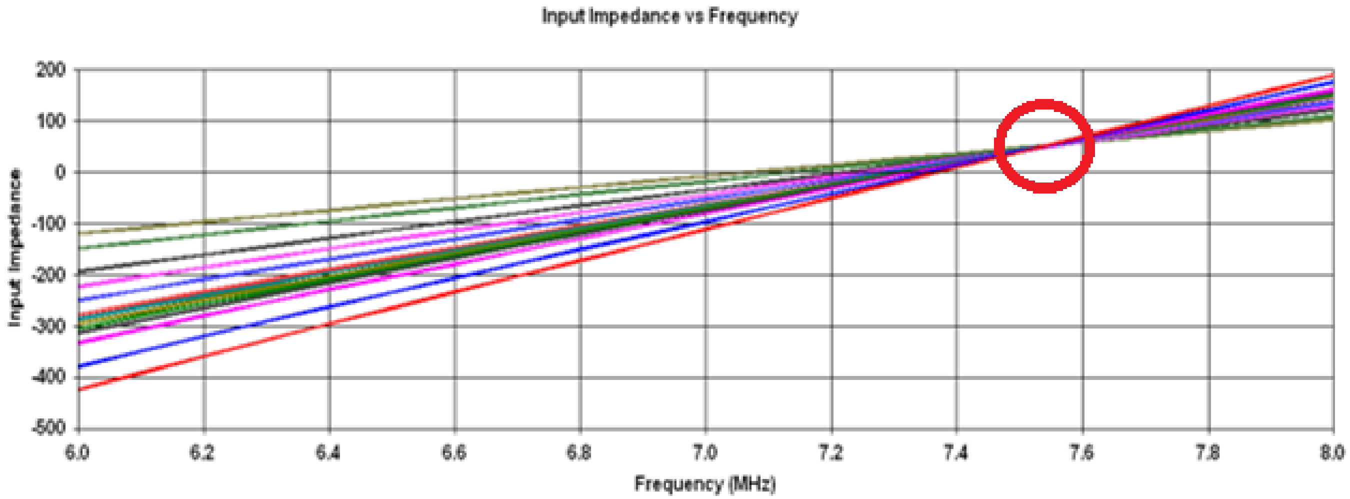
L2 = 67.454 ft, F2 = 7.035 MHz



L = 66.4 ft, F = 7.150 MHz



A New Method that is Independent of the Diameter of the Wire



Imaginary Input Impedance of Dipole with formula 468/freq for 7.15 MHz – 65.454 ft in Free Space

Diameters – Gauges 40, 30, 20, 16, 14, 12, 10, and

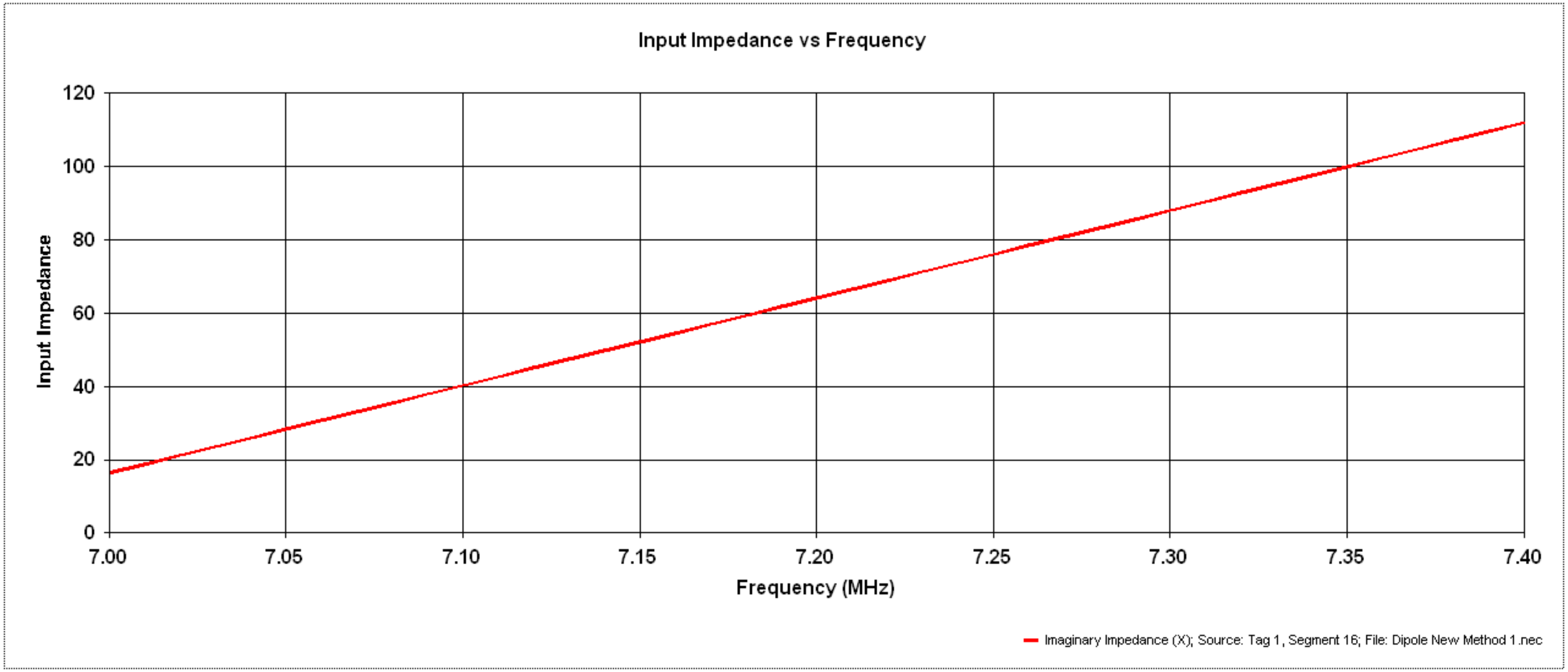
1/8, ¼, ½, 1, 3, 6 inches

All curves go thru at 7.55 MHz with X = j50 ohms
Formula for length now is ➔ 494/f (close to 492/f)

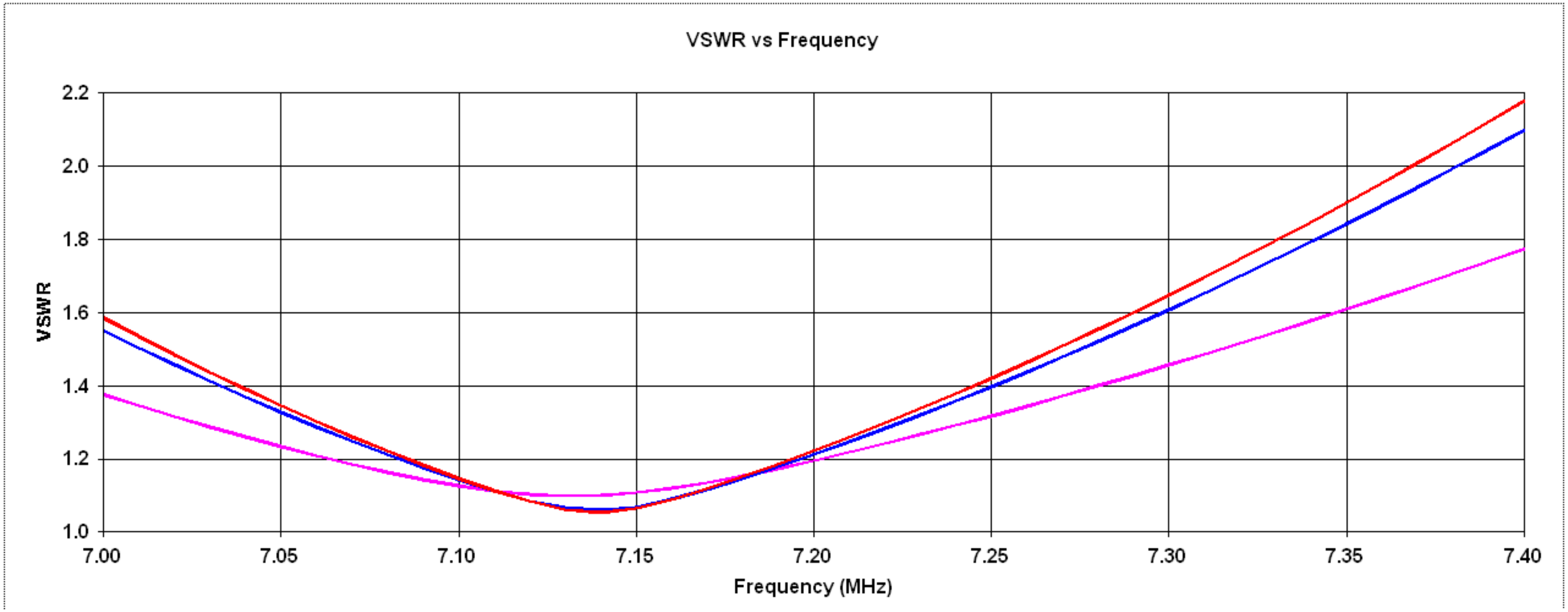
How to use this finding

- **Suppose we want the resonance at 7.15 MHz**
- **X = j50 ohms. Need to cancel with X = -j50 ohms**
- **Need a capacitor in series with X = -j50 ohms**
- **$X = 1/(2\pi f C) \rightarrow C = 1/(2\pi f X)$**
- **$C = 1/(2\pi \times 7.15\times10^6 \times 50) =$ 445 pF**
- **L = 494/7.15 = 69.09 ft**

Impedance at 7.15 MHz
L = 69.09 ft



Final Design with Series Capacitor



Red - #14, Blue - #10, Violet – 1 inch diameter

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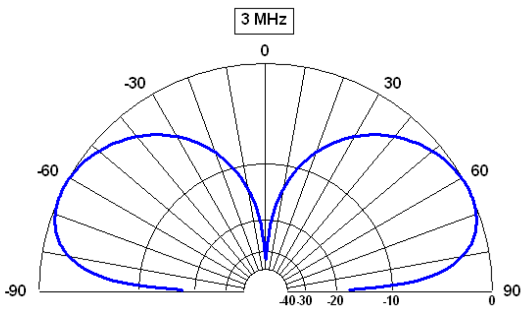
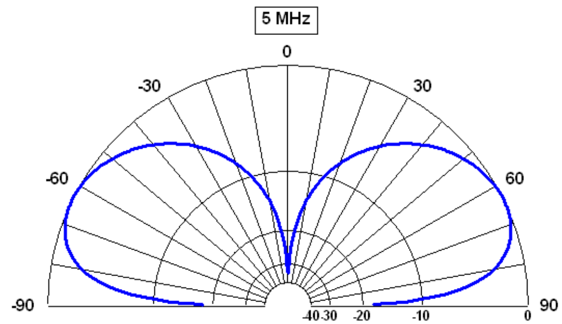
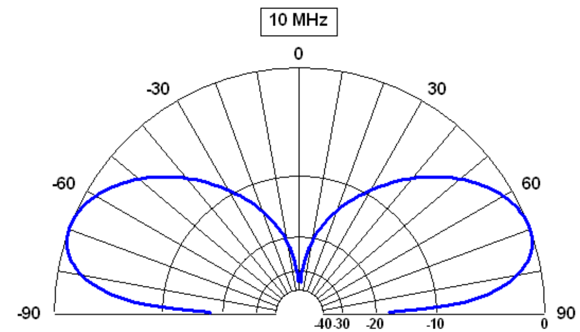
The 43 foot vertical – is that really the best height?

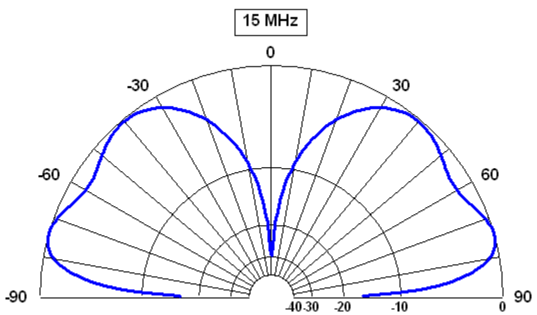
Requires tuner at feedpoint

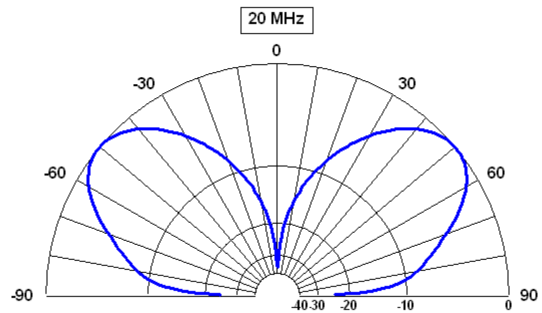
Assume many radials for these results

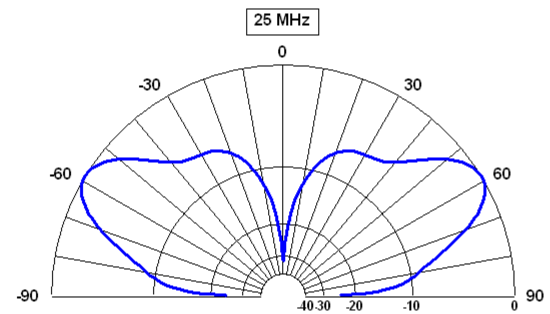


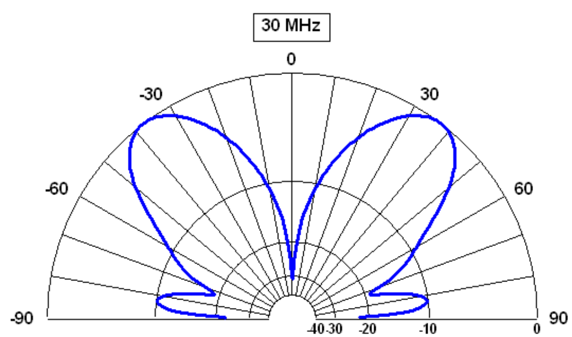




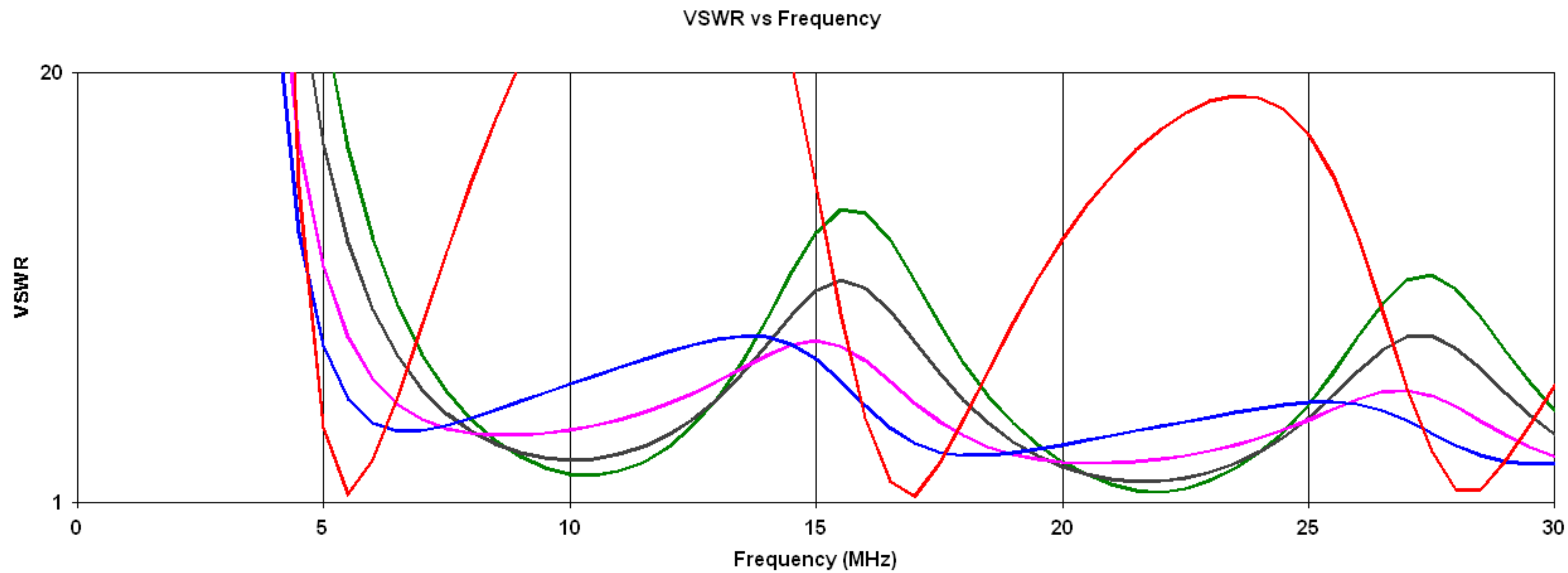






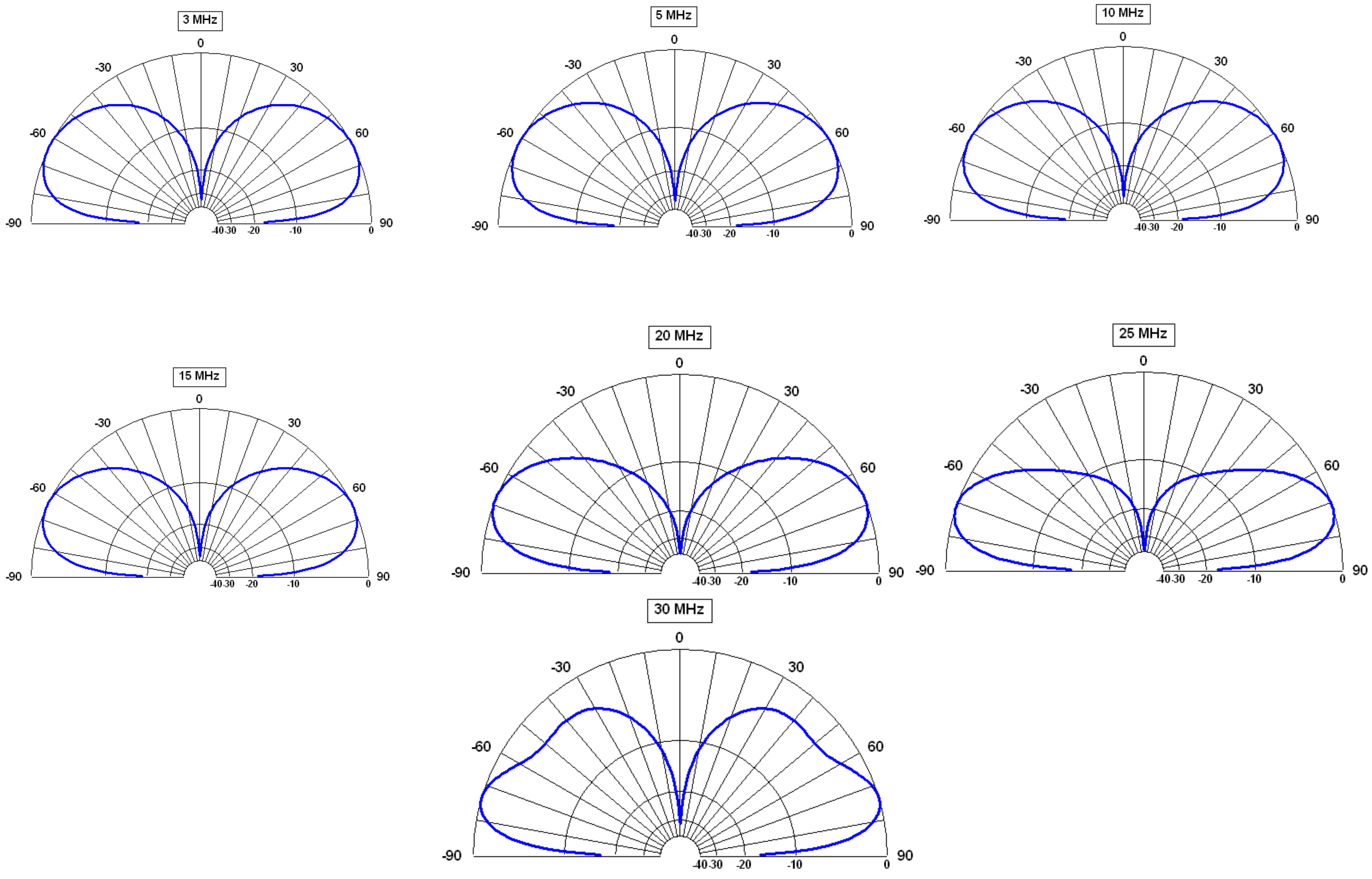


43 ft vertical SWR with different UnUns

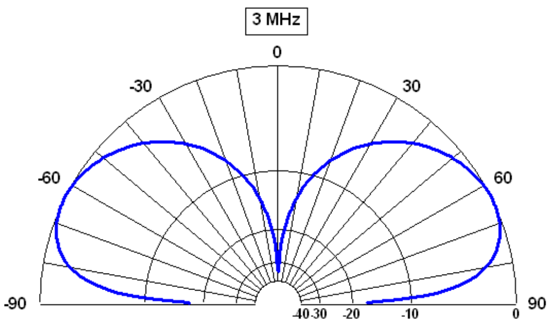


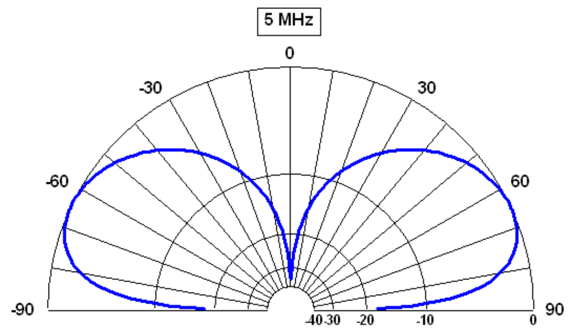
Red (1:1) Blue (1:4) Violet (1:6) Black (1:9) Green (1:12)

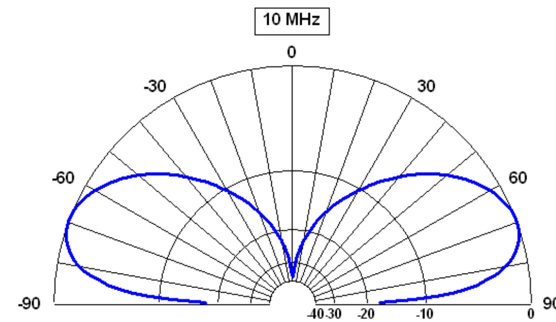
A better choice of height is 20.5 ft

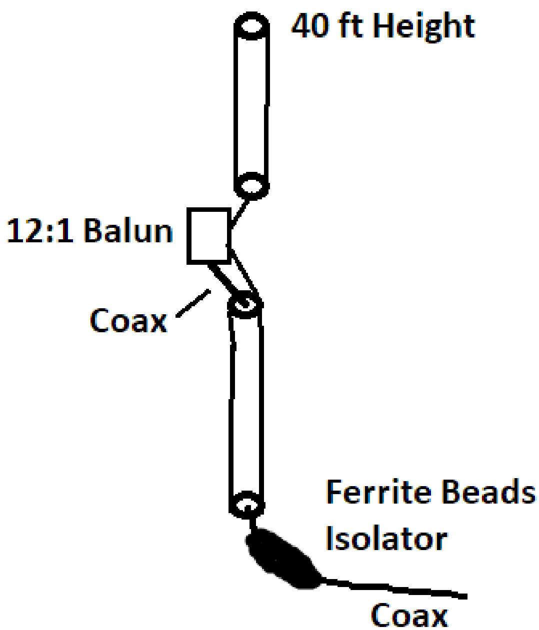


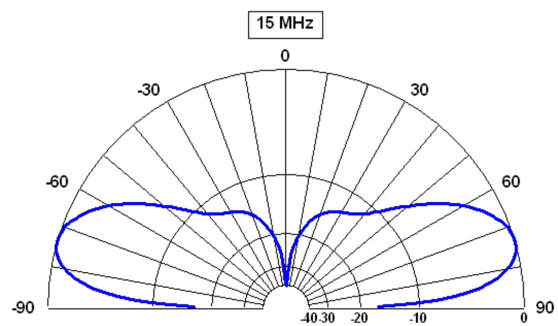
An even better approach is a 40 ft vertical dipole 1 ft off the ground

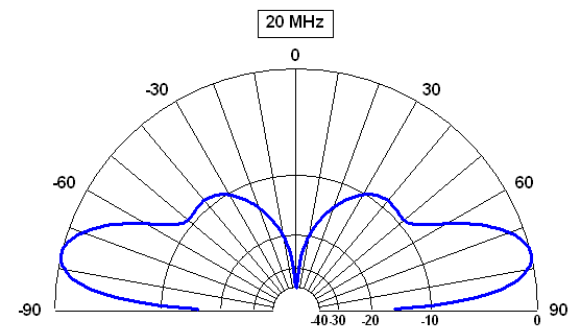


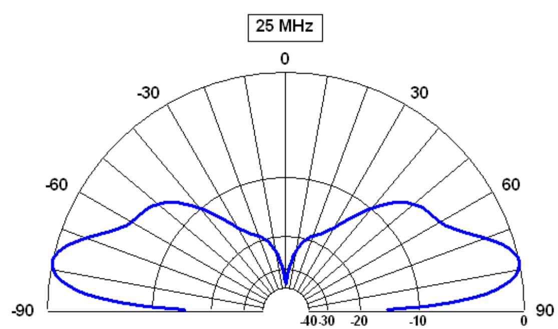


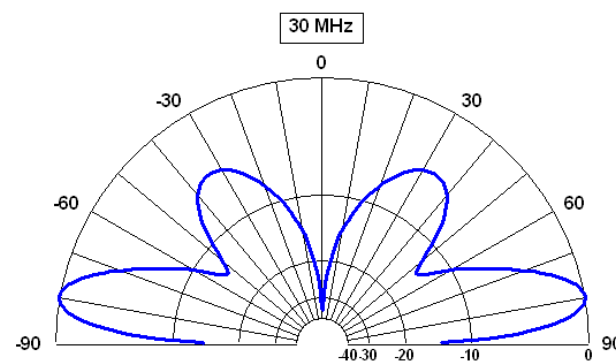




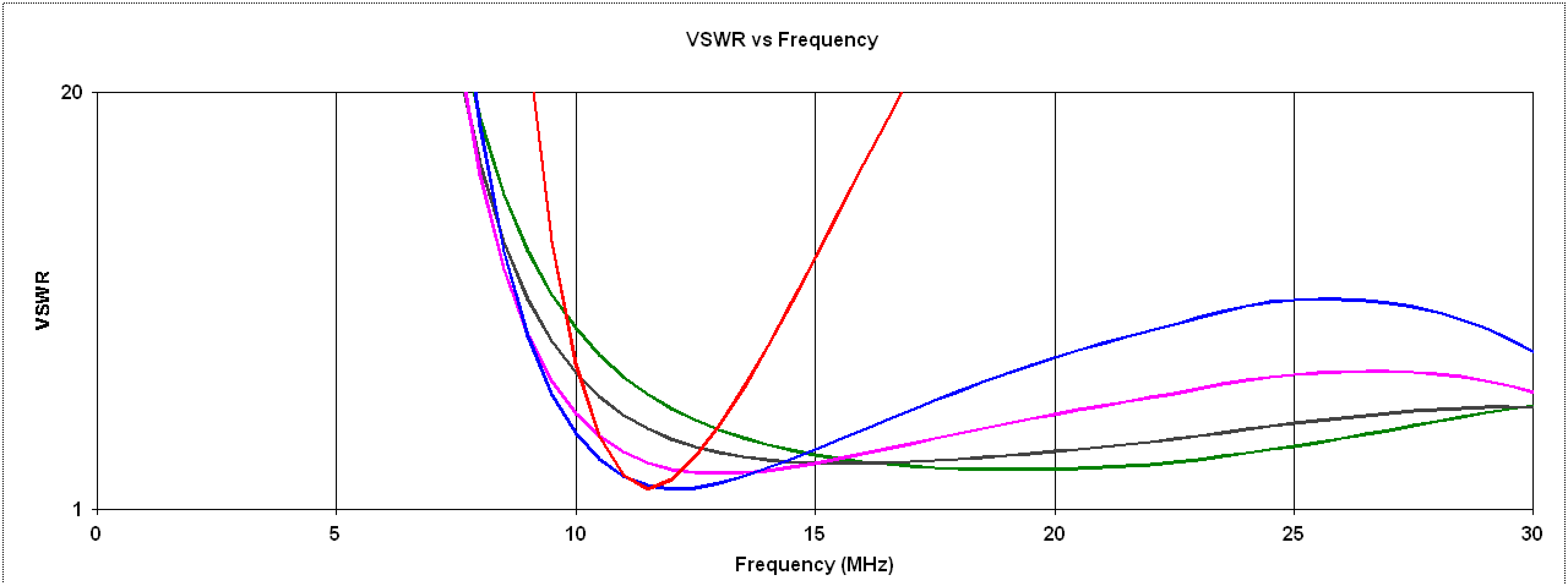






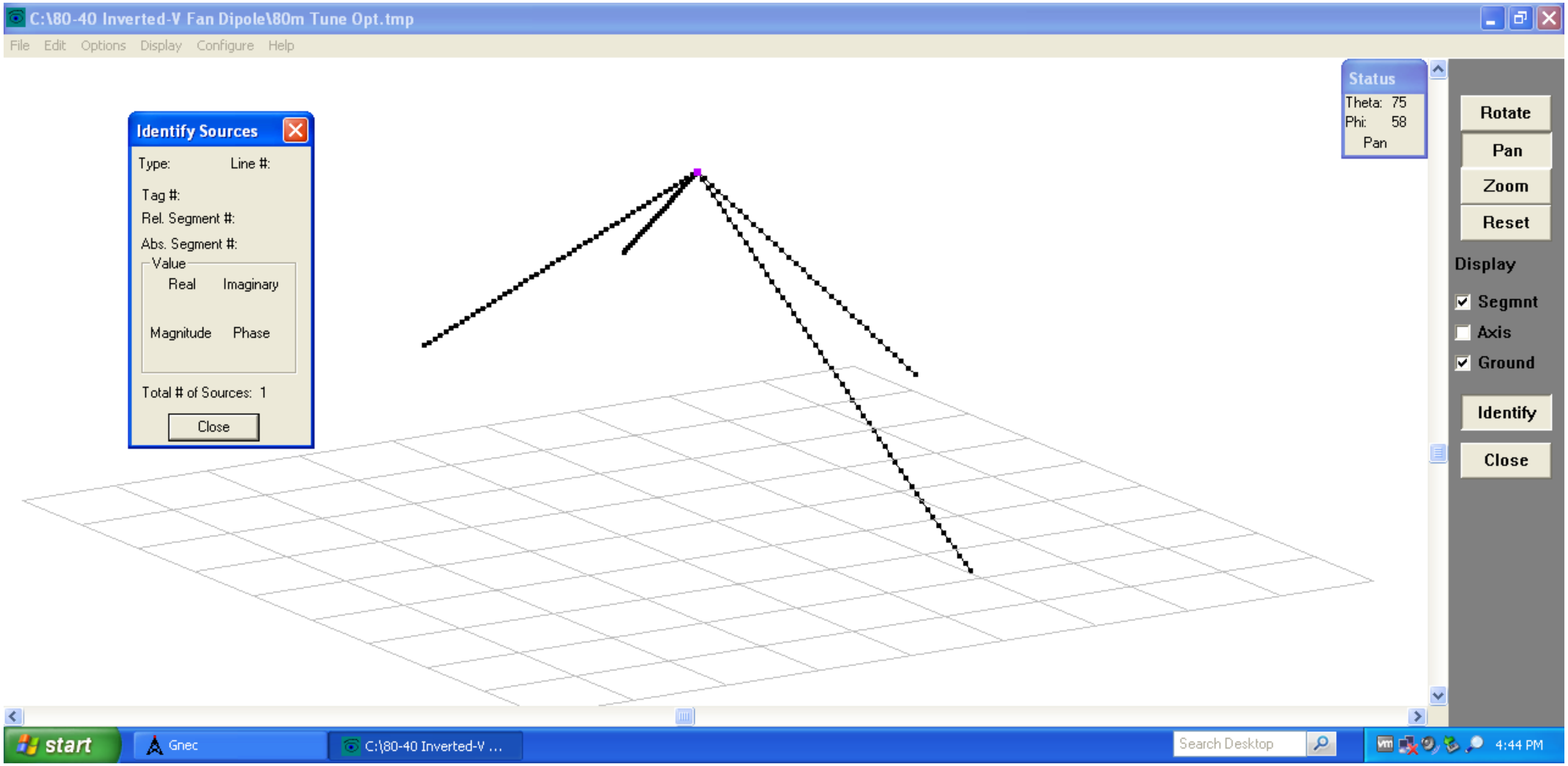


Need an isolator at base to decouple the coax from the radiator

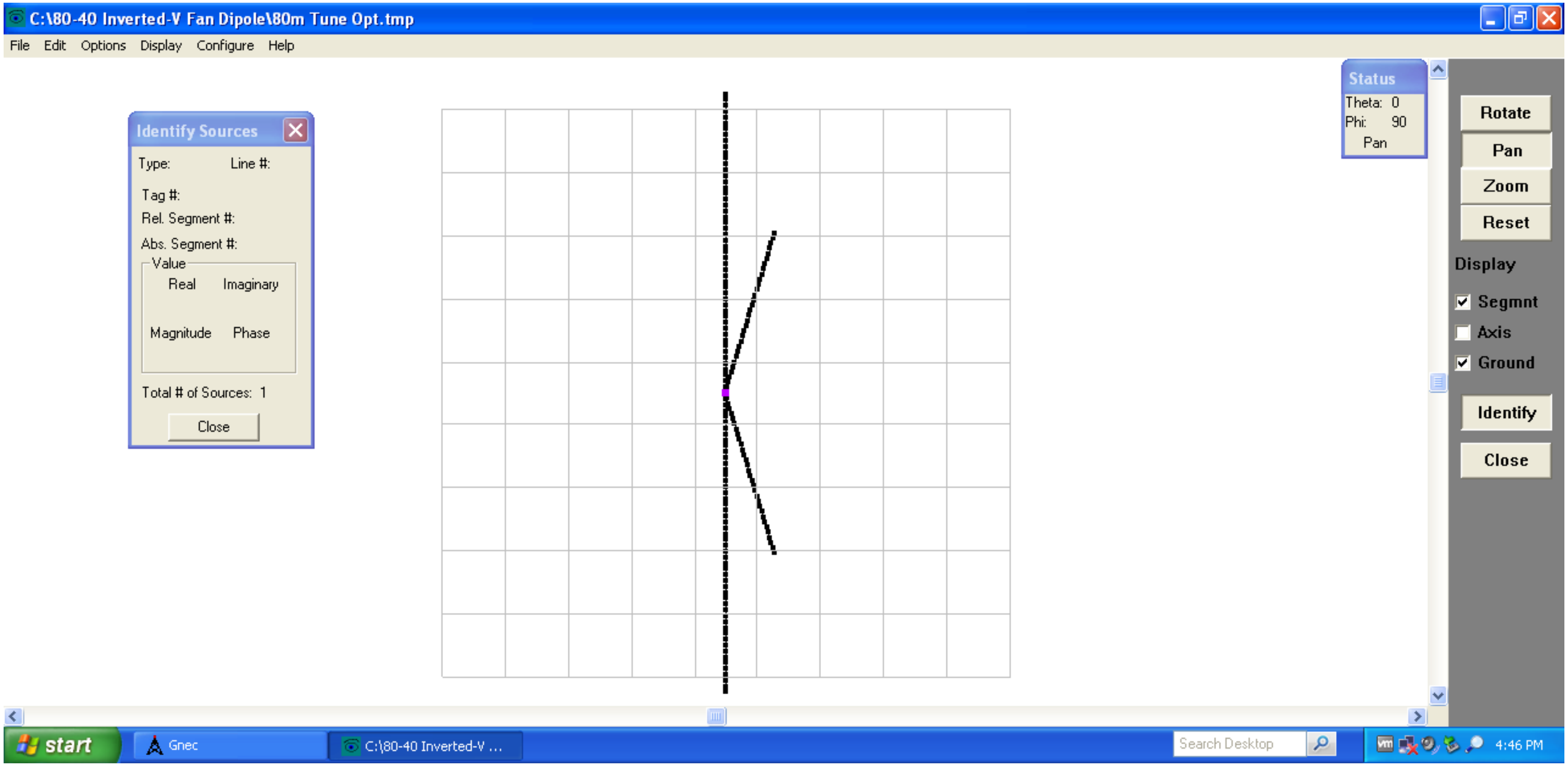


Red (1:1) Blue (1:4) Violet (1:6)
Black (1:9) Green (1:12)

80/40 Inverted-V from same Feedpoint Used at WA3FET since 1990s



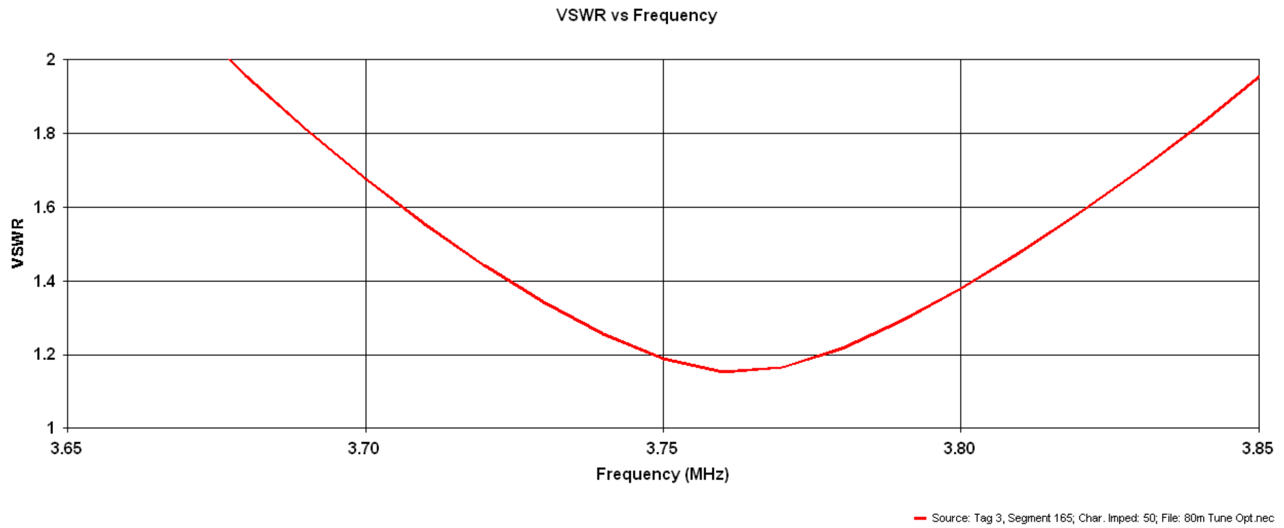
Top View – 40m legs tilted 15 degrees from 80m legs – Center at 40 ft
Slope to ground is 30 deg from horizontal

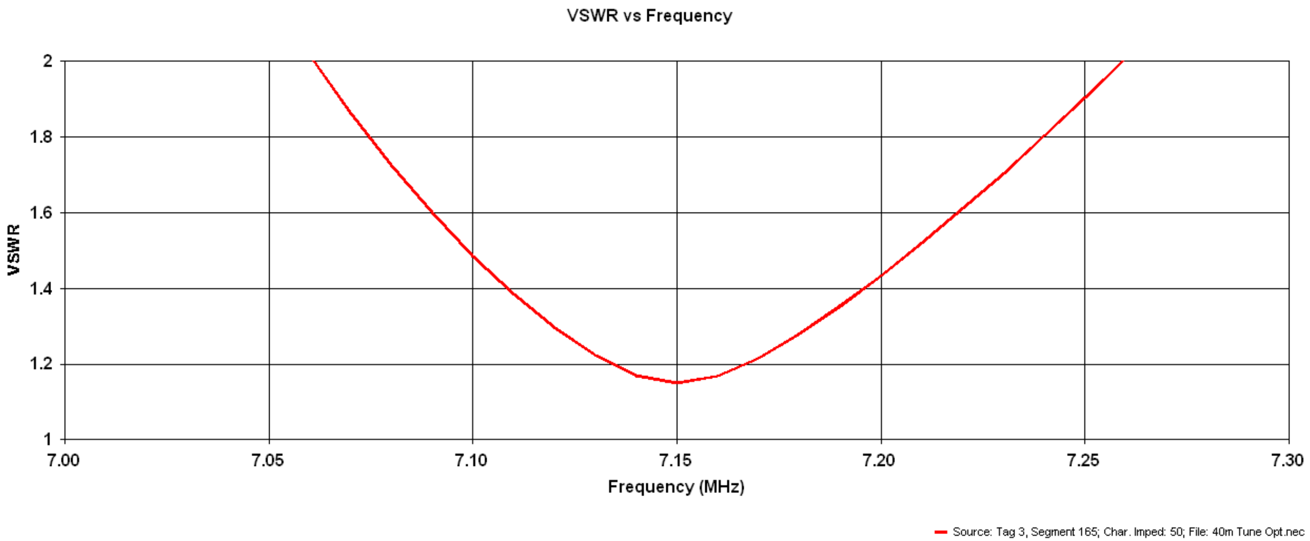


80/40 Inverted-V Fan Dimensions

- Wire Gauge - #12 bare Alumoweld
- 80m Leg – 62.375 ft
- 40m Leg – 34.469 ft
- Height of common feedpoint – 40 ft
- 1:1 Current Balun
- Requires 4 anchors at ground
- Tune Lowest Frequency First

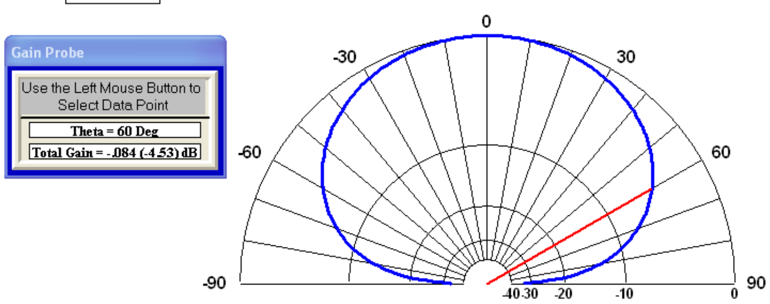
80/40 Inverted-V Fan SWR



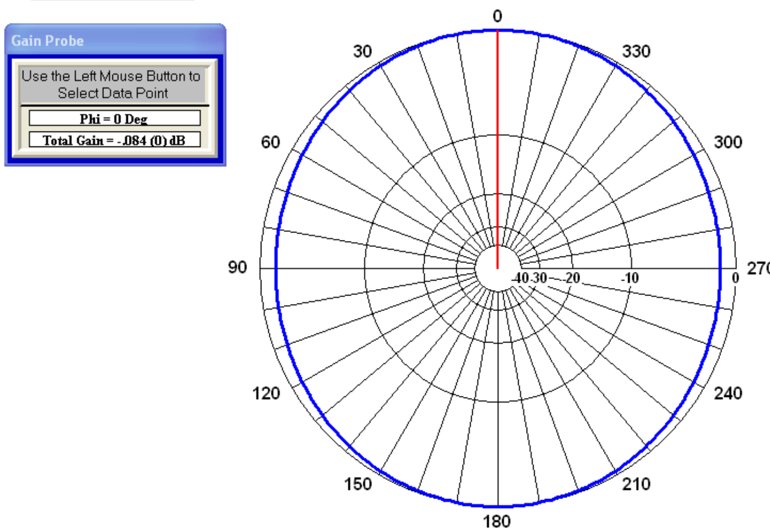


80/40 Inverted-V Fan Patterns

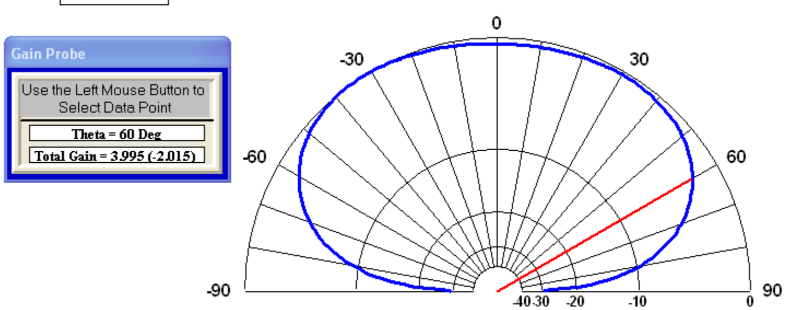
3.75 MHz



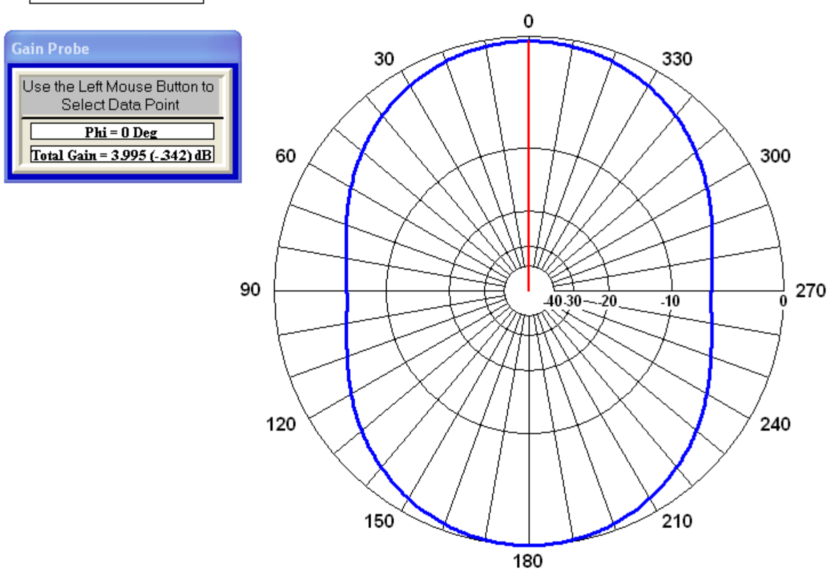
3.75 MHz



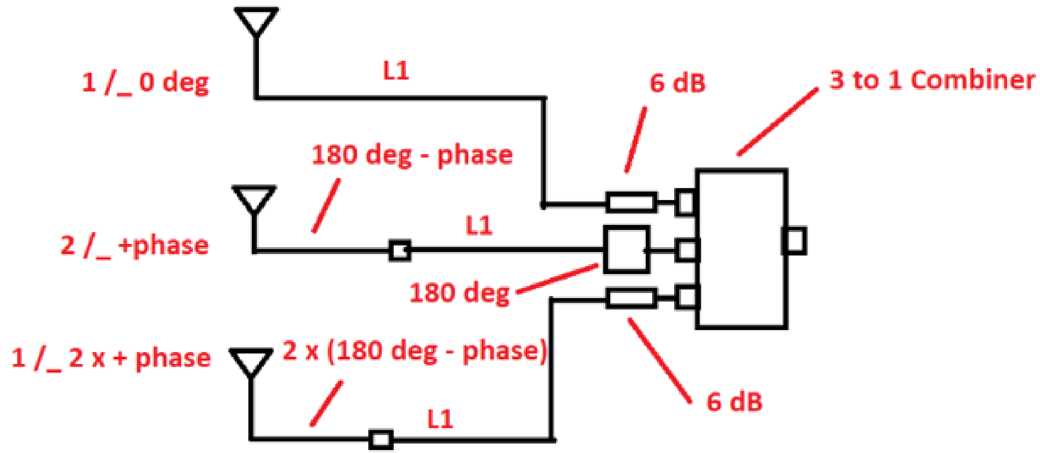
7.150 MHz



7.15 MHz



I built a 6 element 40m Hamstick passive array back in the 1990s



Phase = 150 deg

2 * Phase = 300 deg

F-ant = 0 deg phase (or 150 deg lag from C-ant)

C-ant = 150 deg phase

R-ant = 300 deg phase (or 150 deg lead from C-ant)

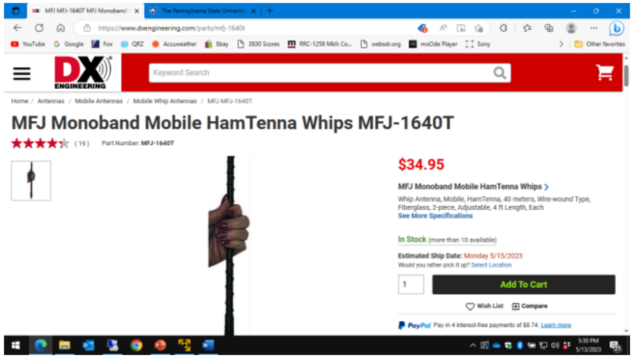
Line to F-ant = L1

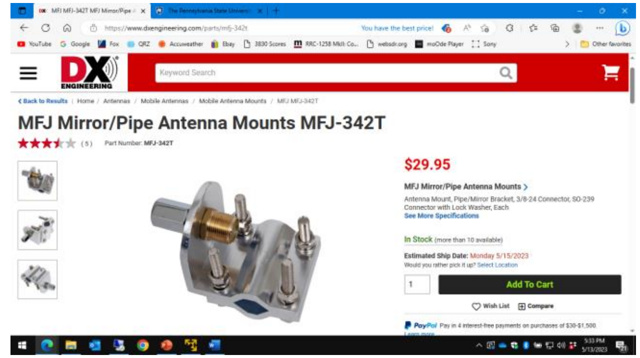
Line to C-ant = L1 + (180 deg – 150 deg) or L1 + 30 deg length of line at 7.2 MHz

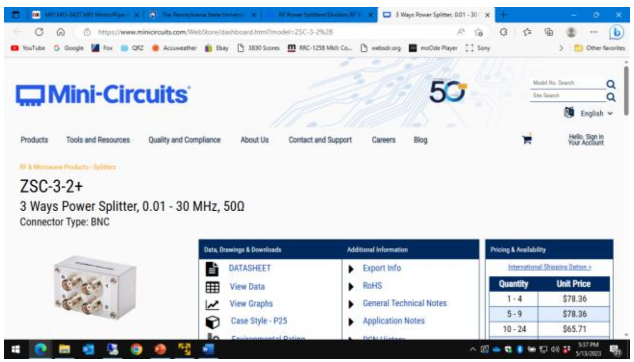
Line to R-ant = L1 + 2 * (180 deg – 150 deg) or L1 + 60 deg length of line at 7.2 MHz

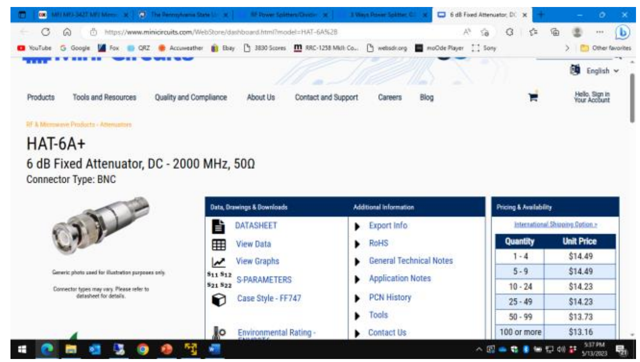
Phase Inverter goes to C-Ant

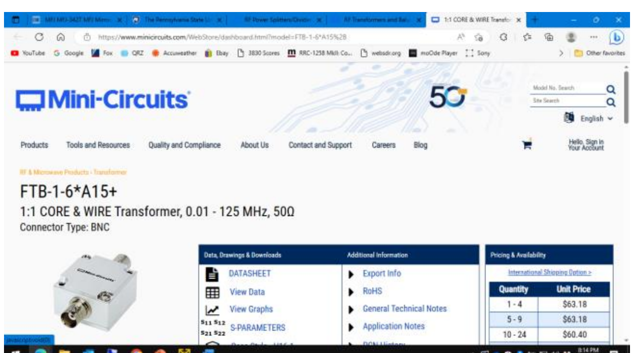
What is needed – Hamstick Receive Array

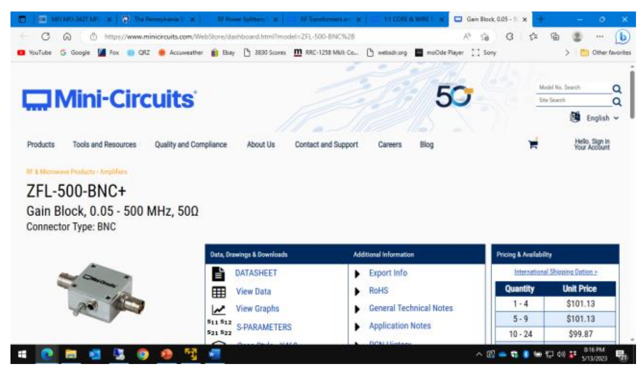






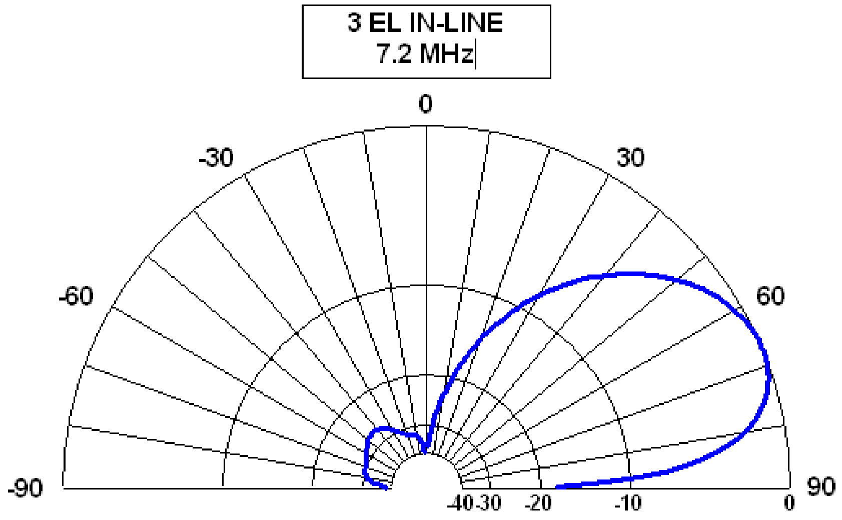


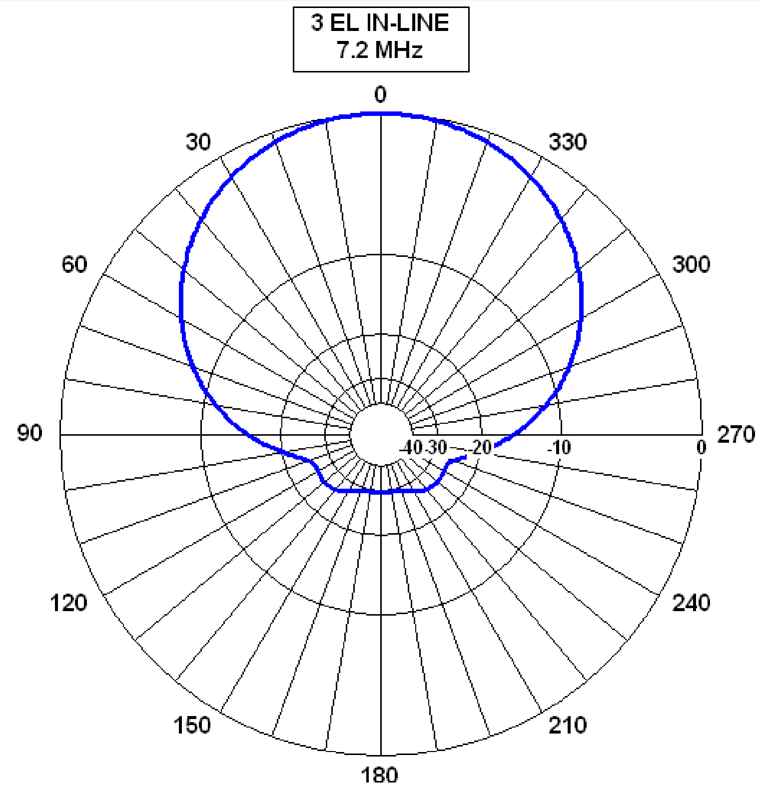




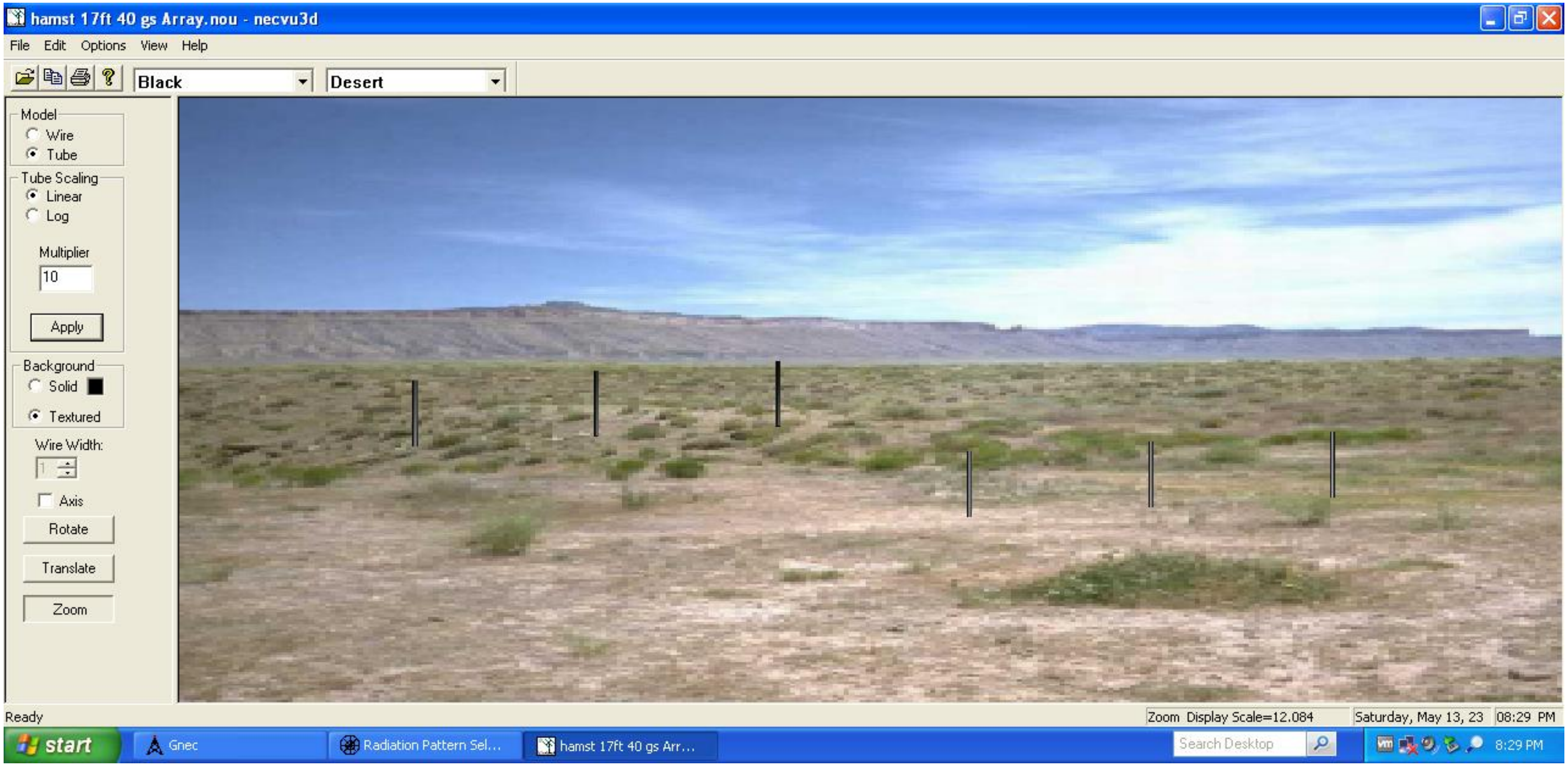
Single 3 element in-line array
Spacing = 17 ft for 7.2 MHz

Single 3 element in-line array Patterns

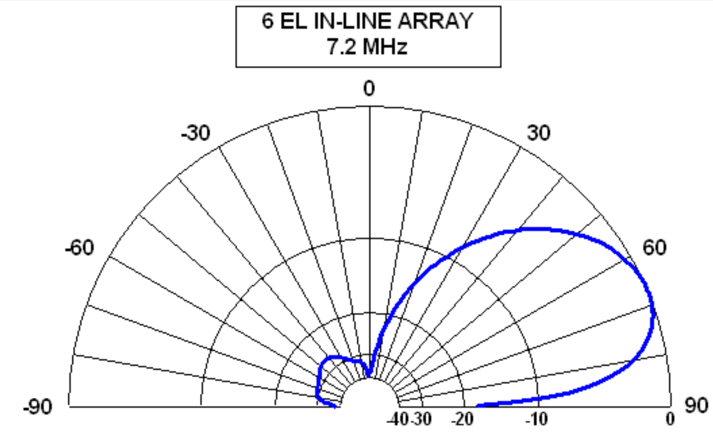


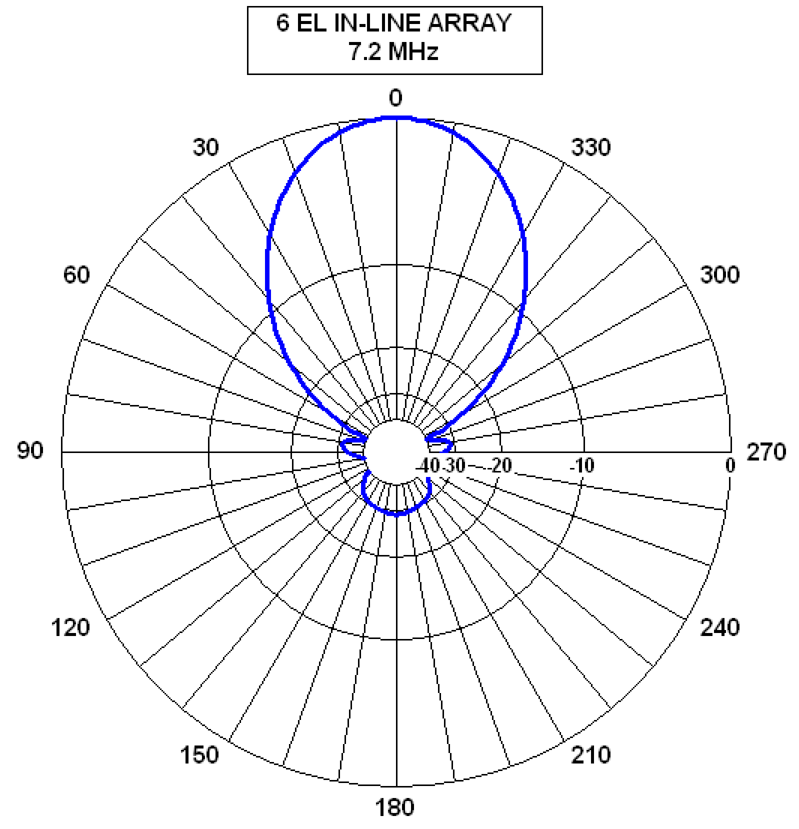


6 element array
Two in-line columns spaced 80 ft

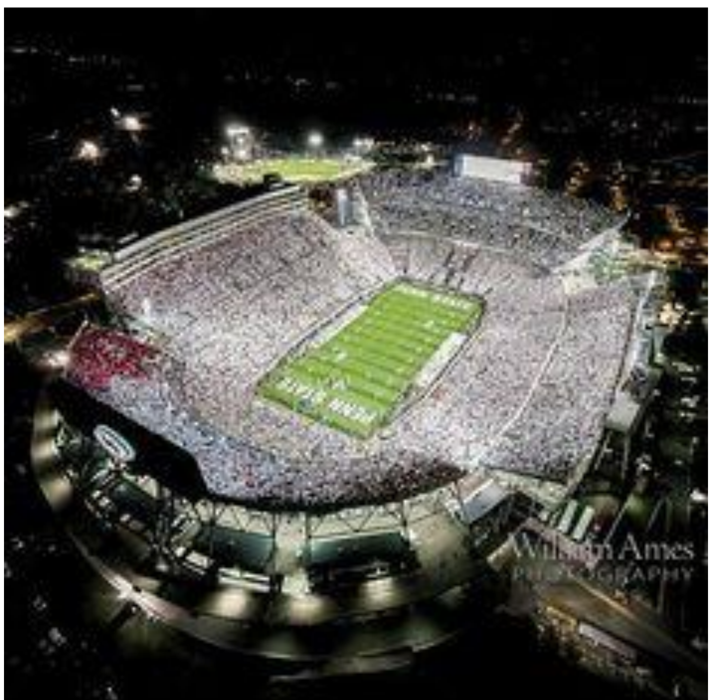


6 element array Patterns






ROSE BOWL!
VS.
JAN. 2, 2017 - 5:00 PM KICKOFF
UNRIVALED
PENN STATE FOOTBALL
6


William Ames
PHOTOGRAPHY


Rose Bowl

SuperDARN

- **Super Dual Auroral Radar Network**
- **35 high-frequency (HF) Doppler radars located in the high-latitude and midlatitude regions of the northern and southern hemispheres**
- **Backscatter from ionospheric electron density irregularities that deduce various parameters**
- **Only currently available experimental technique capable of providing time series of large-scale direct observations of the high-latitude electric field**
- **Global structure and dynamics are fundamental to understanding large-scale plasma processes in the near-Earth space environment**
- **Importance for determining electrodynamic energy input to the high-latitude regions of the Earth's upper atmosphere**

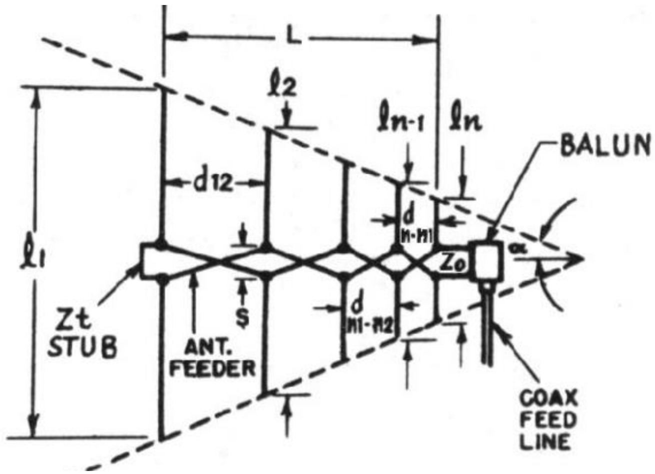
SuperDARN Antenna Array in Holmwood SDA, Saskatoon

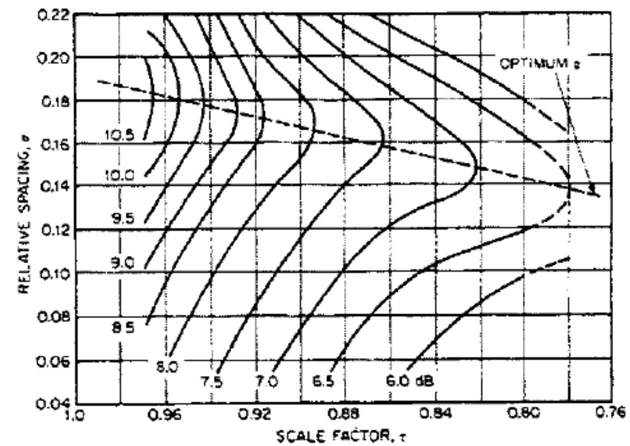
Typical SuperDARN Array Design

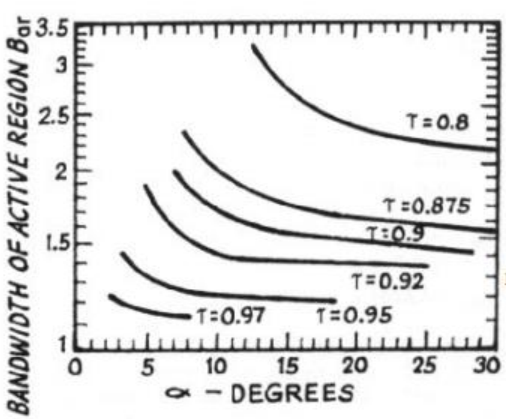
- **Row of 16 log periodic (LP) antennas at a typical height of 50 feet with a side-to-side spacing of 50 feet covering a range of 8 to 20 MHz**
- **Additionally, 4 log periodic antennas behind the main array row to provide additional elevation angle determination**
- **Software defined radio (SDR) system for transmitting and receiving with a pulse peak power of 600 watts to each antenna**
- **Sabre Communications Corp. Model 608 log periodic covering 8 to 20 MHz**

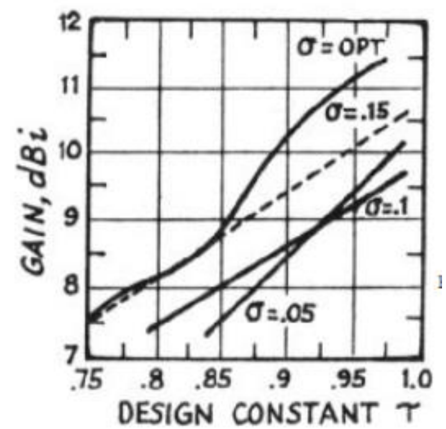
Log Periodic Antenna Design

- Handbook design where one chooses parameters from plots but has no control on what the boom length or number of elements is
- Front-to-back ratio is not a parameter that is part of the design

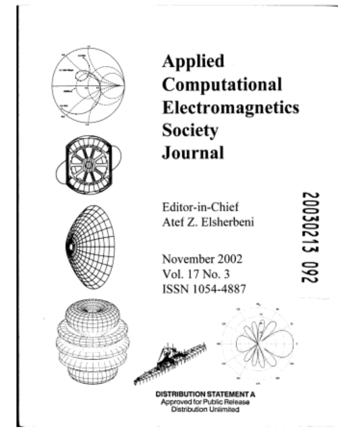








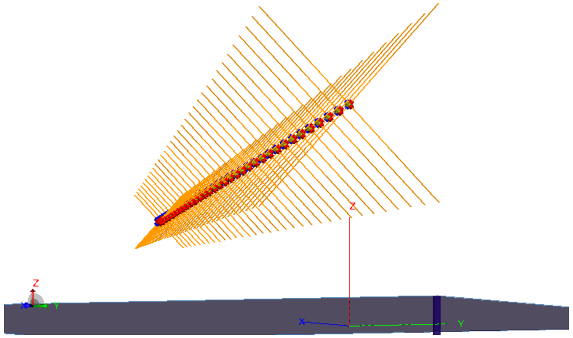
A NEW DESIGN METHOD FOR LOW SIDELOBE LEVEL LOG-PERIODIC DIPOLE ANTENNAS

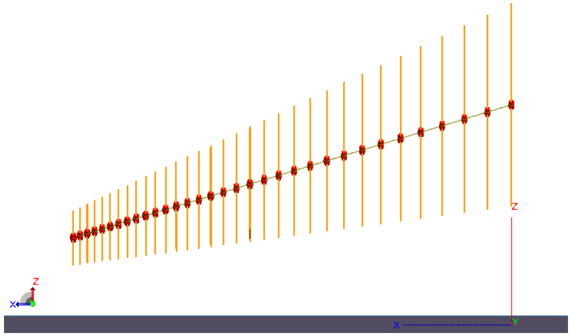


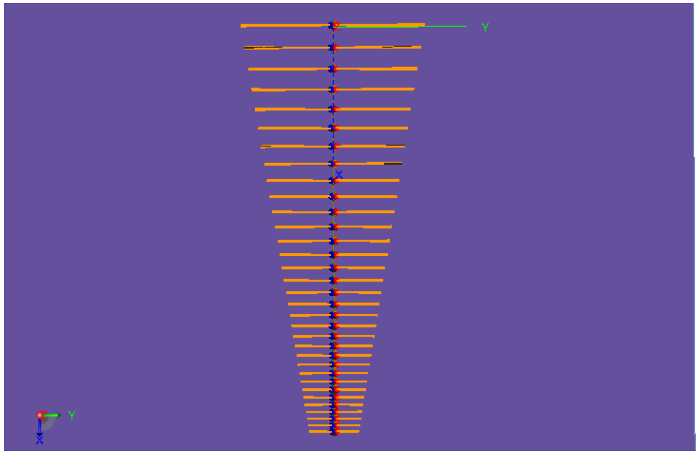
- Prof. Breakall and Rafael A. Rodriguez Solis – Penn State
- Applied Computational Electromagnetics Society Journal – July, 1996
- First pick $f_L = f_1$ = the minimum frequency of operation
- Next, pick f_H = the highest frequency of operation
- Then pick $f_N = 1.5 * f_H$ to insure a smooth transition at the upper cutoff frequency
- Pick the tau factor τ = scaling factor between lengths and spacings of adjacent elements
- The number of elements (nearest integer) $N = \left\{ \frac{\left[\log\left(\frac{f1}{fN}\right)\right]}{\log(\tau)} \right\} + 1$
- Length of largest element $l_1 = \lambda_1 / 2$
- Pick the boom length, L
- Distance between first and the second element $d_{12} = L[(\tau -1)/(\tau^{(N-1)}-1]$
- One then calculates the next to the largest element length as $l_2 = \tau l_1$, and then $l_3 = \tau l_2$, etc
- Similarly, the distance $d_{23} = \tau d_{12}$, $d_{34} = \tau d_{23}$, etc.

Optimized Crossed Diagonal Log Periodic Antenna Design over Ice

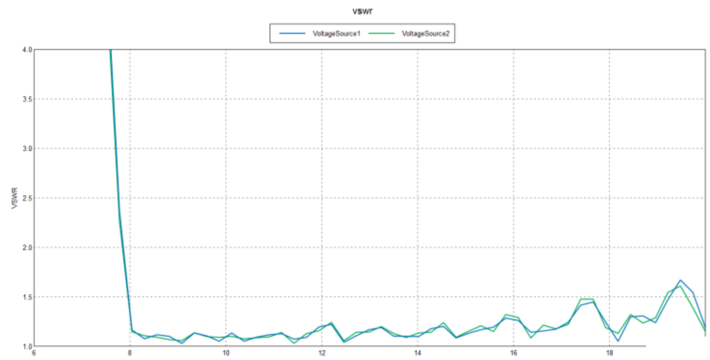
- **Number of wires N = 33, τ = .96, f_L = 8 MHz, f_H = 20 MHz, boom length L = 100 ft**
- **Height of the longest element tip = 70 ft, height of the shortest element tip = 25 ft, and a wire diameter of .125 inches**
- **Crossed transmission lines used in the design have an impedance of 400 ohms resulting in an input impedance of 200 ohms where a 4 to 1 balun is used**

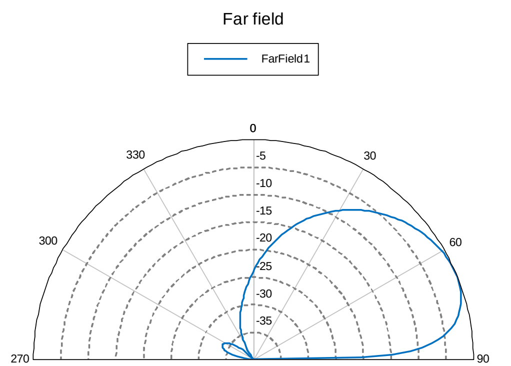




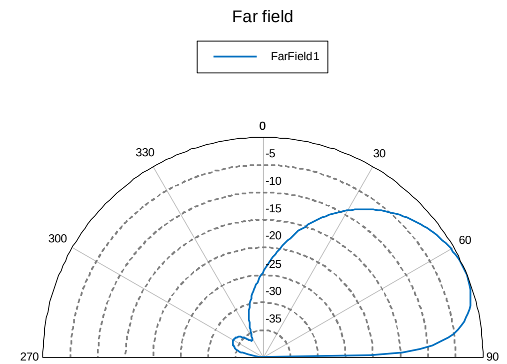


Performance of Design

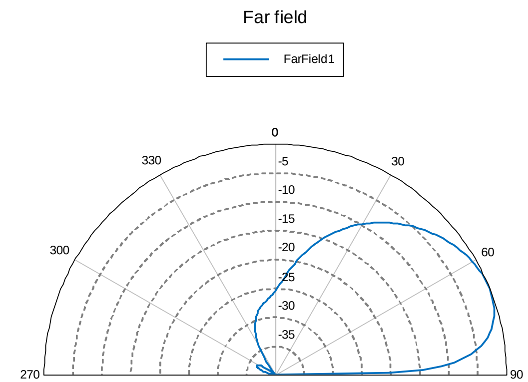




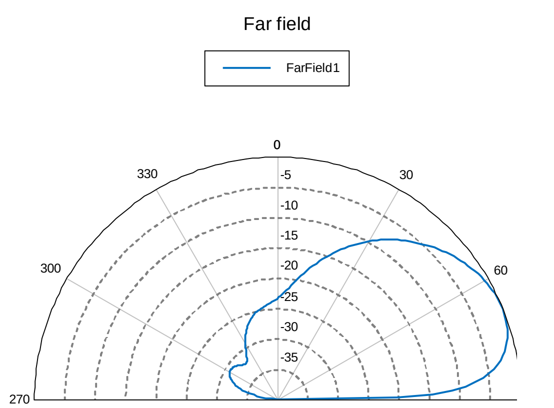
Total Gain [dBi] (Frequency = 10 MHz; Phi = 0 deg) - lpda8_0.96_100_70-25p_to_p_boom_length



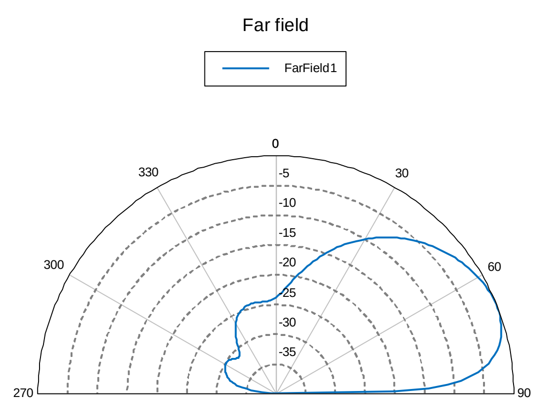
Total Gain [dBi] (Frequency = 12 MHz; Phi = 0 deg) - lpda8_0.96_100_70-25p_to_p_boom_length



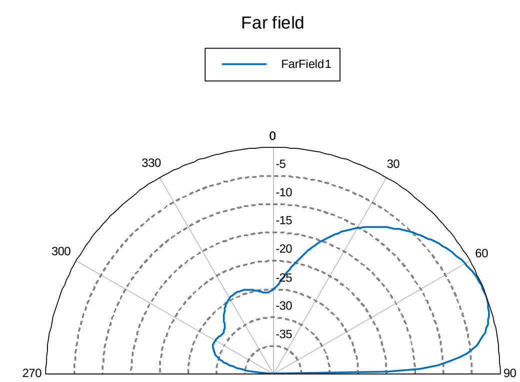
Total Gain [dBi] (Frequency = 14 MHz; Phi = 0 deg) - lpda8_0.96_100_70-25p_to_p_boom_length



Total Gain [dBi] (Frequency = 16 MHz; Phi = 0 deg) - lpda8_0.96_100_70-25p_to_p_boom_length



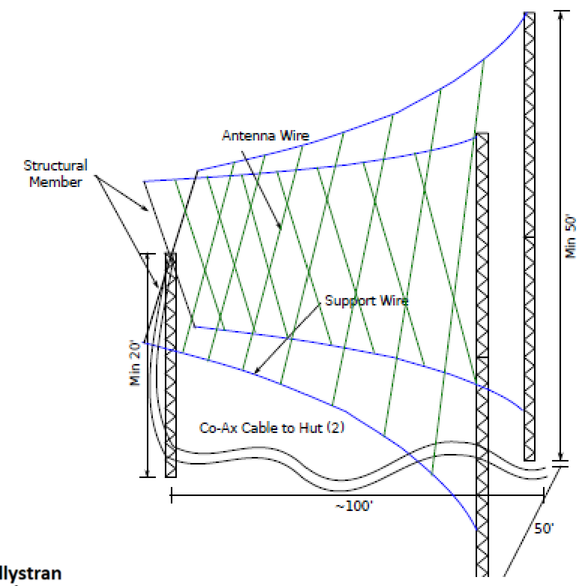
Total Gain [dBi] (Frequency = 18 MHz; Phi = 0 deg) - lpda8_0.96_100_70-25p_to_p_boom_length

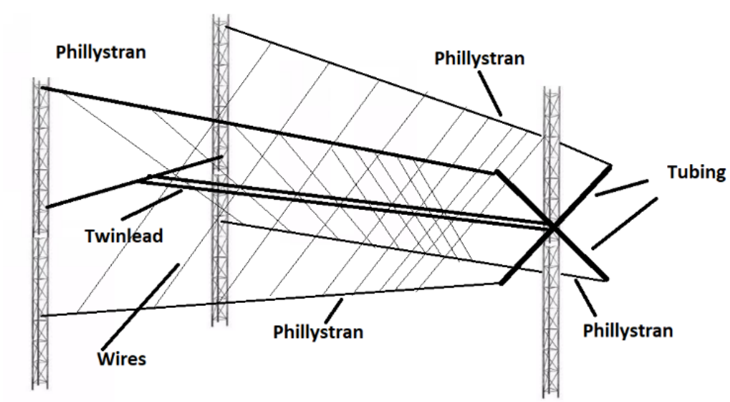


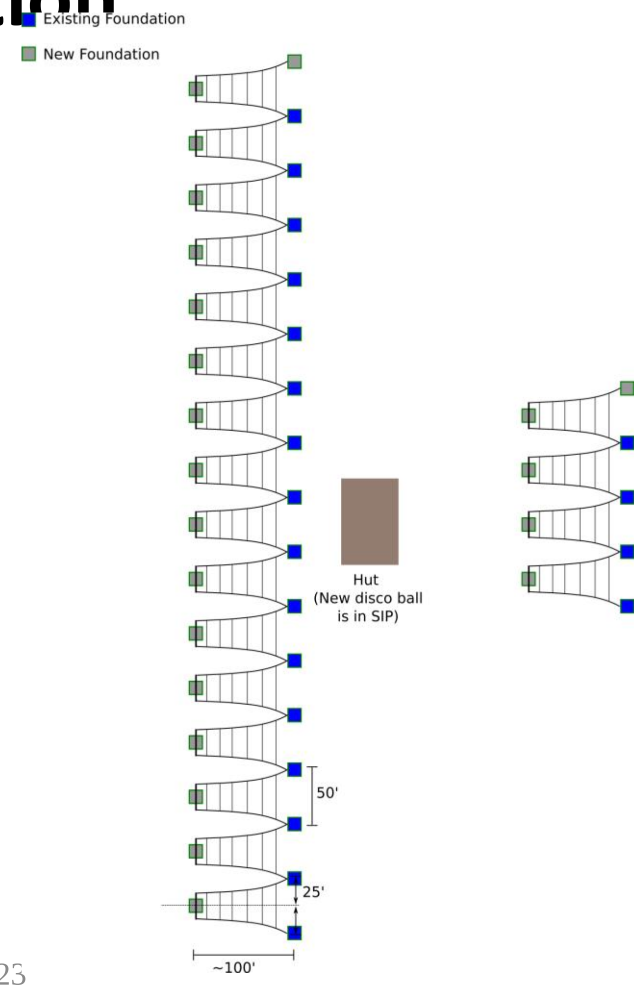
Total Gain [dBi] (Frequency = 20 MHz; Phi = 0 deg) - lpda8_0.96_100_70-25p_to_p_boom_length

What the Antenna Array Might Look Like

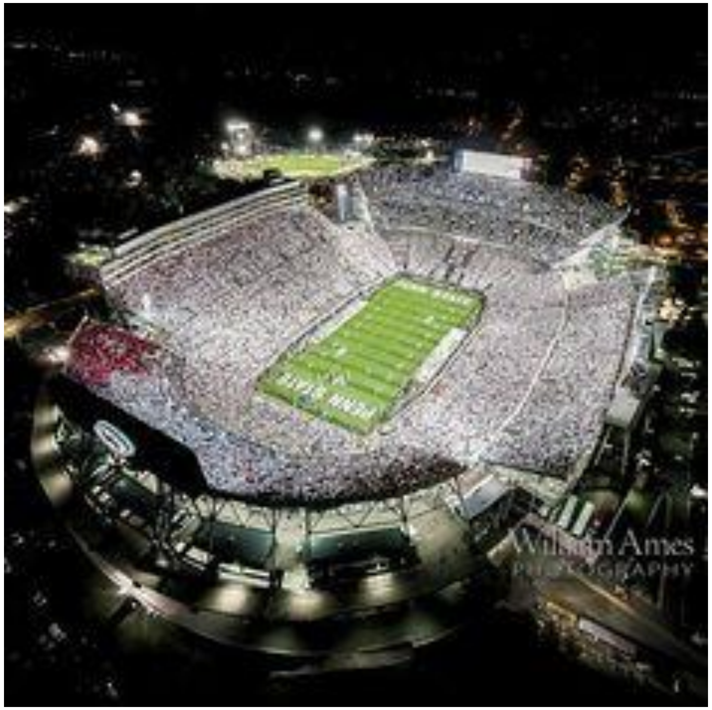
- **Some Concepts for Construction**







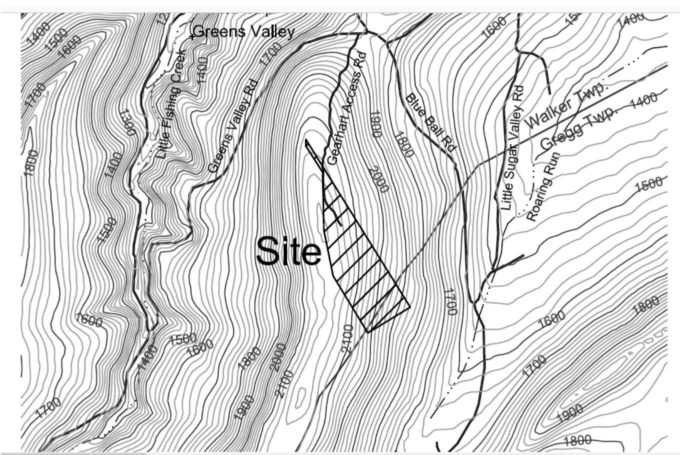

ROSE BOWL!
VS.
JAN. 2, 2017 - 5:00 PM KICKOFF
UNRIVALED


William Ames
PHOTOGRAPHY


Rose Bowl

Camp Kilowatt (Camp K) Contest Station
on The Magic Mountain – KC3R
(N3EB, WA3FET, K0LO, NK8Q, K3ARL, K3GEM)

- **HFTA Shows Incredible Terrain Enhancement**
- **Rime and Ice and Wind and Lightning – All Big Issues**
- **The 20m 6 Element OWA-ICE Design on 52 ft Boom**
- **44 MPH with 1.5 inch radial ice**
- **SWR < 2 (13.25 – 14.95 MHz); SWR < 1.5 (13.75 – 14.9 MHz)**



20m 6 Element OWA-ICE Design on 52 ft Boom
Stack at 44 ft, 84 ft, and 124 ft
All Turned by K0XG Ring Rotators

- **K0XG Rings are Super Strong and Towers and Anchors at Camp K are too !!!**







Camp K – More Photos

James Clerk Maxwell, 1831 – 1879

A TREATISE

ON

ELECTRICITY AND MAGNETISM

BY

JAMES CLERK MAXWELL, M.A.

[illegible]

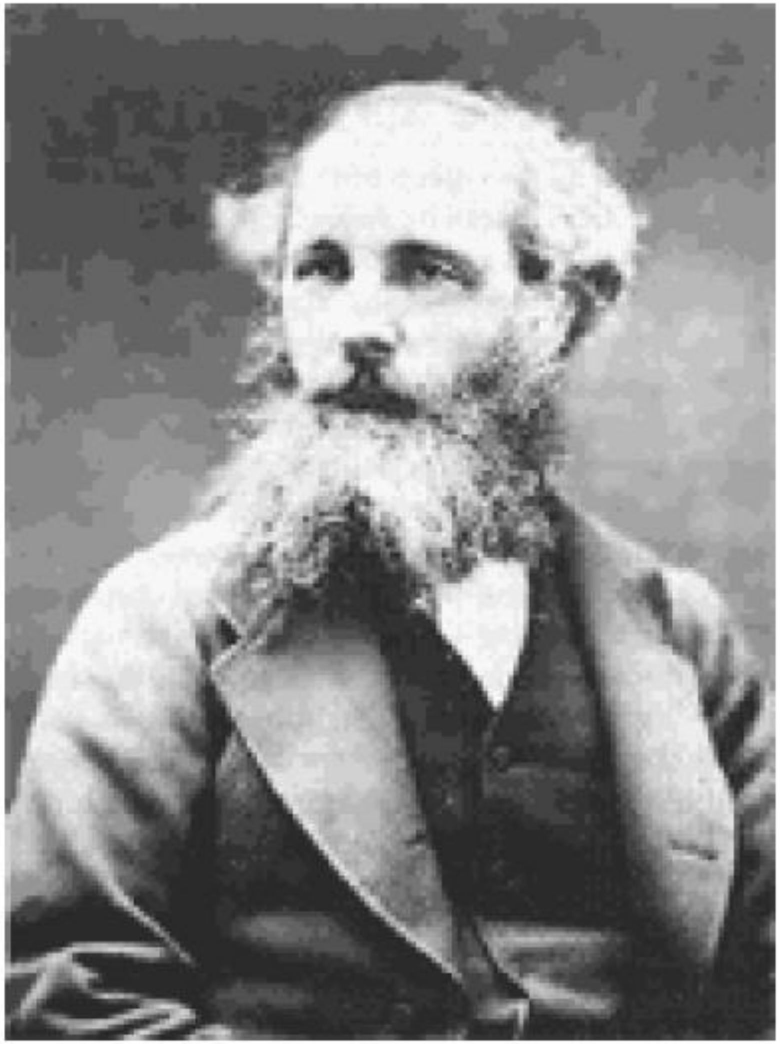
VOL. II

THIRD EDITION

OXFORD

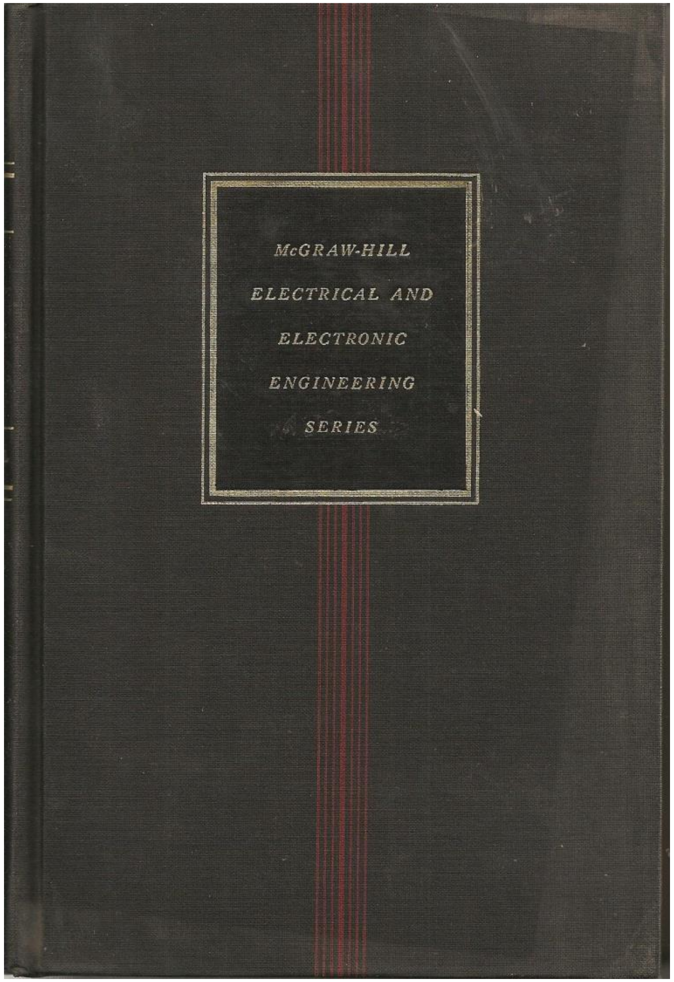
AT THE CLARENDON PRESS

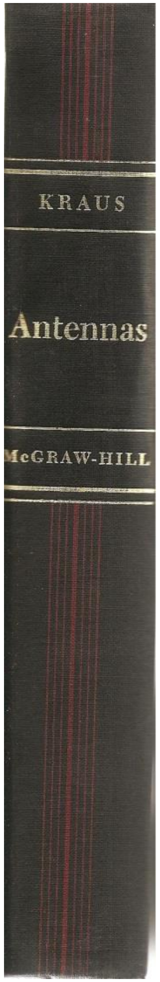
1904



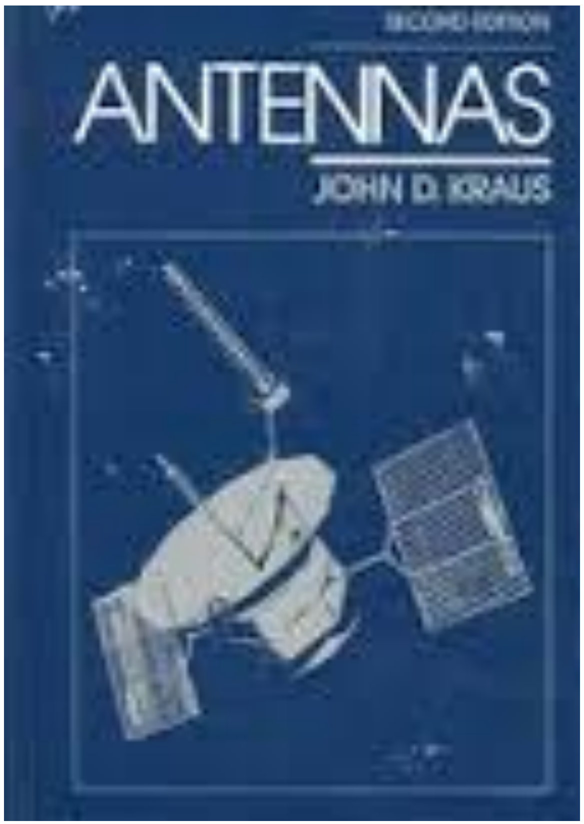
W8JK – Antennas Book -1950

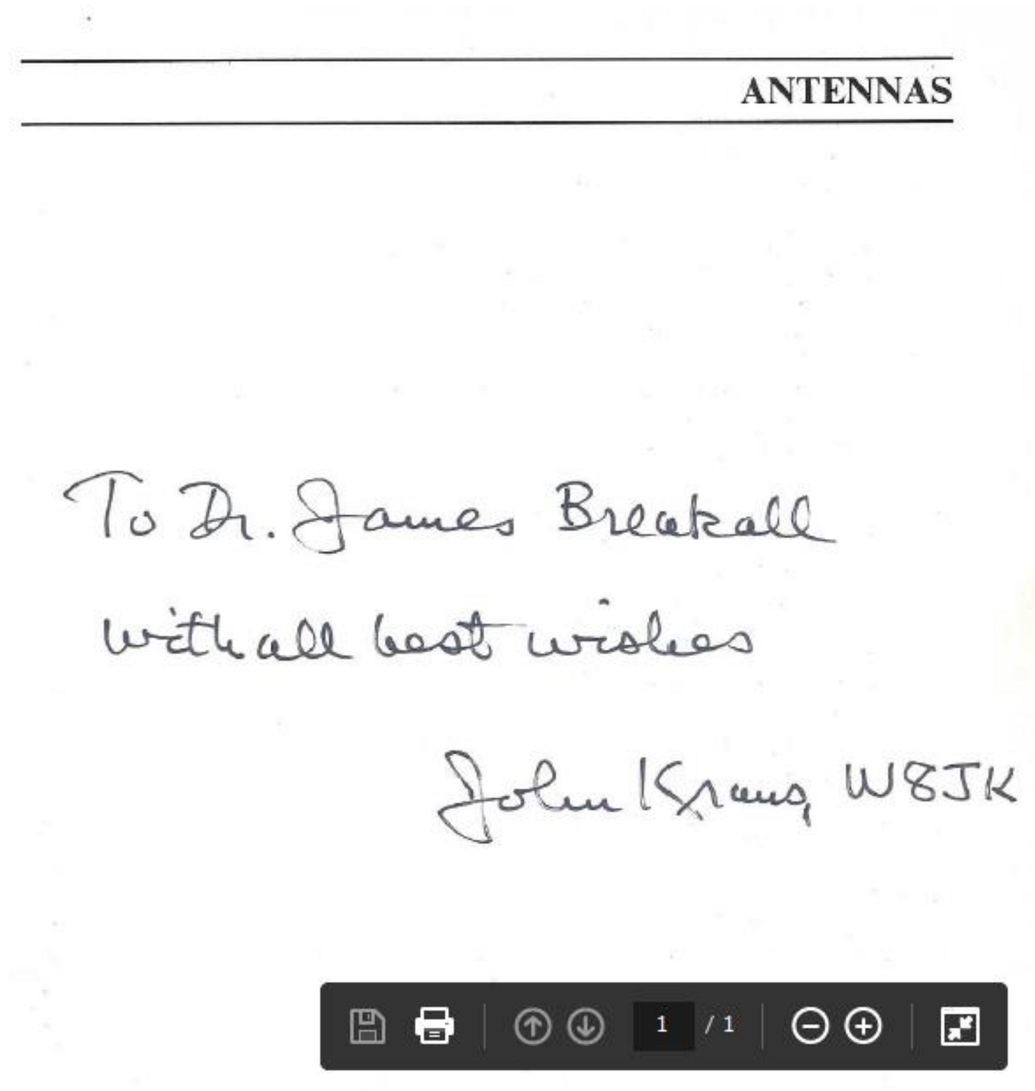
John Daniel Kraus, 1910 – 2004





Prof. Kraus Sent Me His 2nd Edition

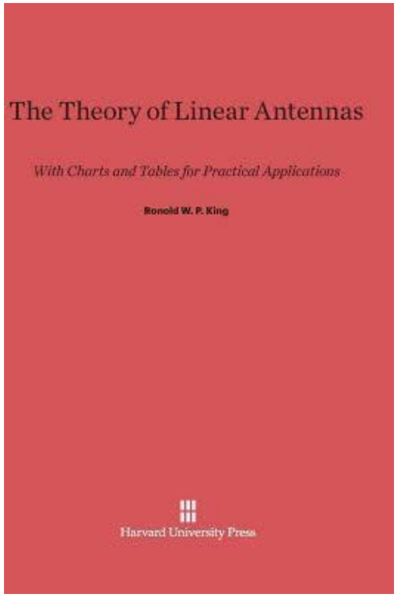


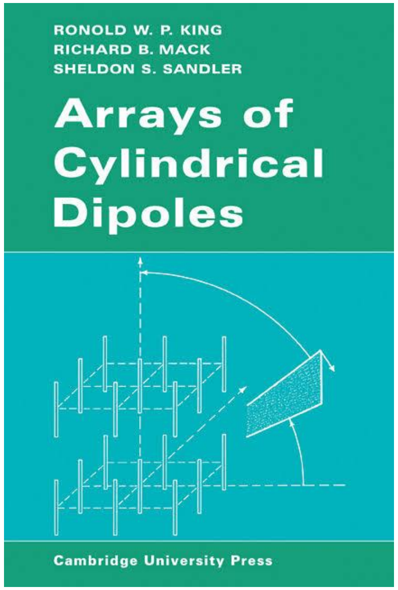

ANTENNAS

To Dr. James Breakall
with all best wishes

John Kraus, W8JK

Ronald Wyeth Percival King, 1905-2006





R.W.P. King speaking at his 100th birthday party, Oct. 2005.

WE ARE... PENN STATE

Thank You!!!