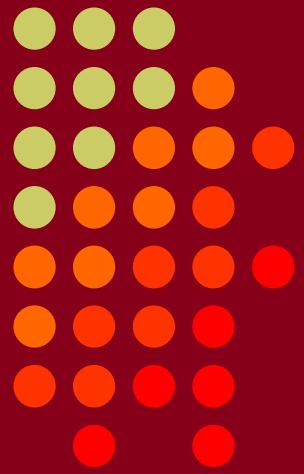
Maximizing Performance of HF Antennas with Irregular Terrain

Jim Breakall
WA3FET

Penn State University
January 23, 2021



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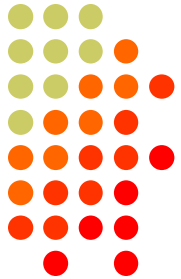
HF Antennas in Irregular Terrain



- How did it all start?
- Navy Helicopter Measurements in Utah
- Geometrical Theory of Diffraction (GTD-UTD)
- K6STI TA; N6BV VOACAP and HFTA
- K6TU Topography Service
- WP3R Contest Station at WA3FET KP4 Farm
- Magic Mountain – Camp Kilowatt in PA
- The Future – 3D Modeling??

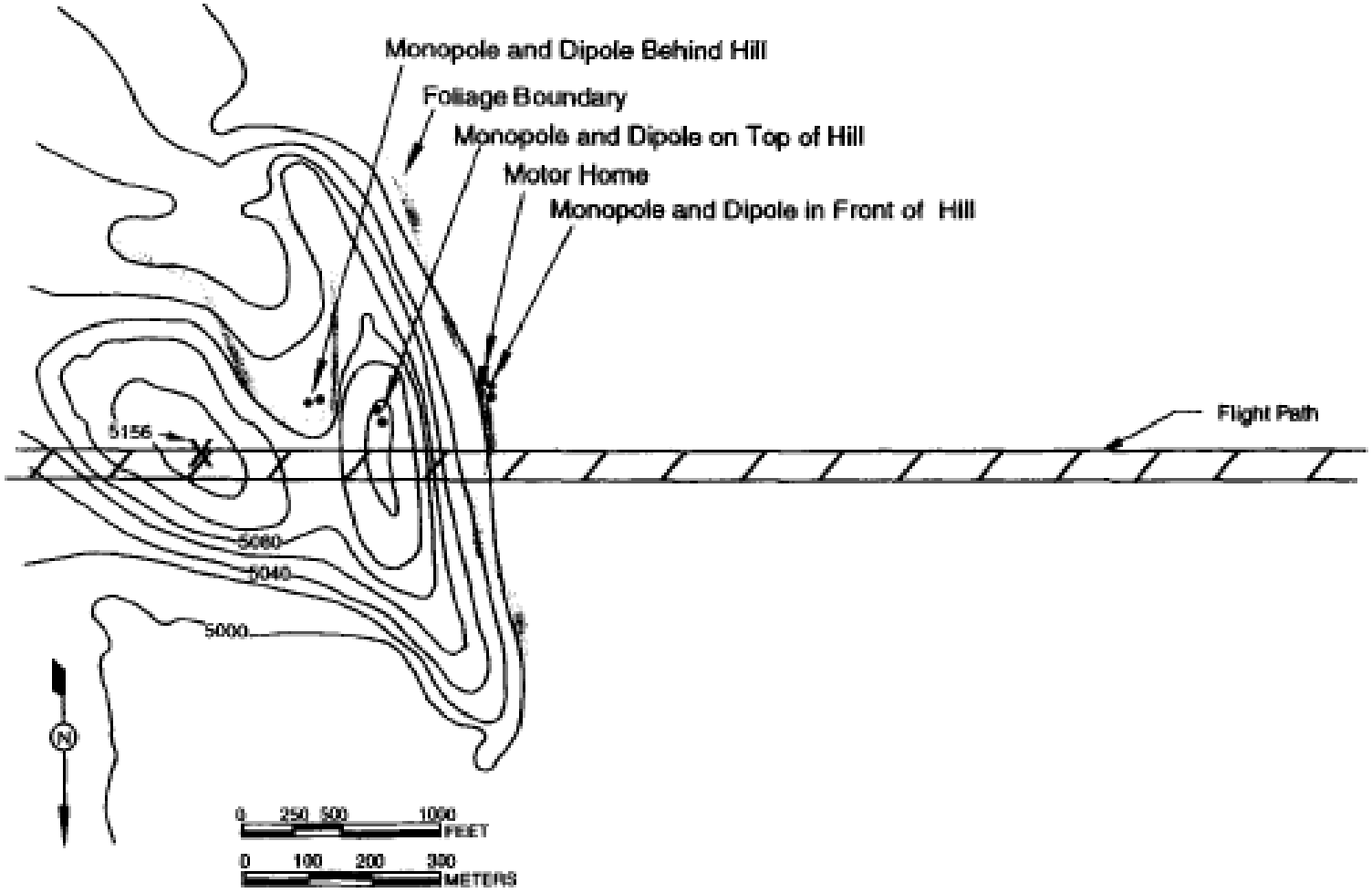
SRI and Eyring Helicopter Measurements of HF Antenna Patterns in Irregular Terrain in Utah for Navy – Started Terrain Modeling for Ham Radio – TA and HFTA

IEEE Transactions on Antennas and Propagation - 1994

The Modeling and Measurement of HF Antenna Skywave Radiation Patterns in Irregular Terrain

J. K. Breakall, *Member, IEEE*, J. S. Young, G. H. Hagn, *Fellow, IEEE*,
R. W. Adler, *Member, IEEE*, D. L. Faust, *Member, IEEE*, and D. H. Werner, *Member, IEEE*

Overview and Topography of Cedar Valley, UT, Test Area and Antenna Siting



Relative Permittivity (Dielectric Constant) and Conductivity of Earth Soil Measured

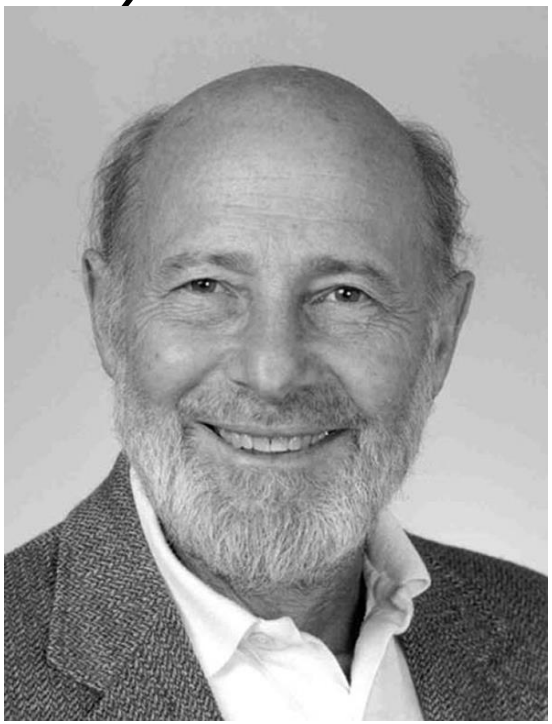
- Ground Constants measured by SRI and Eyring with OWL and Inverted Monopole

Frequency (MHz)	ϵ_r	σ (mS/m)
8.0150	14.9	6.5
15.3415	11.7	9.3
27.7415	9.5	16.1

Geometrical Theory of Diffraction GTD

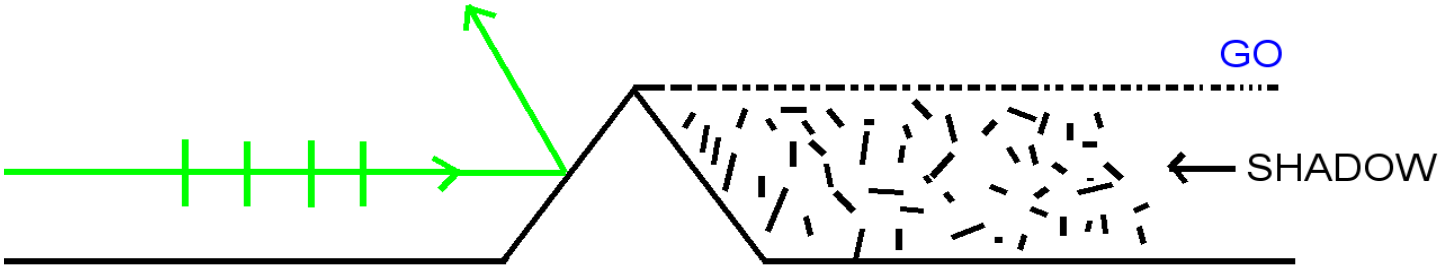
- Prof. Joseph Keller – Applied Mathematician
- Courant Institute of Mathematics (NYU)
- Stanford University
- *Geometrical theory of diffraction in* *Journal of Optical Society of America*

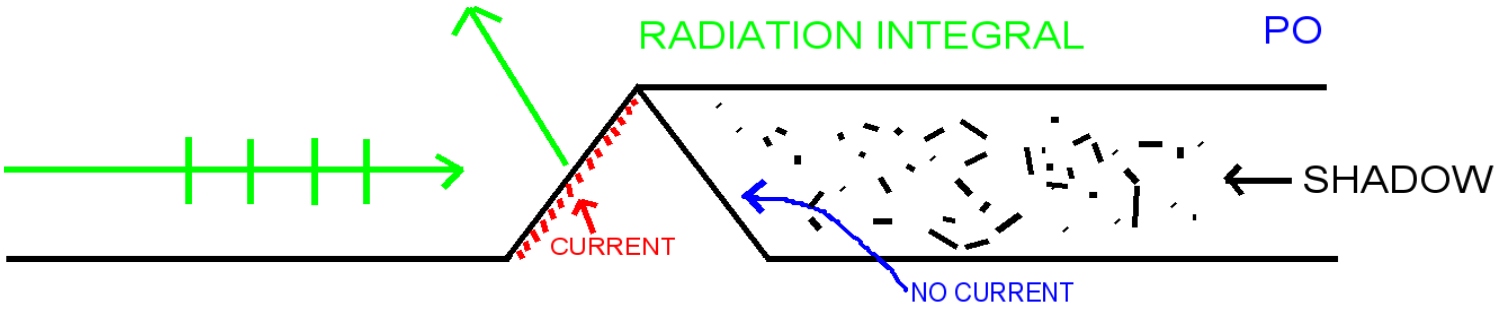
  1962
- Died in 2016 at Stanford, CA



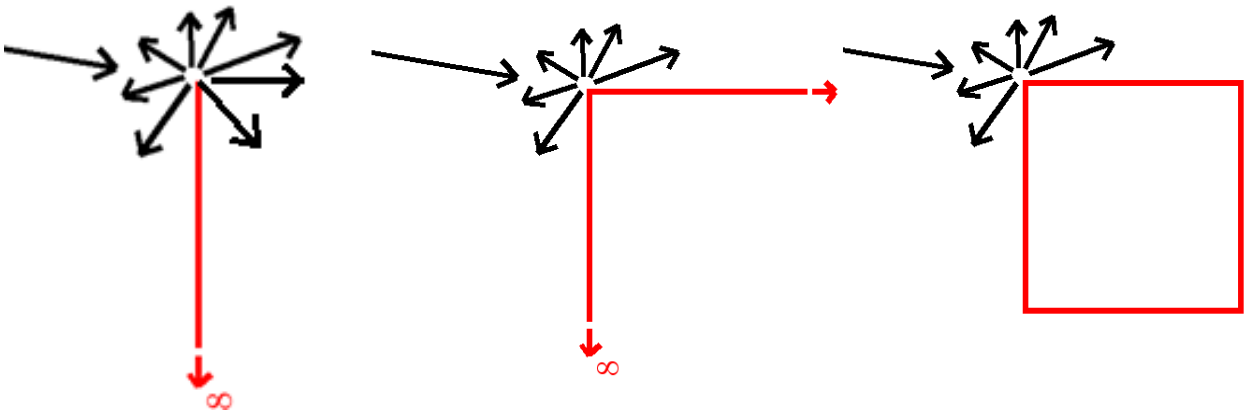
GTD Became the Improved Uniform Theory of Diffraction (UTD) at Ohio State University

- Geometrical Optics (GO) – Ray Tracing
- Physical Optics (PO) – Current Induced

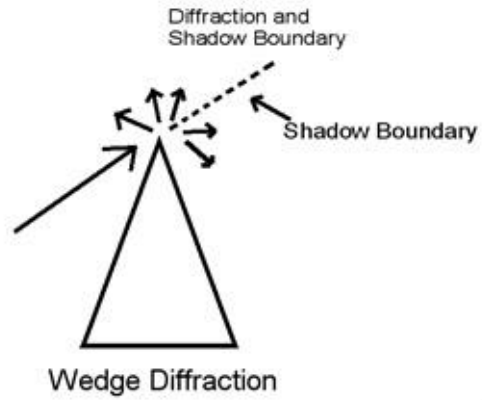




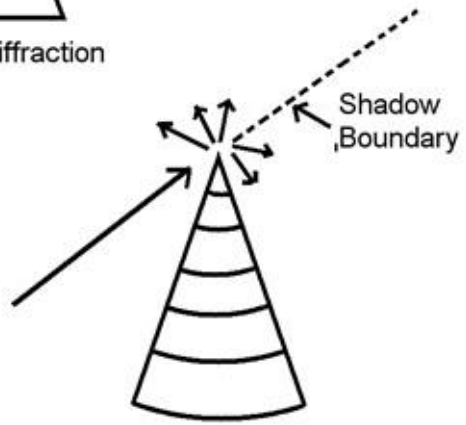
Arnold Sommerfeld – Scattering and Diffraction from an Infinite Half-Plane and Wedge



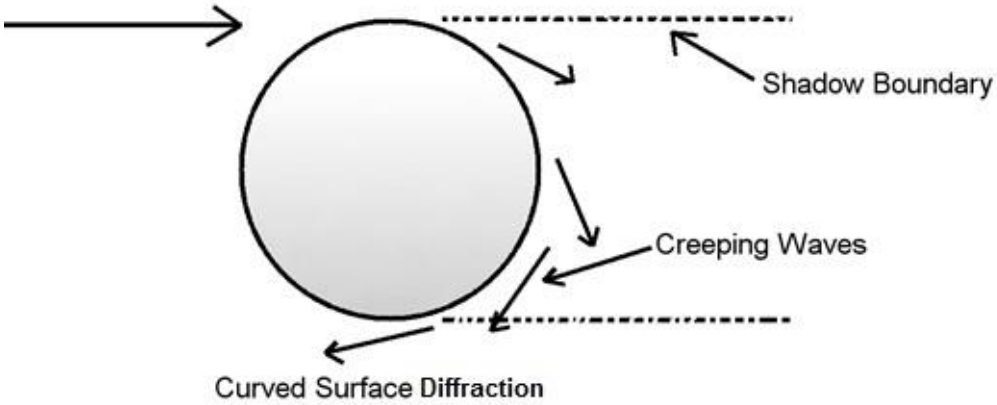
GTD-UTD



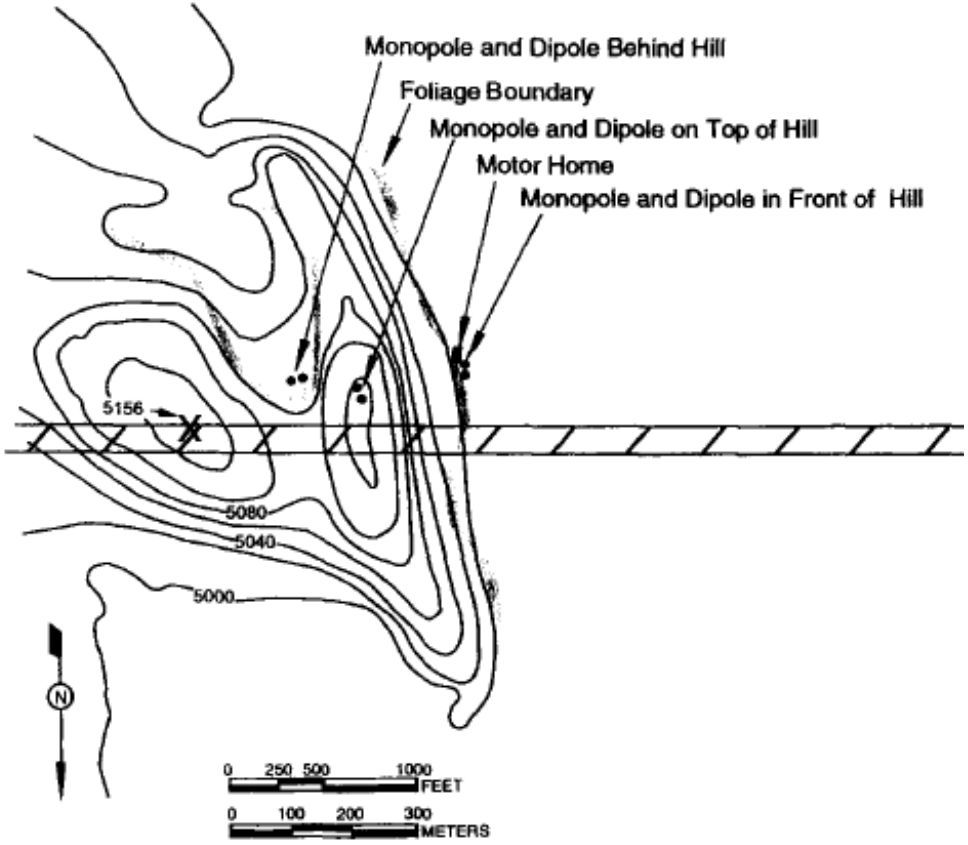
Wedge Diffraction

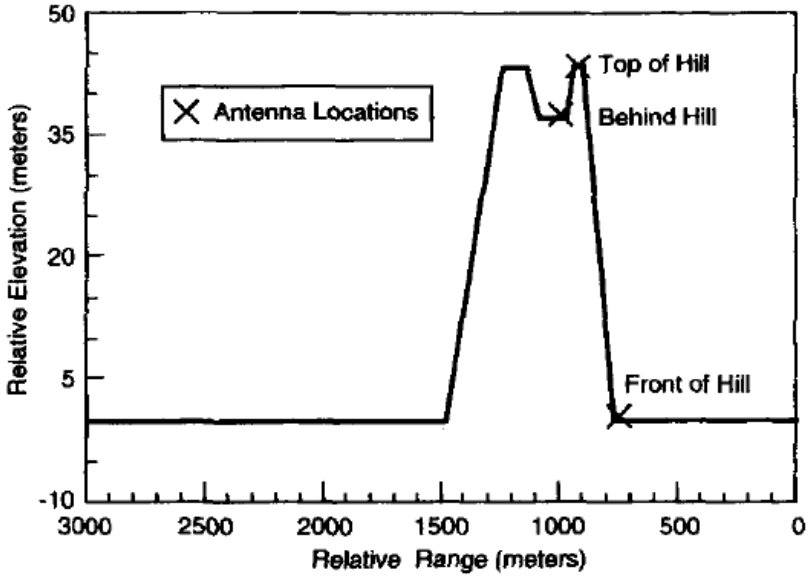


Cone, or Tip Diffraction



Simple GTD Model of Cedar Valley Topography





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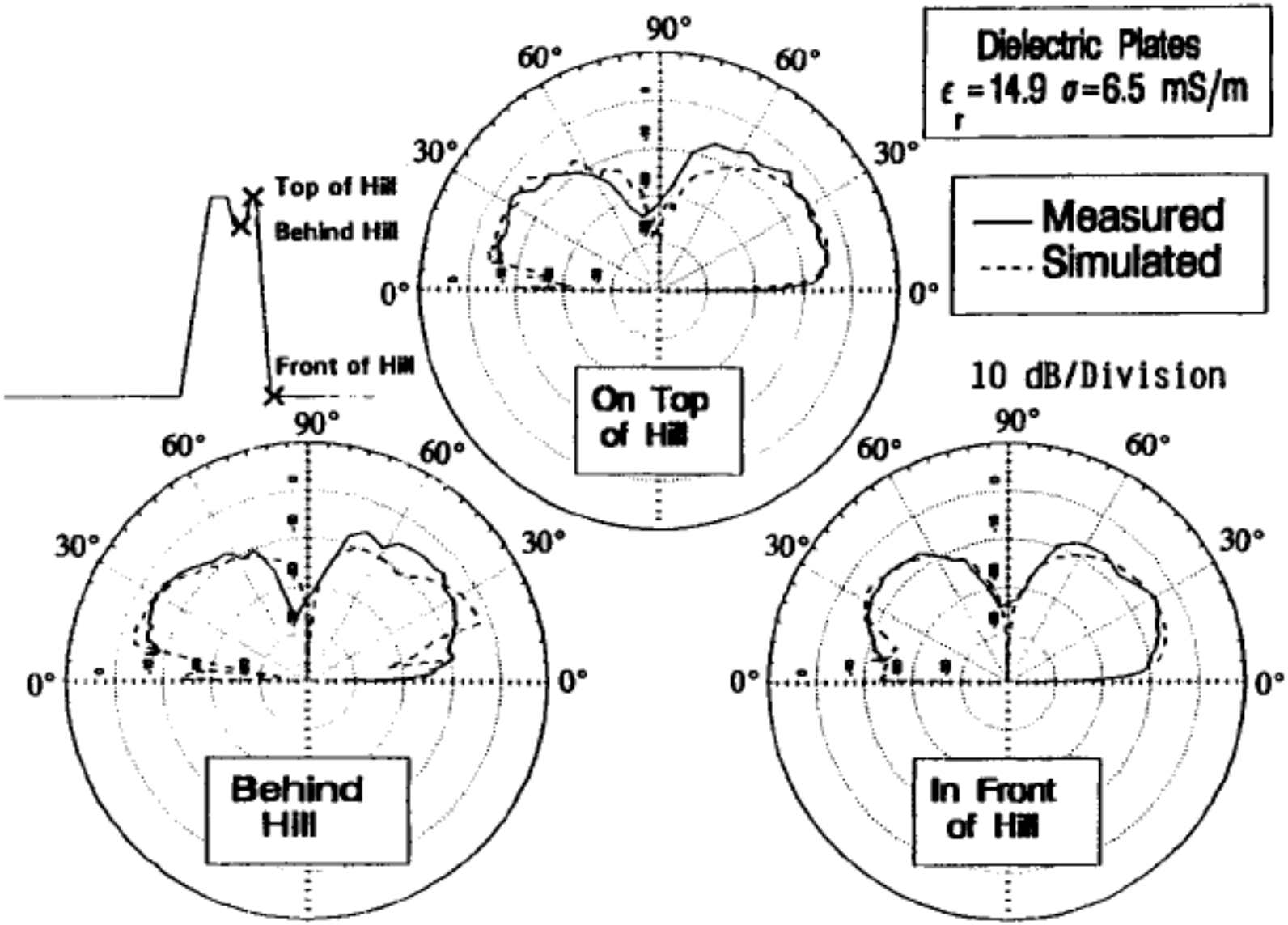
Antennas in Front, On Top, and Behind Hill

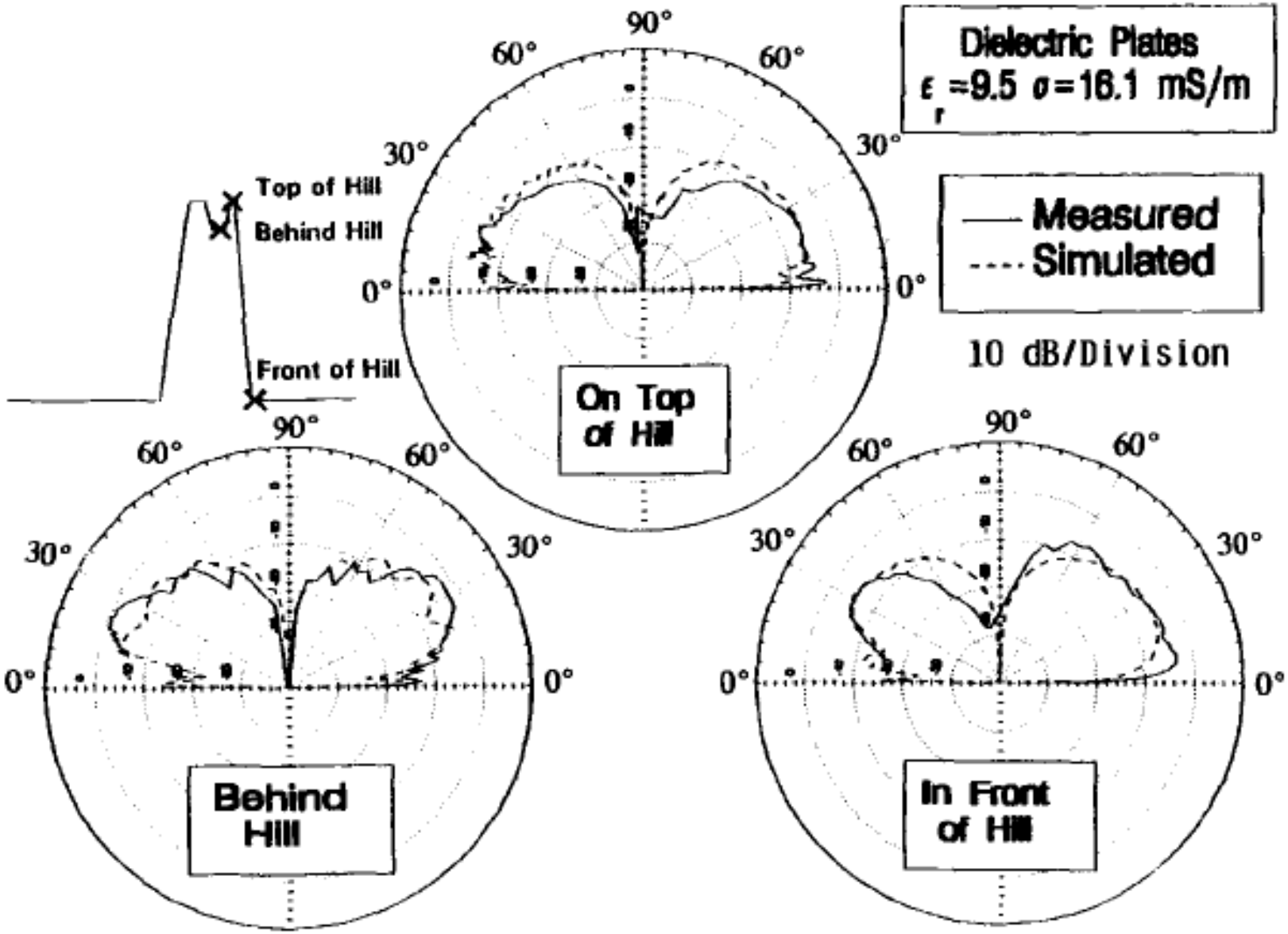
- Each monopole 4.9m with four 7.6m radials lying on the ground at each location
- Each dipole cut to be a λ/2 at a height of 4.6m above locally flat ground at each location

Frequency (MHz)	Thickness (m)	Width (km)
8.0150	4	60
15.3415	2	60
27.7415	1.1	60

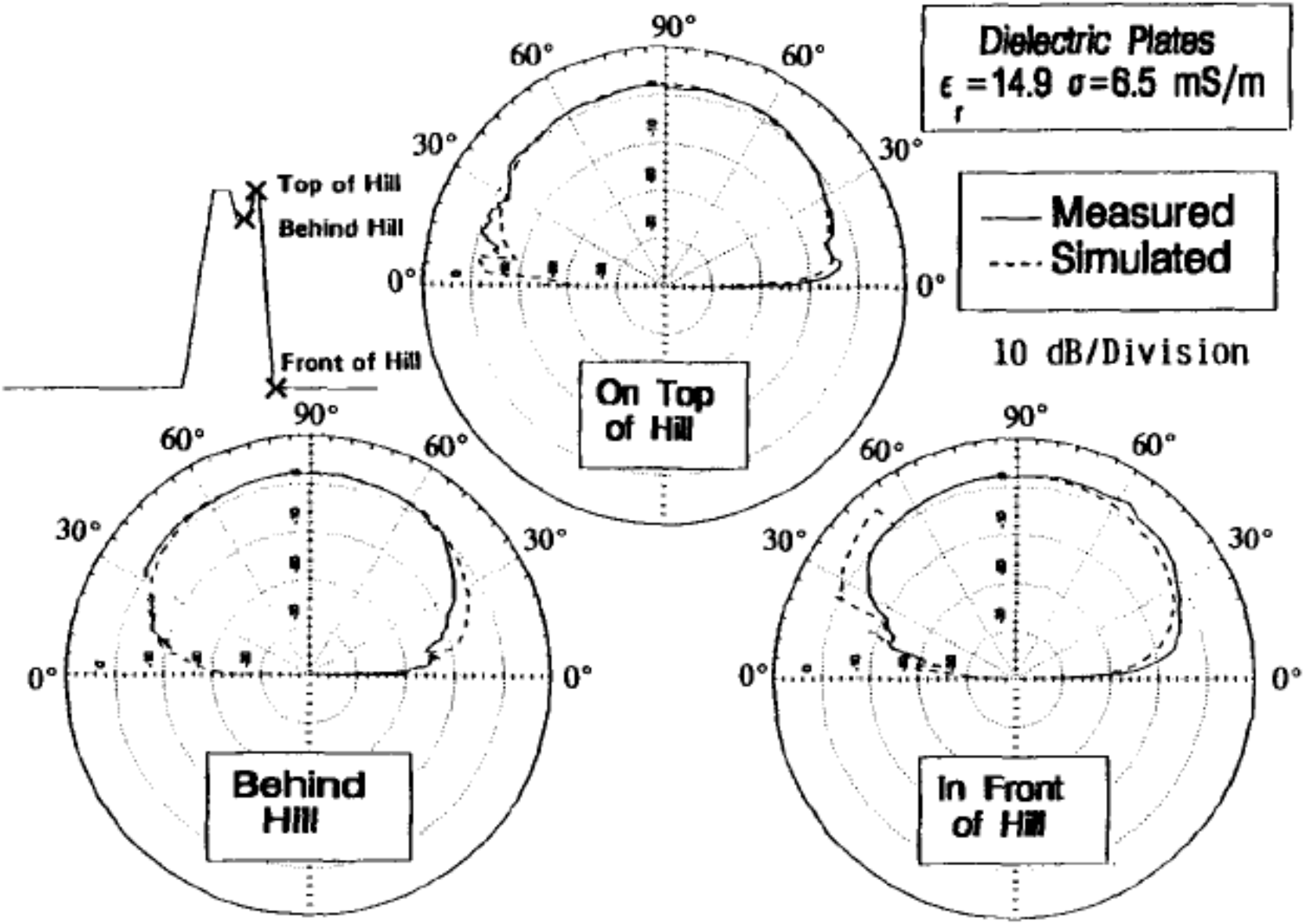
8 MHz Monopole Results



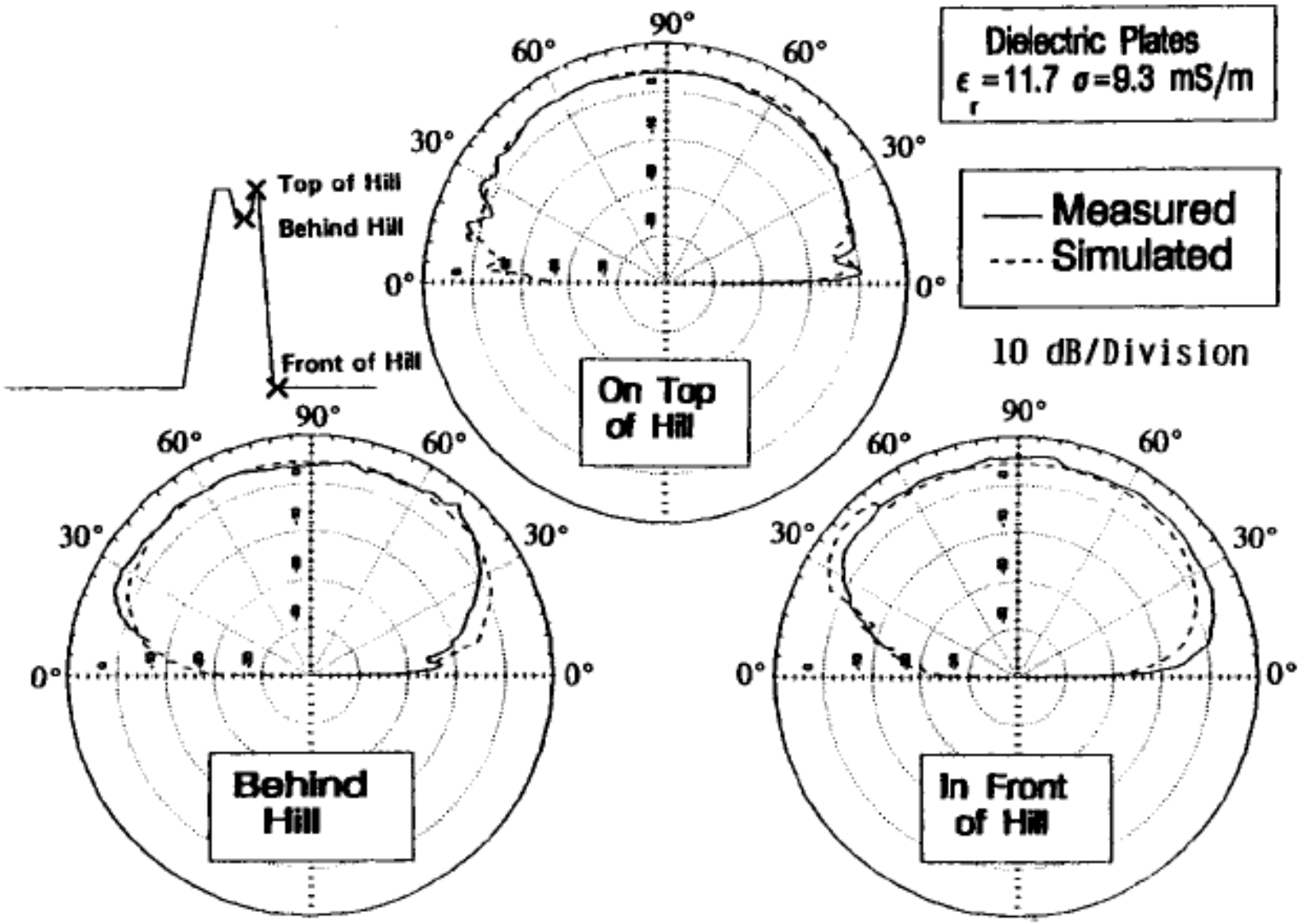
27 MHz Monopole Results



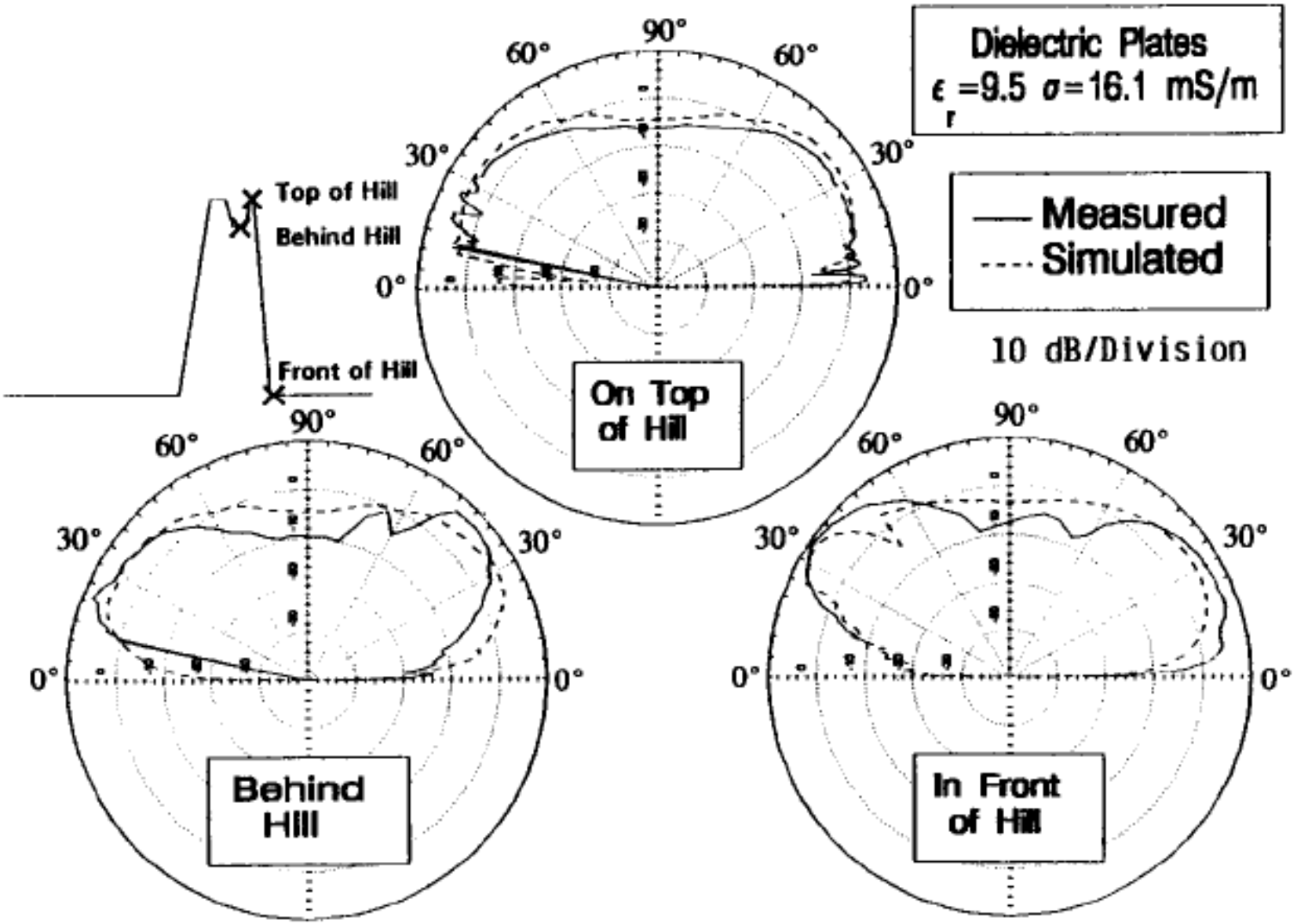
8 MHz Dipole Results



15 MHz Dipole Results



27 MHz Dipole Results

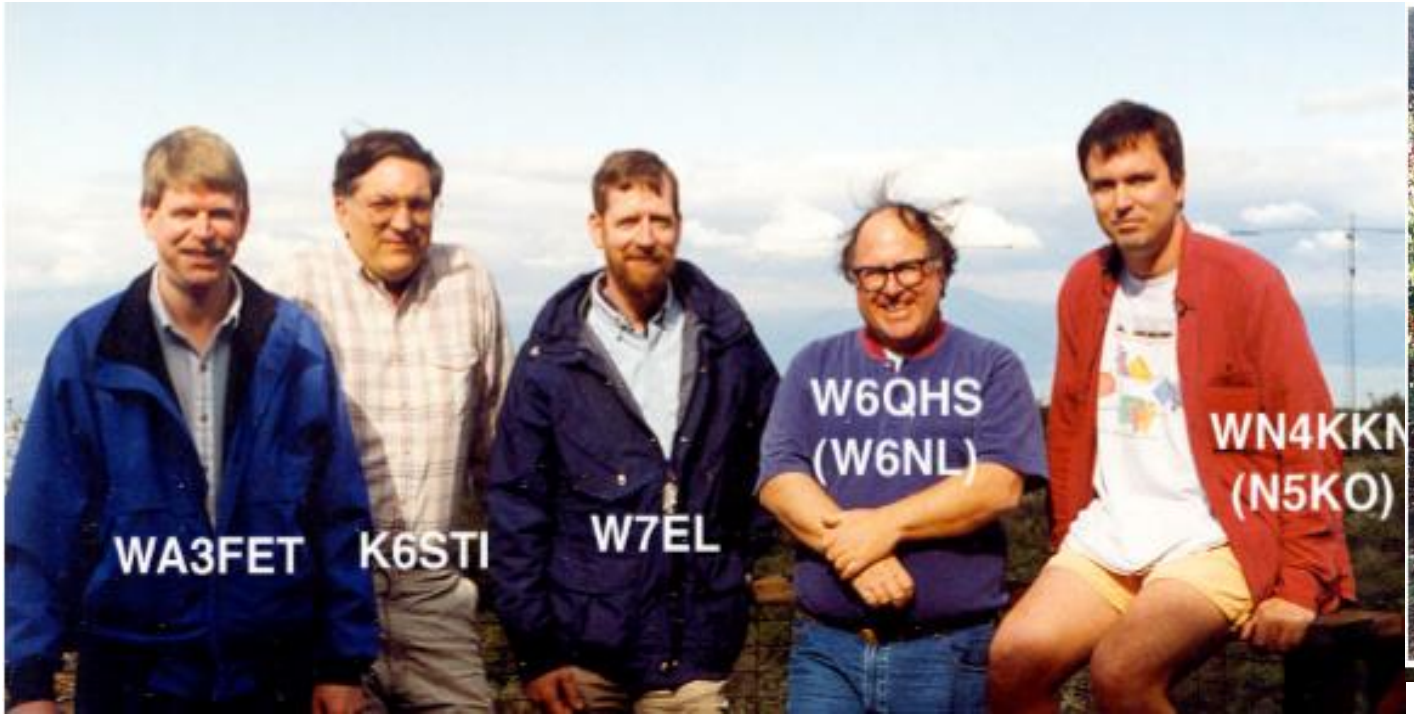


Two Important Theses at Penn State for Irregular Terrain Modeling at HF

Title – M.S. Thesis
Simulation of irregular terrain effects on antenna patterns using the uniform geometrical theory of diffraction (UTD)
Author
Young, Joel S., 1964-
Pub date:
1993.

Title – Ph. D. Thesis
Simulation of antenna patterns over 3-dimensional irregular terrain using the uniform geometrical theory of diffraction (UTD)
(Development of the paint system)
Author
Young, Joel S., 1964-
Pub date:
1994.

It Started Here at the ACES Conference and a Get-together at the Home on Top of W6NL's Mountain



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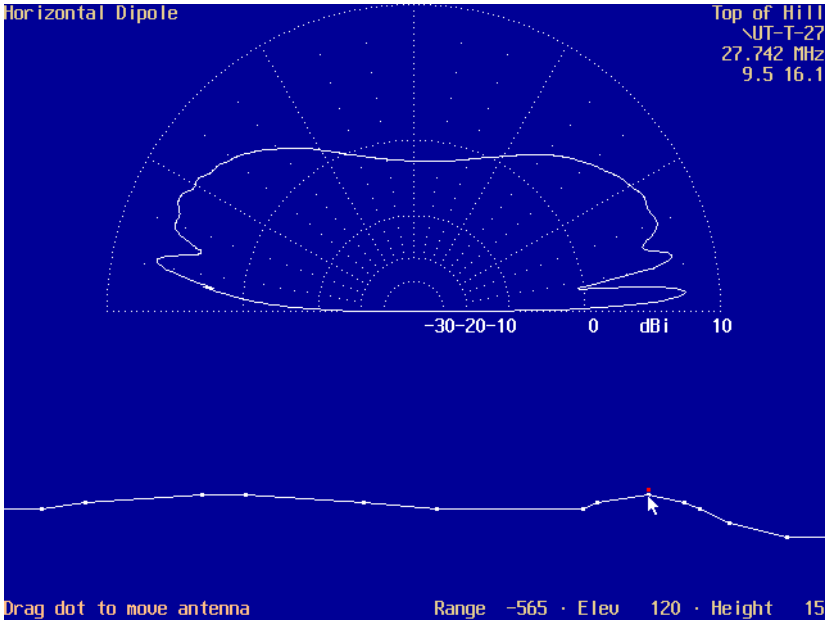
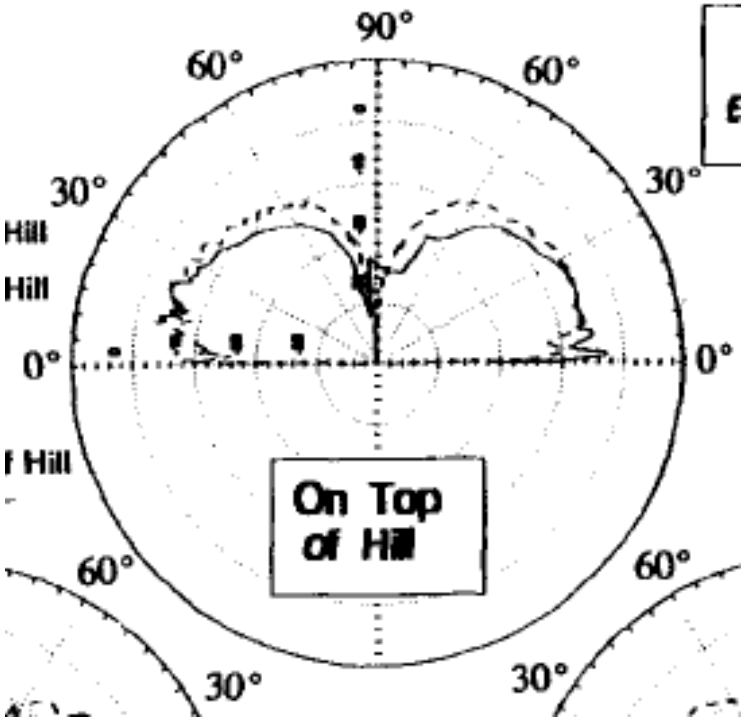
Brian Beezley – K6STI Terrain Analyzer (TA)

TA vs Simple GTD-UTD Model On Top of Hill 27 MHz





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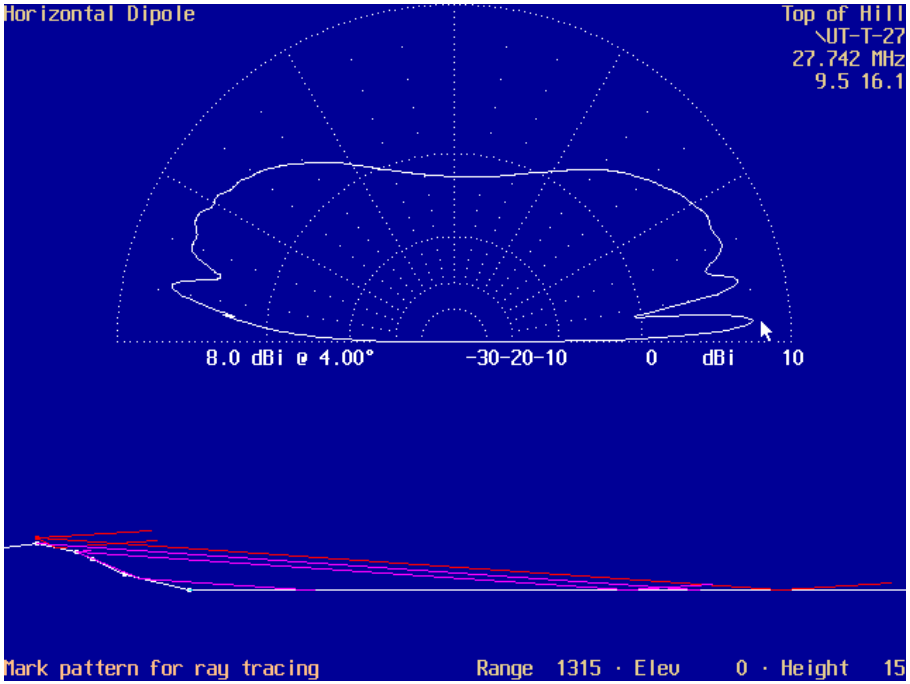
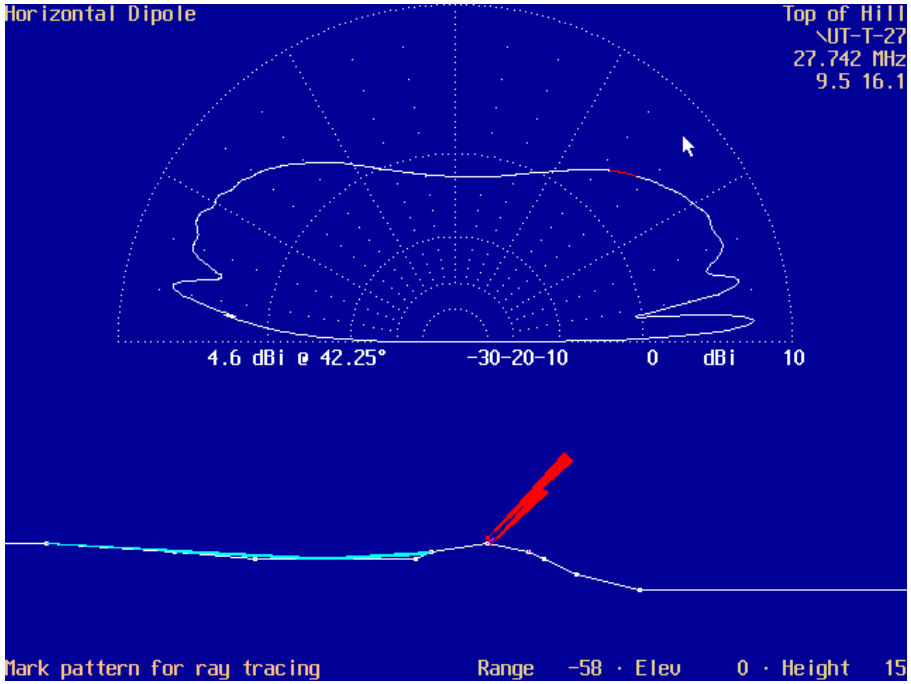
TA Showing GO Reflected and GTD-UTD Diffracted Rays Top of Hill 27 MHz





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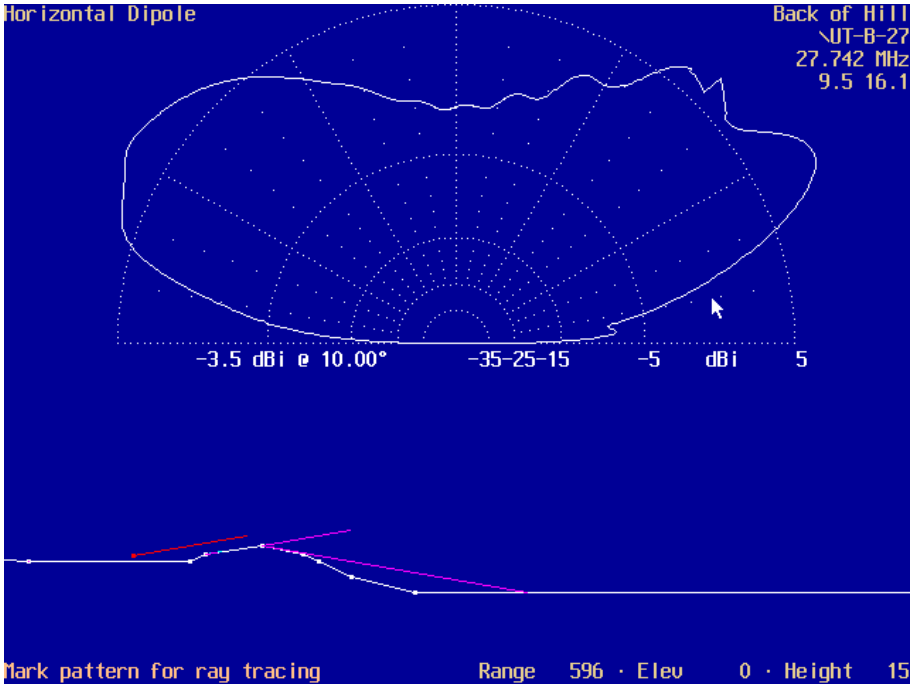
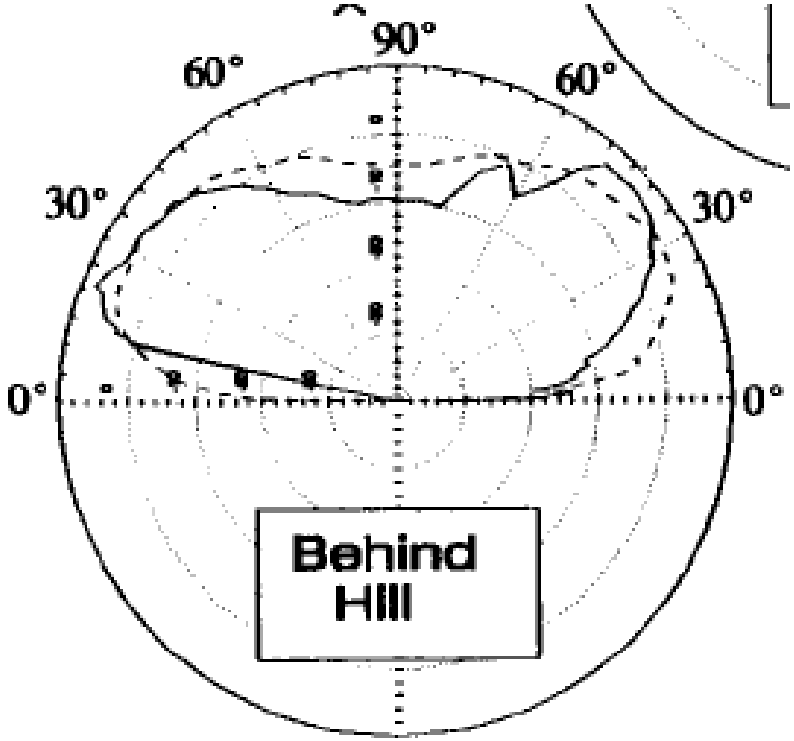
TA vs Simple GTD-UTD Model Behind Hill 27 MHz





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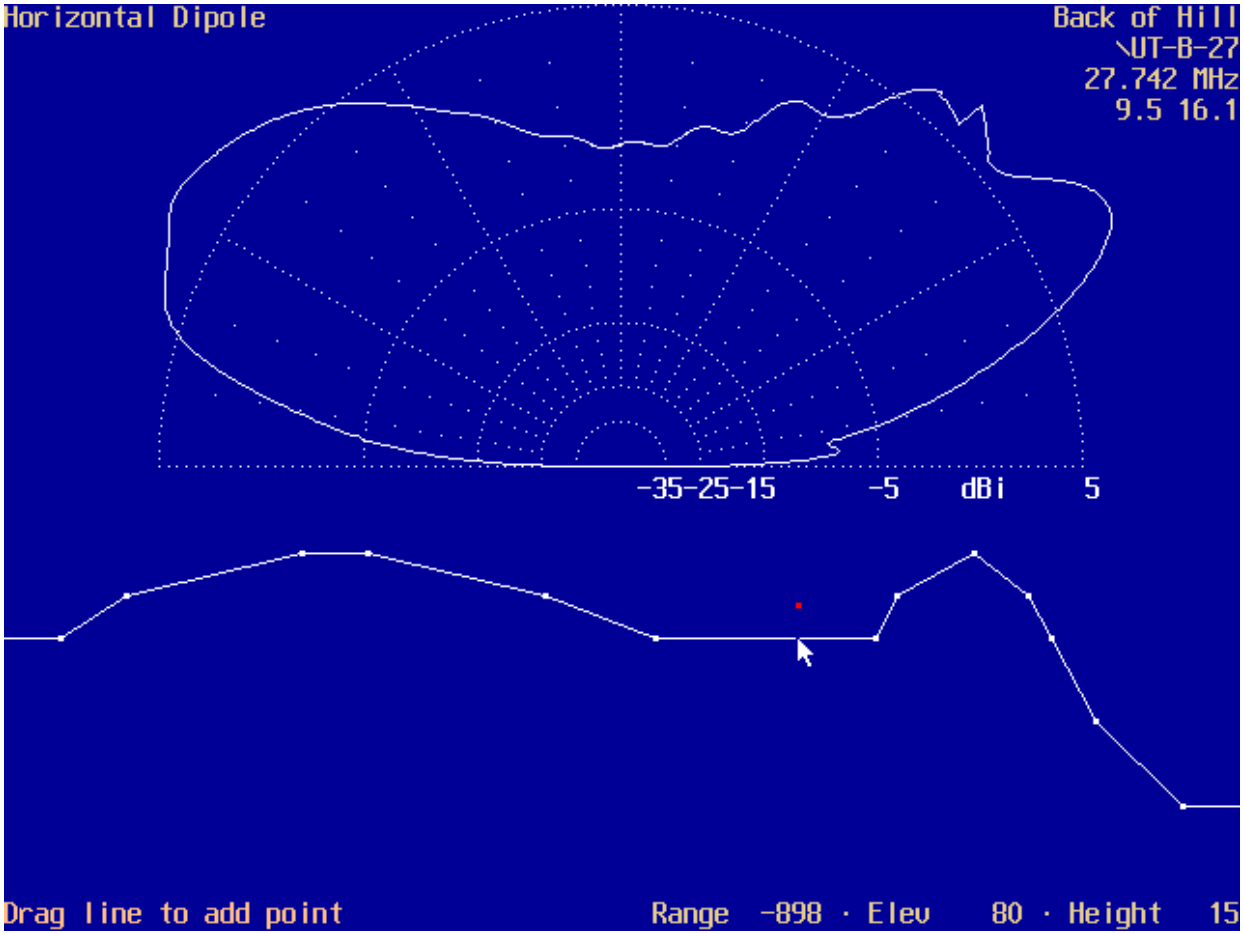
TA vs Simple GTD-UTD Model Behind Hill 27 MHz Terrain Expanded



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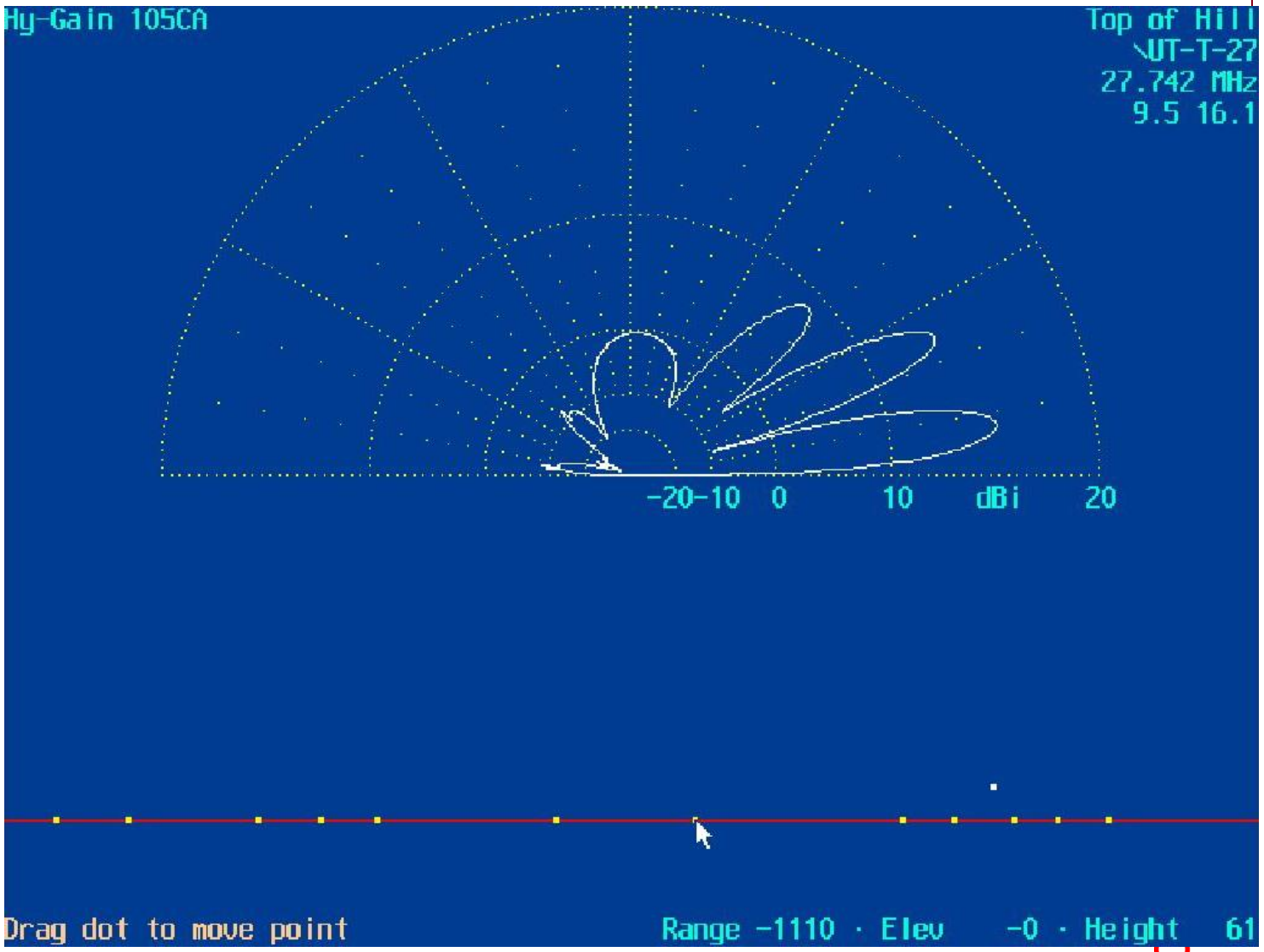
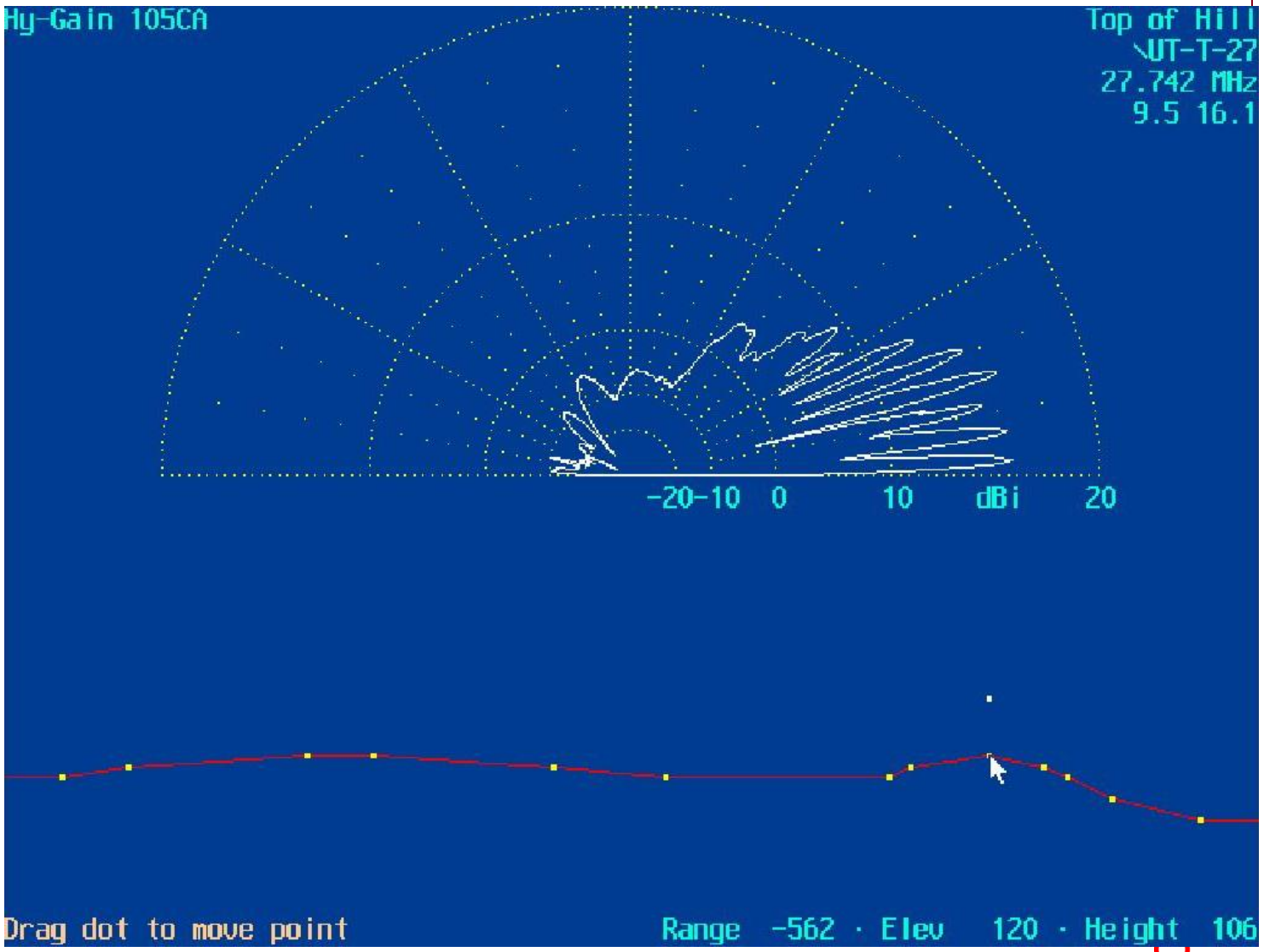
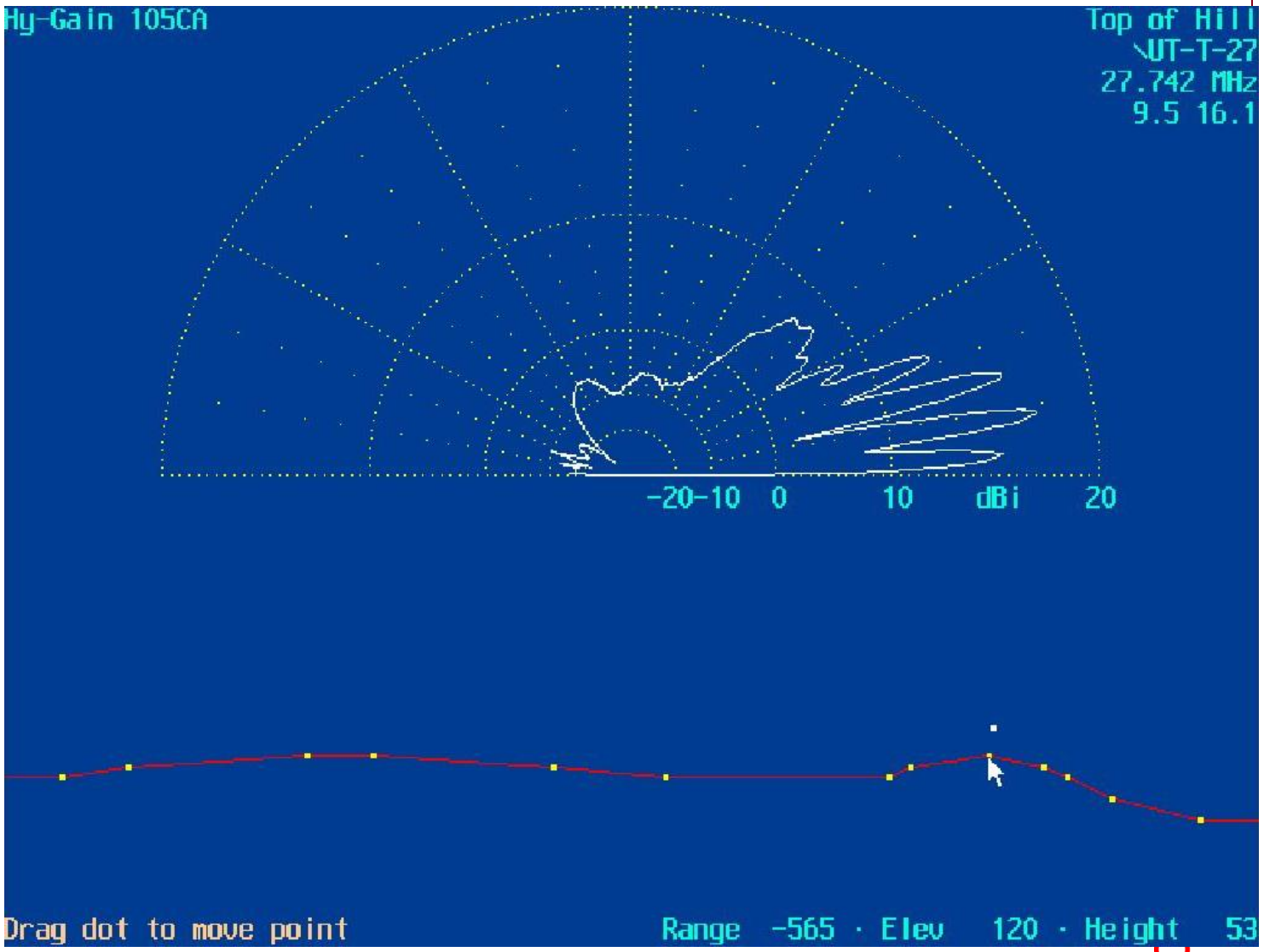
K6STI TA - Hy-Gain 105CA 61 ft over Flat Ground



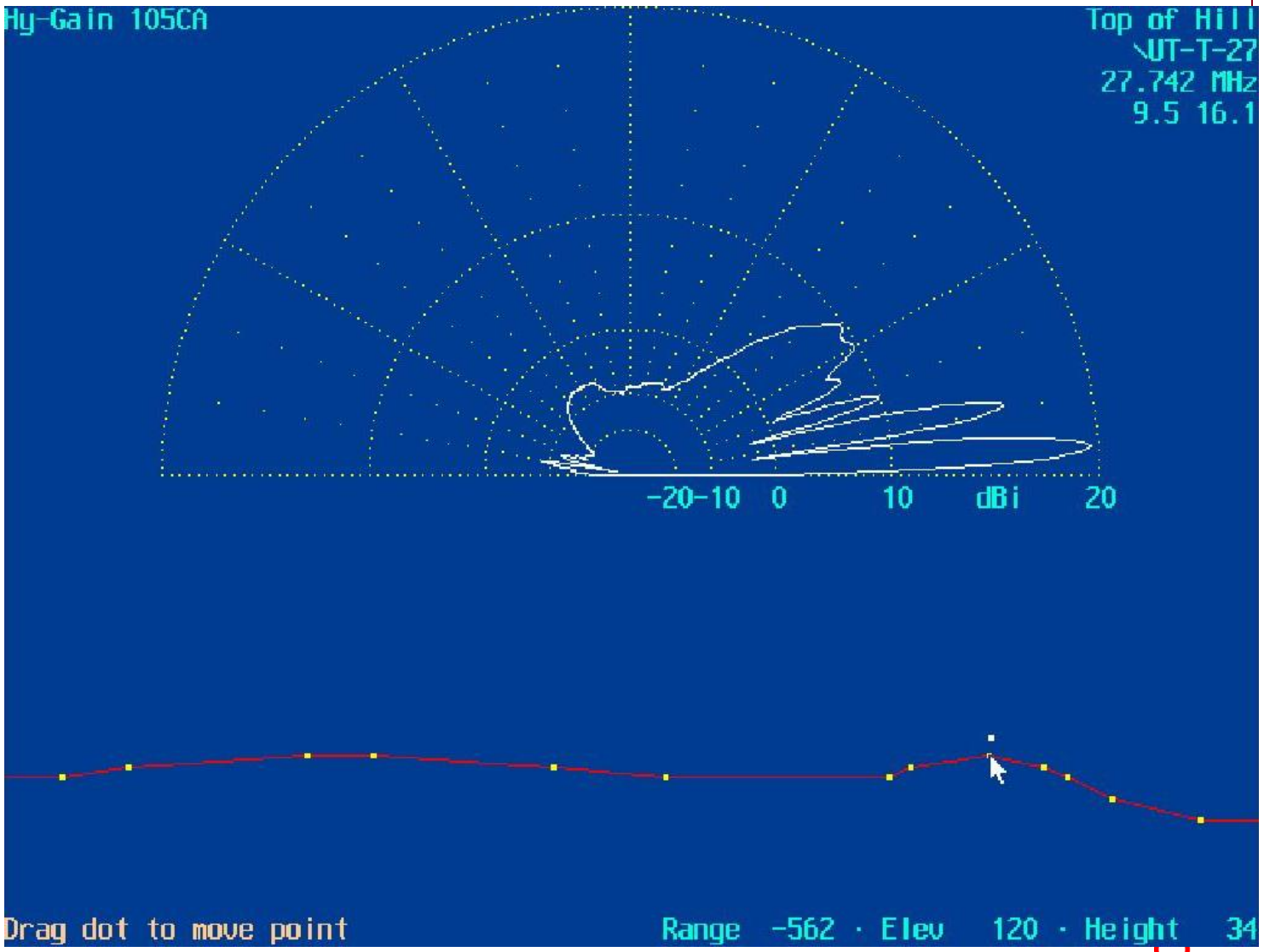
Hy-Gain 105CA 106 ft on Top of Hill in Utah



Hy-Gain 105CA 53 ft on Top of Hill in Utah



Hy-Gain 105CA 34 ft on Top of Hill in Utah

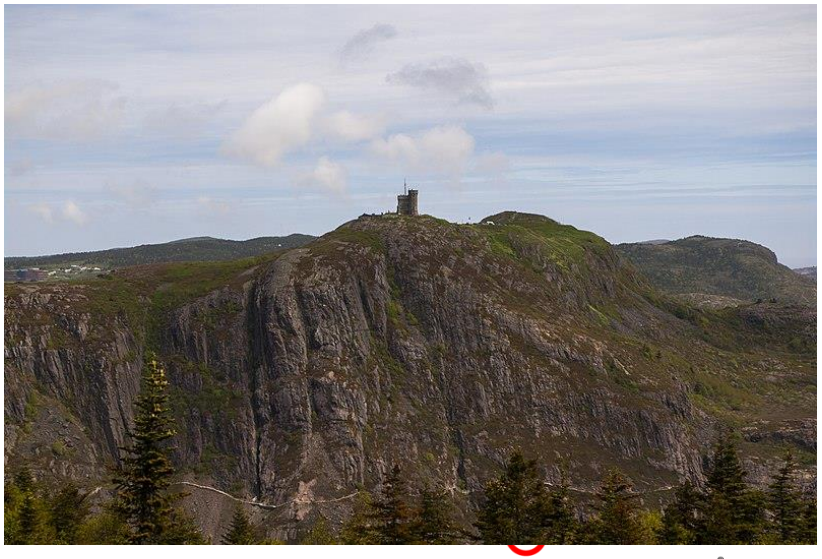


Dean Straw, N6BV, Created the High Frequency Terrain Assessment (HFTA) Program

"The subject of how to choose a QTH for working DX has fascinated Hams since the beginning of amateur operations. No doubt, Marconi spent a lot of time wandering around Newfoundland looking for a great radio QTH before making the first transatlantic transmission."

The ARRL Antenna Book, 22st Ed.

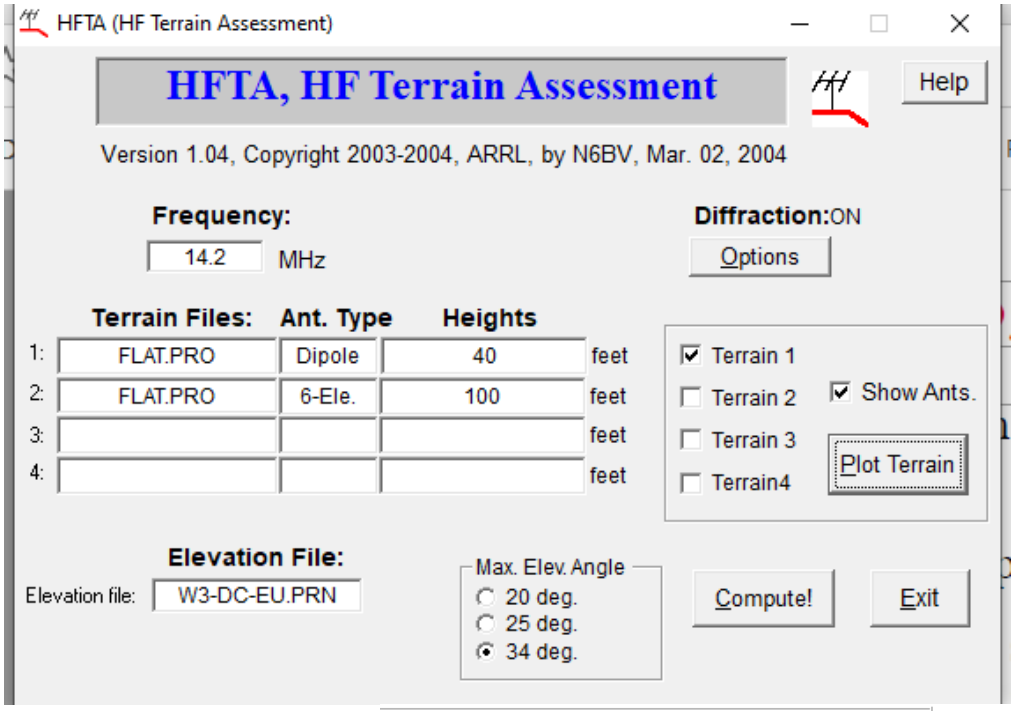
Signal Hill
St. John's, Newfoundland

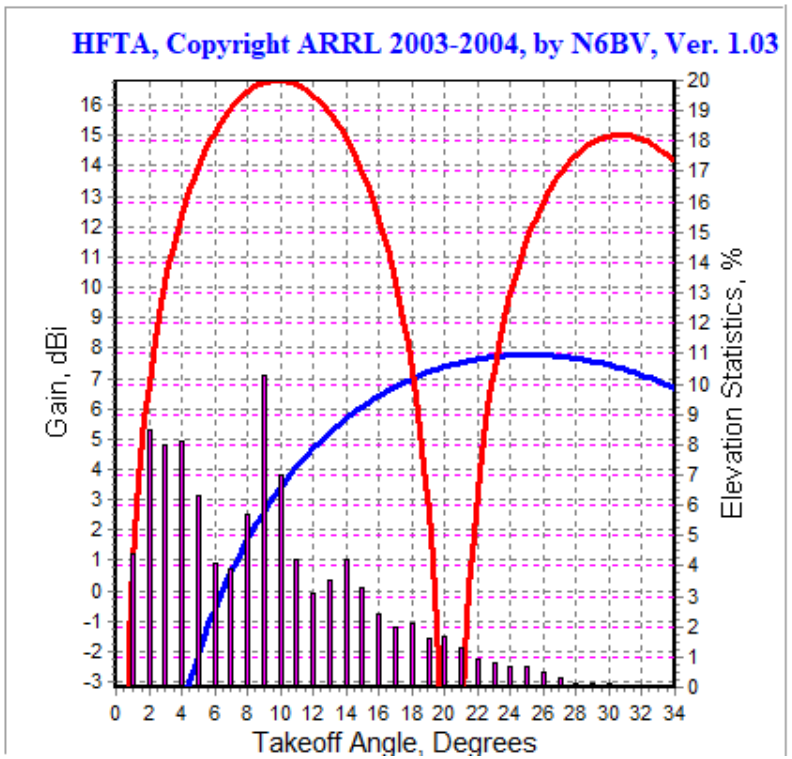


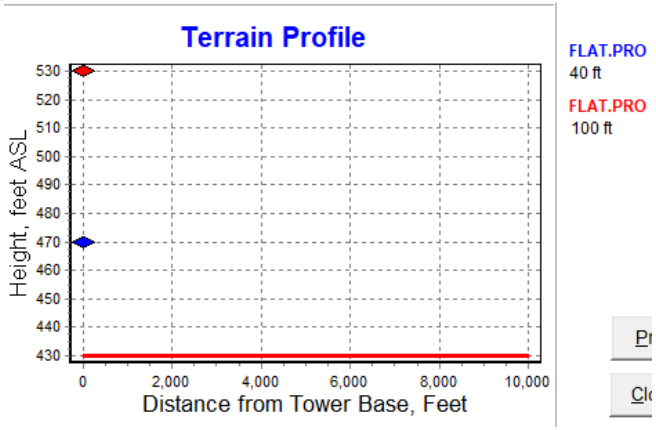
N6BV and HFTA

- Dean completed a detailed study at ARRL HQ on the range of elevation angles needed for communication between various locations around the world.
- He computed statistics using IONCAP and later VOACAP for many receiver QTHs, solar conditions, seasons, time of day, frequency, etc.
- HFTA also computes the effect of irregular terrain on antenna patterns mainly with built in Yagi and Yagi stacks

HFTA Elevation Angle Statistics and Patterns







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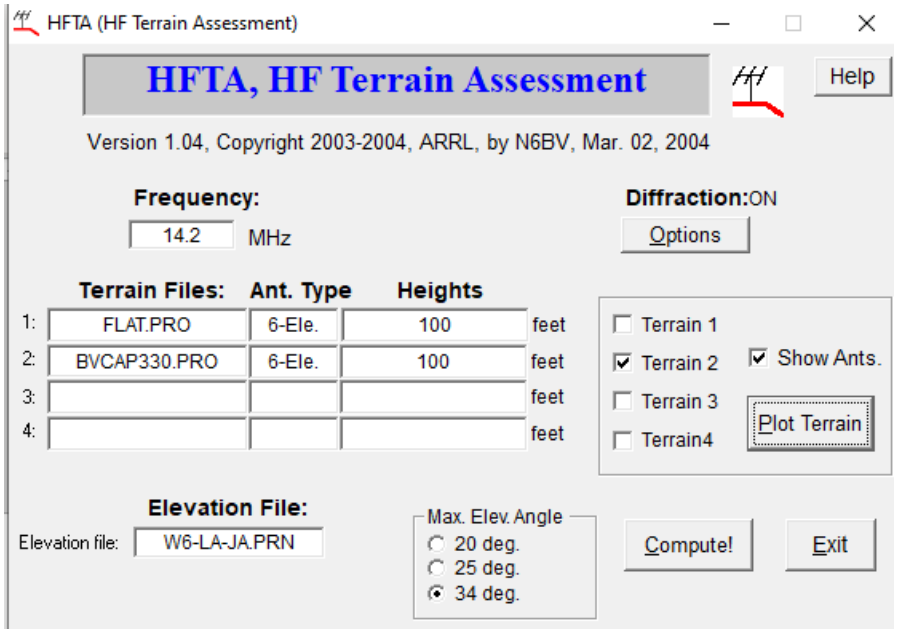
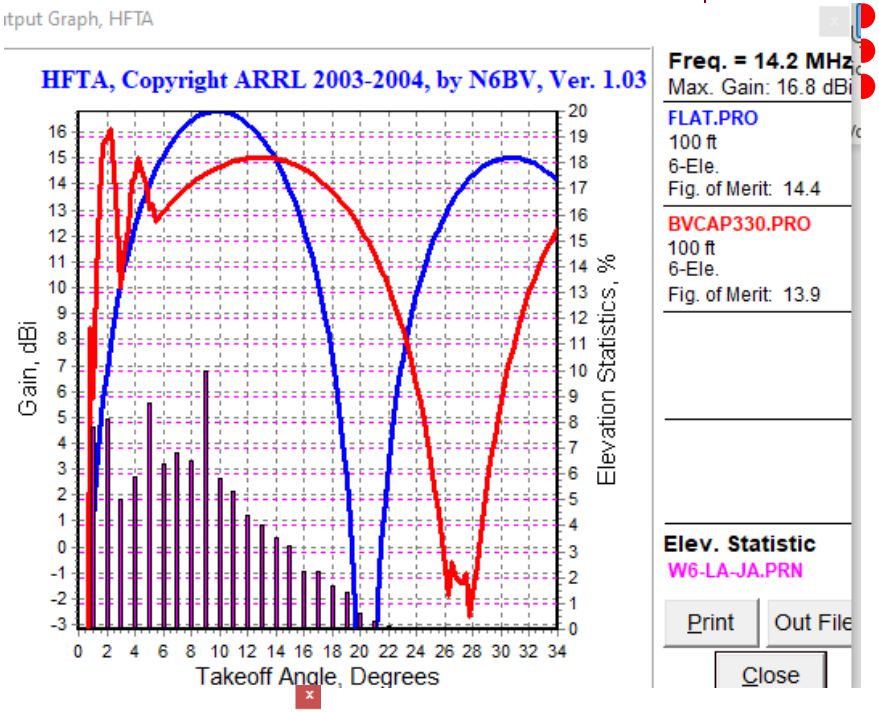
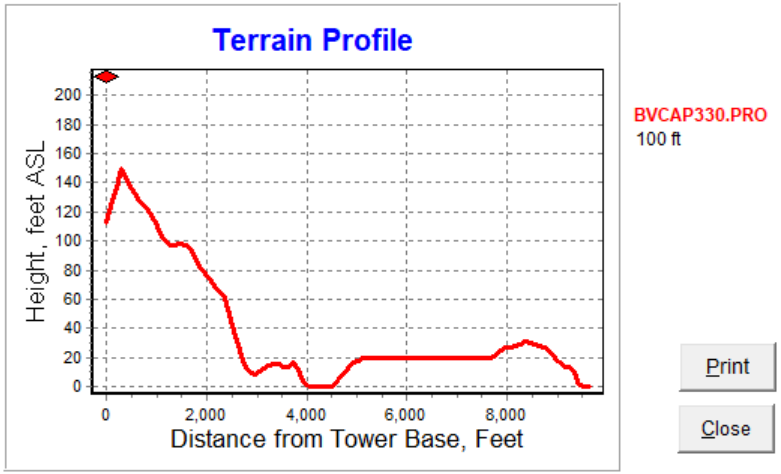
HFTA Elevation Angle Statistics and Patterns
N6BV from CA to Japan



Terrain Plot, HFTA





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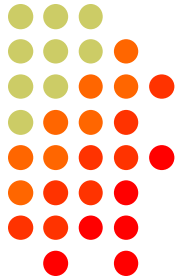
How to get Terrain Files
Stu Phillips – K6TU



- https://paas.k6tu.net (New site)
- Register and it is free to get terrain files
- Best to purchase $35 subscription for more features and easy transfer
- You will get terrain files for every 1 degree for all azimuths around the latitude and longitude that you put in
- Can get lat and long from Google Maps

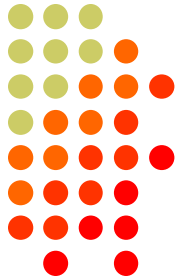
Comparison of WP3R/WA3FET Contest Station on Highest Hill on the North Central Coast of Puerto Rico to the WP3R New Home Station (Flat Ground) to USA and to Europe

- **WP3R Contest Station –**
- **160 – Dipole 60ft**
- **80 – Dipole 60ft**
- **40 – 3 el Wire Yagi (Wide space like 4 el) 60 ft**
- **20 – 6 el 60ft**
- **15 – 6 el 60ft**
- **10 – 6 el 30ft**

- **WP3R new House Station –**
- **160 – Inverted-L modeled as dipole 60ft**
- **80 – dipole 60ft**
- **40 – dipole 60ft**
- **20 – 3 el Yagi 60ft Skyhawk**
- **15 – 3 el Yagi 60ft Skyhawk**
- **10 – 4 el Yagi 60ft Skyhawk**

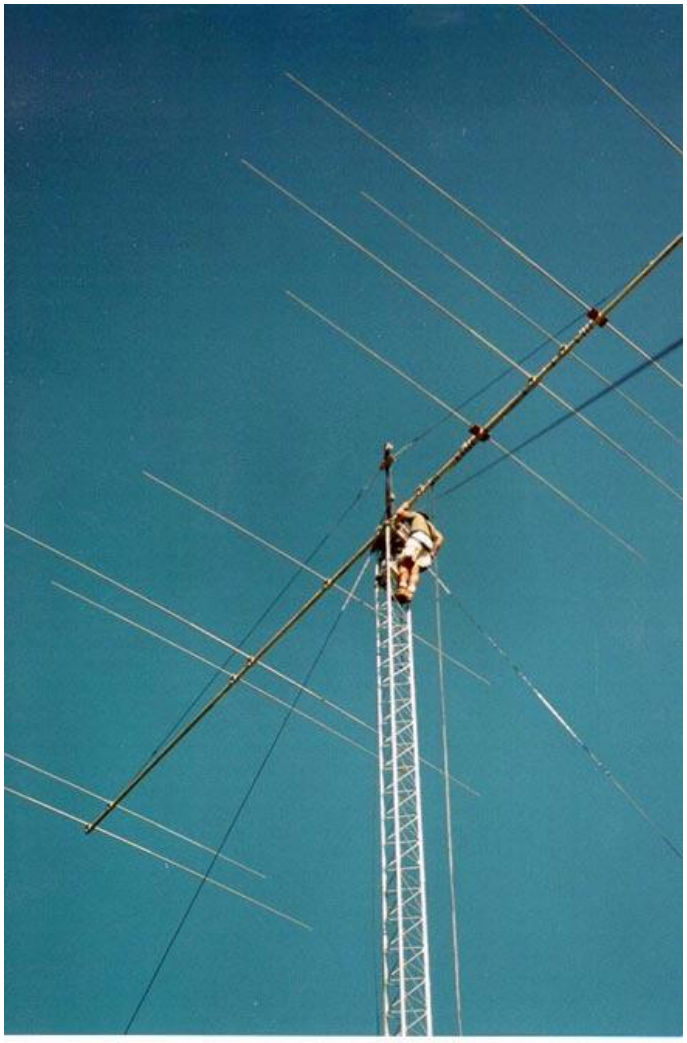
Contest Station Built in 1998 at the WA3FET Puerto Rico Farm using the WP3R Callsign

WA3FET/KP4 Winning Contest Location from Puerto Rico using Callsign WP3R



- Won ARRL SS Phone High Power Single Op 10 years in row – Still have Phone Record – KE3Q
- Won ARRL SS CW High Power Single Op 8/10 years in row – KE3Q
- Won ARRL DX World Both Modes High Power Single Op one year – K9PG
- Won ARRL DX World Both Modes Low Power Single Op the next year – K9PG

WA3FET-WP3R Contest Station, Arecibo PR



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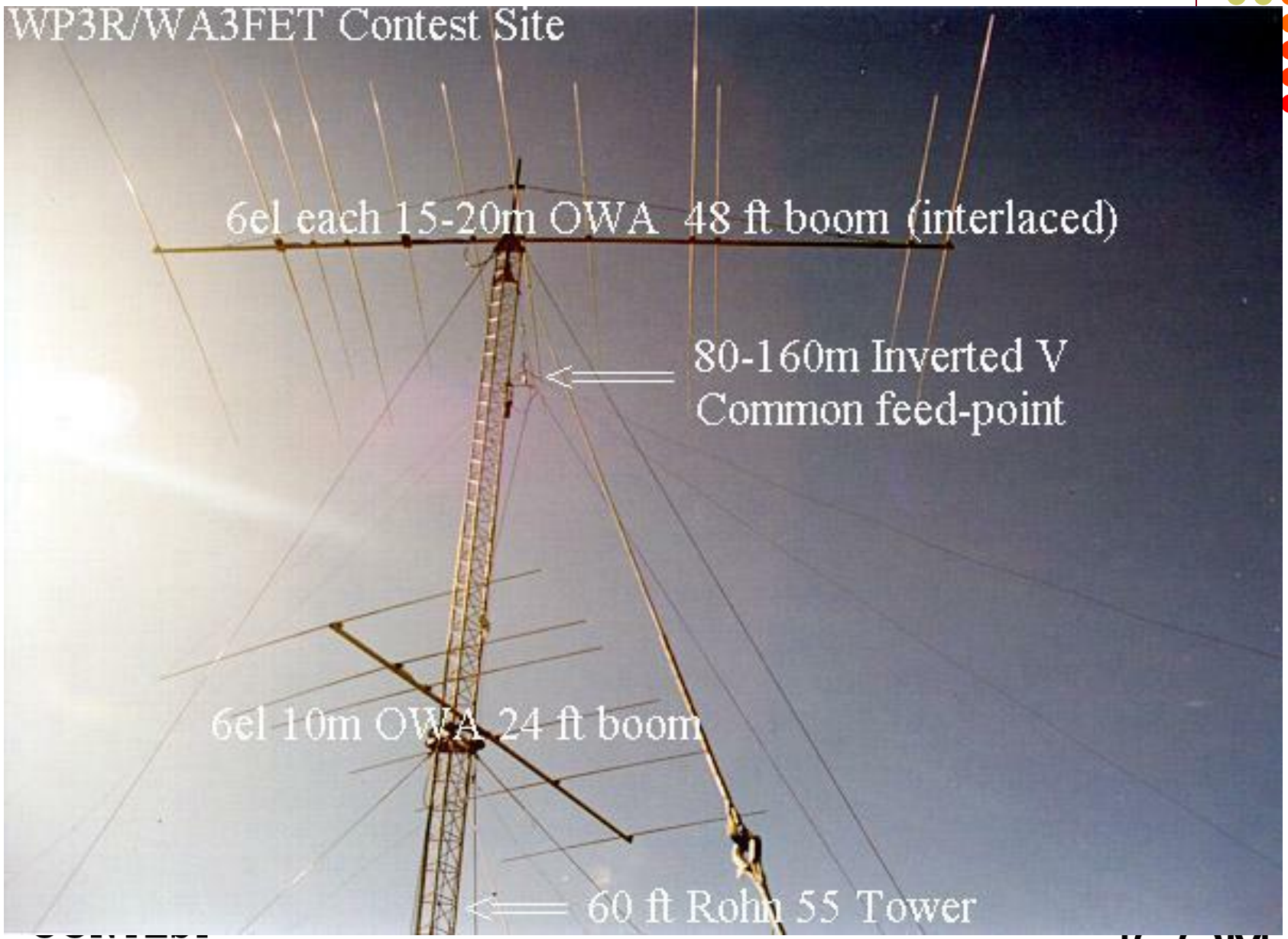
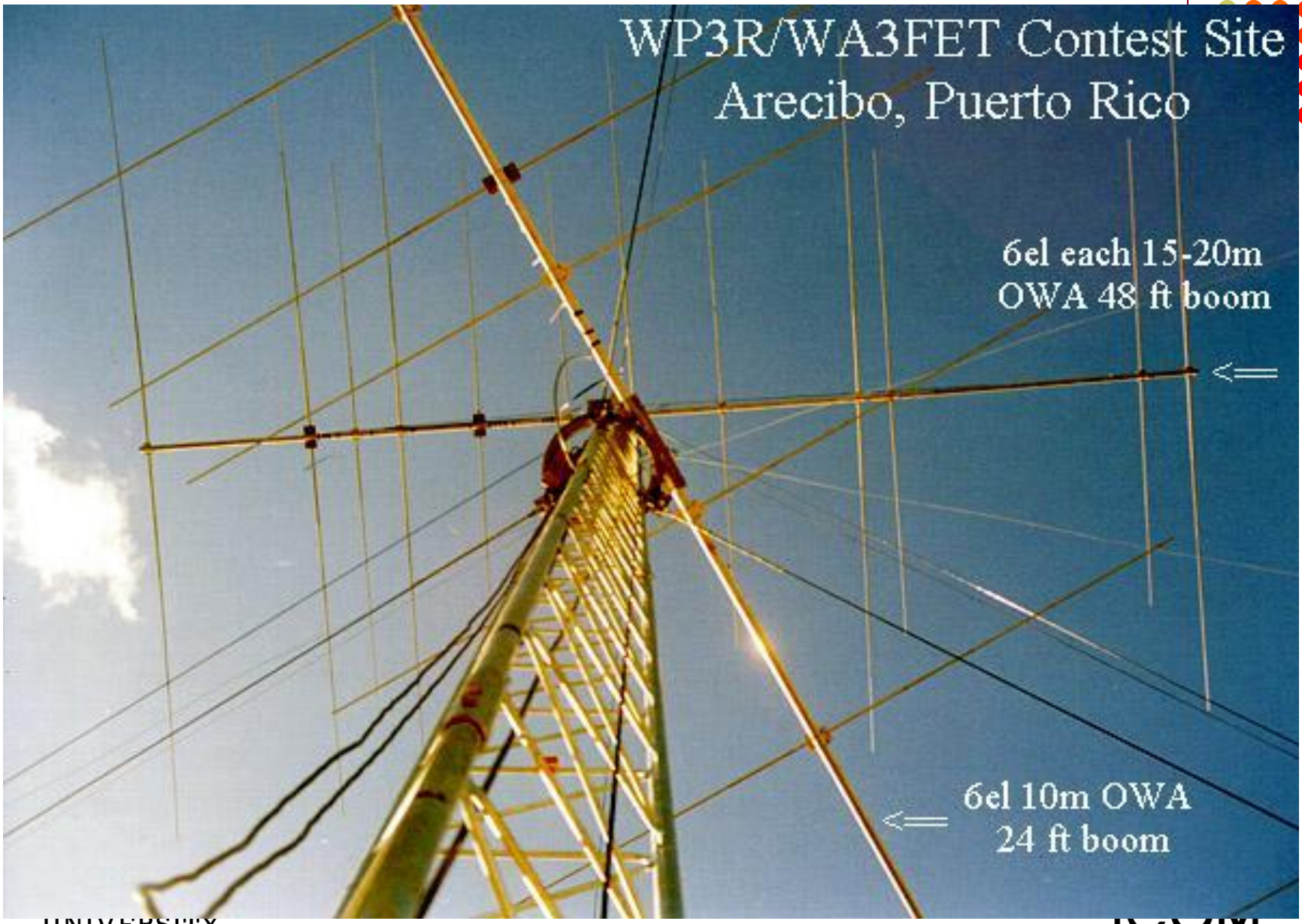
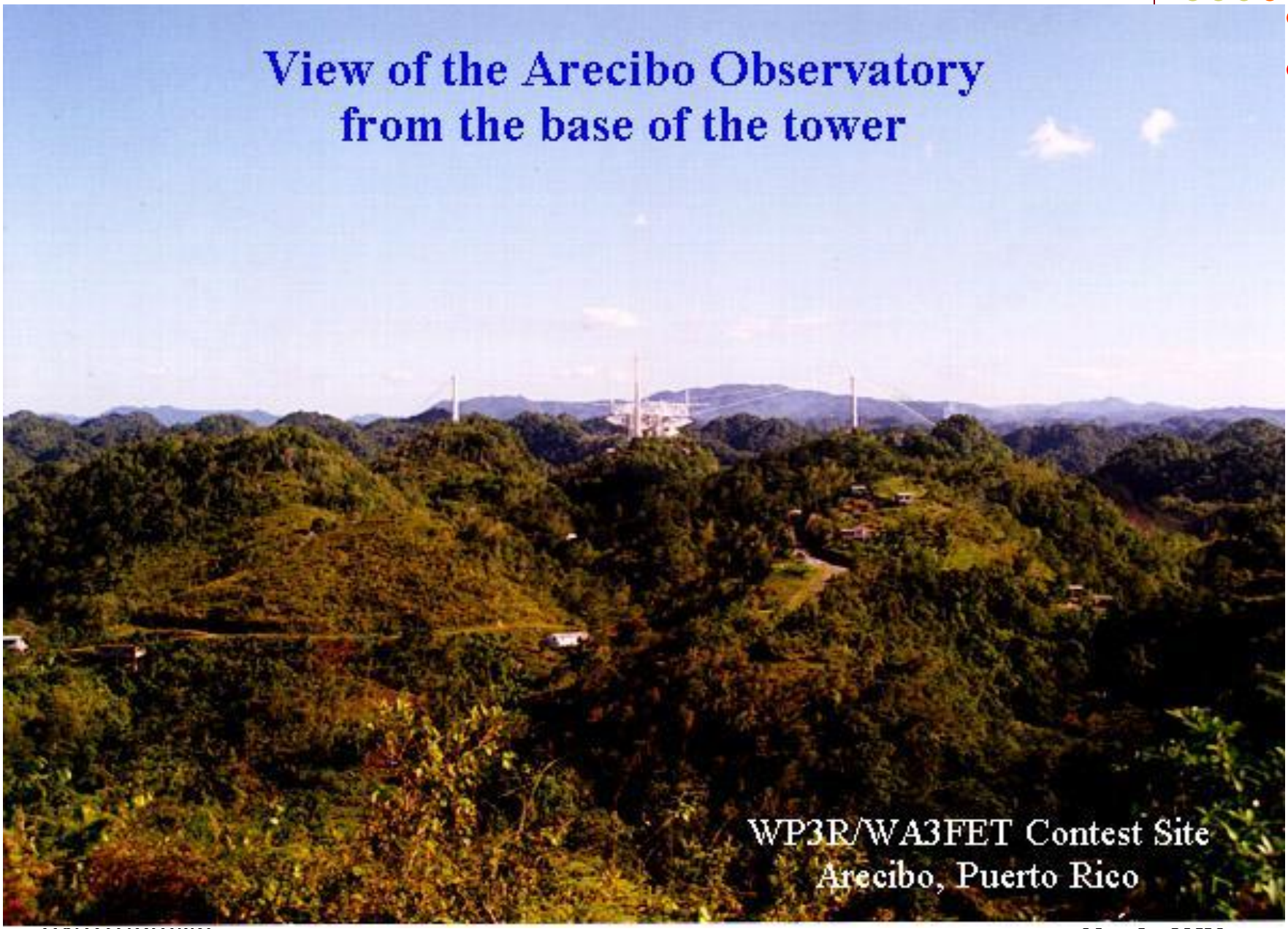
WA3FET-WP3R Contest Station, Arecibo PR

WA3FET-WP3R Contest Station, Arecibo PR

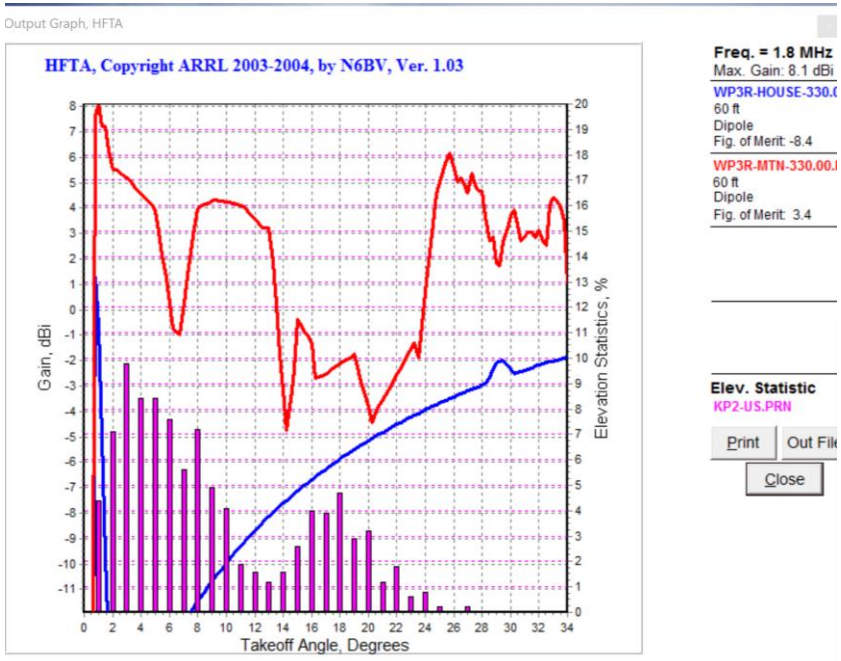

WP3R/WA3FET Contest Site
6el each 15-20m OWA 48 ft boom (interlaced)
80-160m Inverted V
Common feed-point
6el 10m OWA 24 ft boom
60 ft Rohn 55 Tower

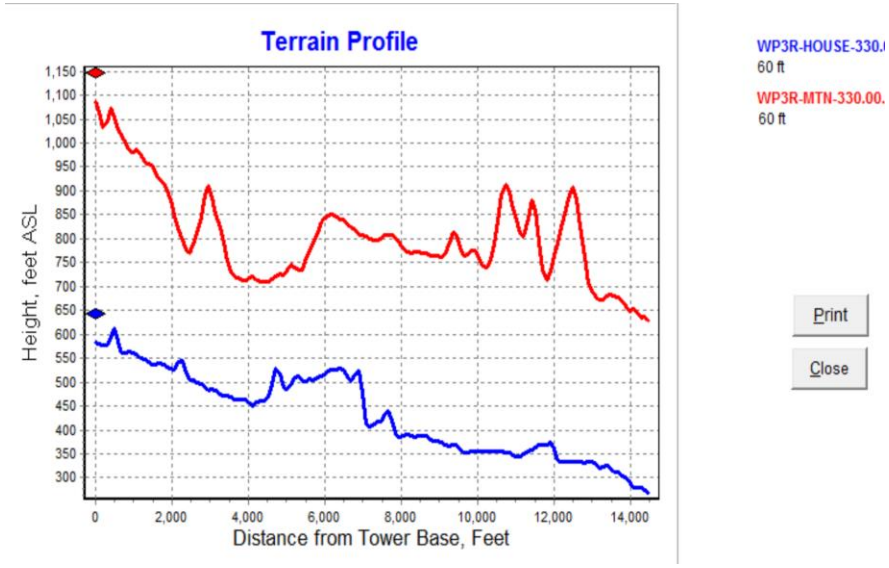

WP3R/WA3FET Contest Site
Arecibo, Puerto Rico
6el each 15-20m
OWA 48 ft boom
6el 10m OWA
24 ft boom


3el 40m Yagi supported by 500 ft catenary
(boom length= 52 ft)
<== driven element
WP3R/WA3FET Contest Site
Arecibo, Puerto Rico


View of the Arecibo Observatory
from the base of the tower
WP3R/WA3FET Contest Site
Arecibo, Puerto Rico

Following to USA (330 deg bearing) 160m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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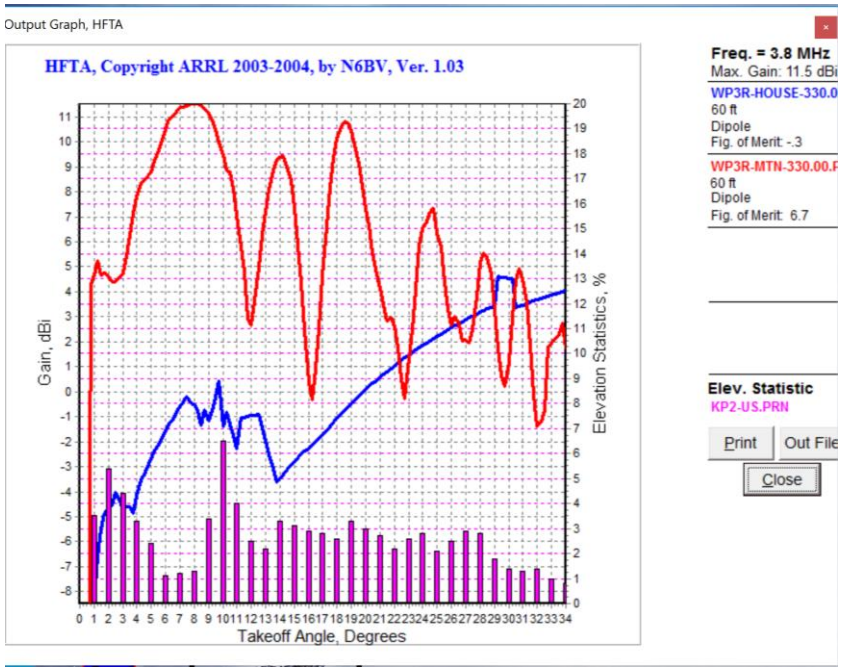
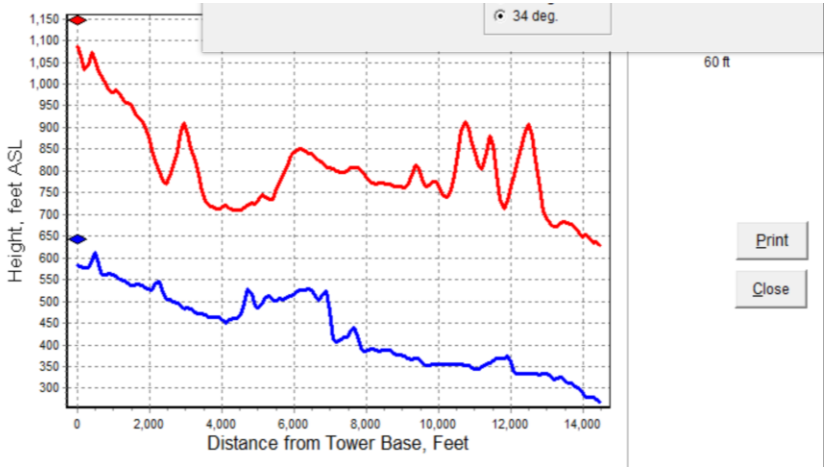
Following to USA (330 deg bearing) 80m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station

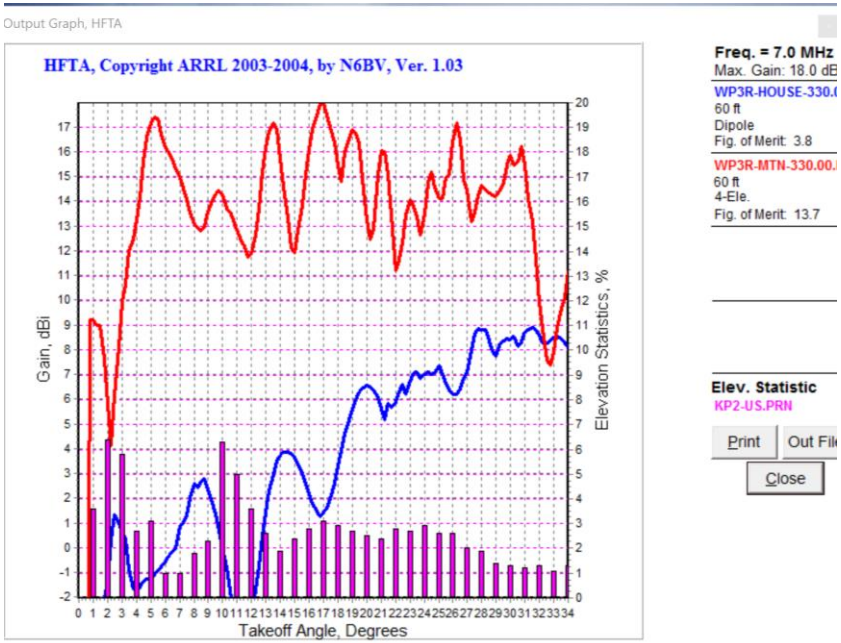




CTU CONTEST UNIVERSITY

ICOM

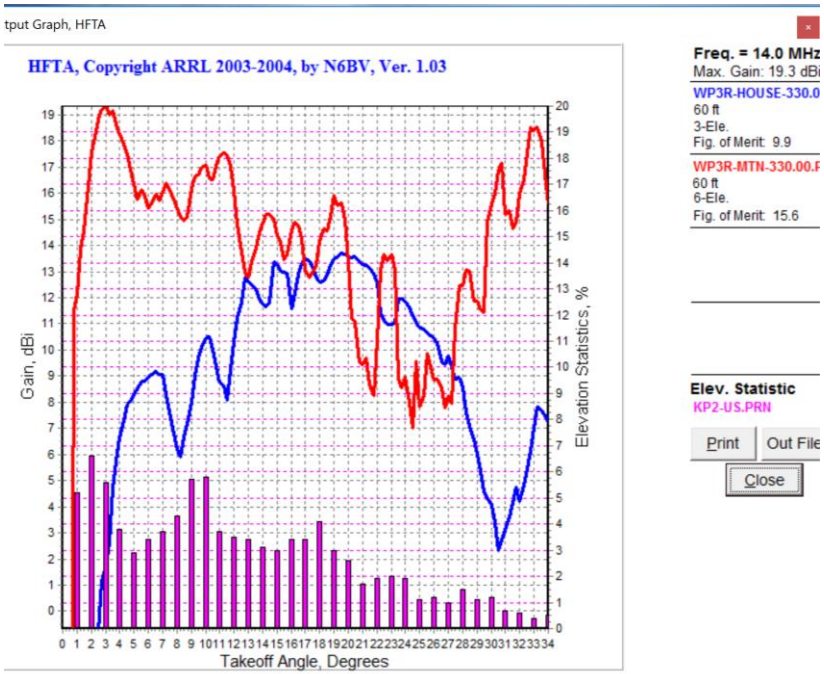
Following to USA (330 deg bearing) 40m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station

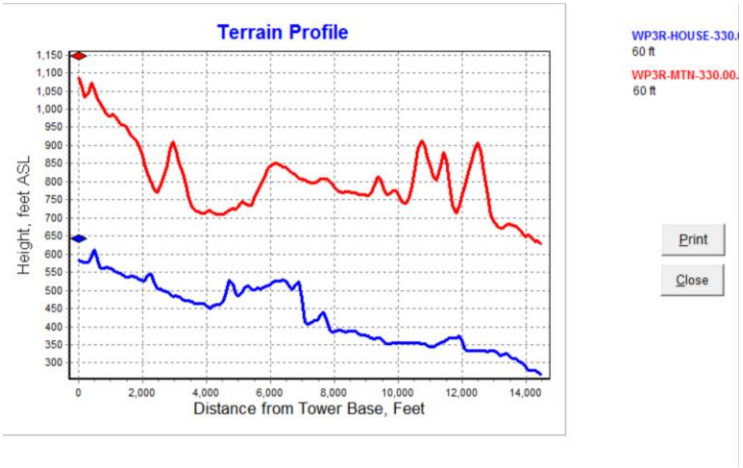


CTU CONTEST UNIVERSITY

ICOM

Following to USA (330 deg bearing) 20m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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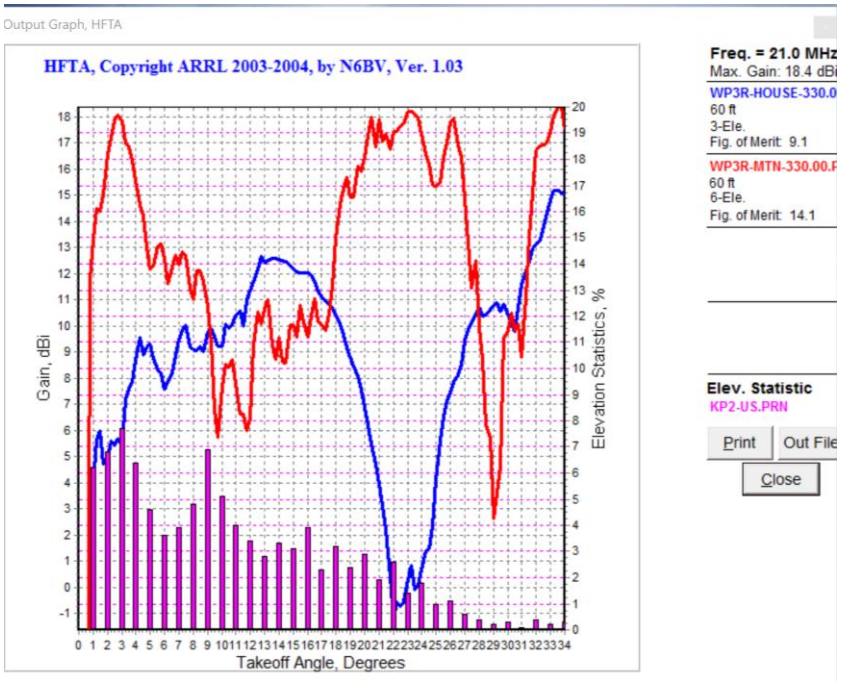
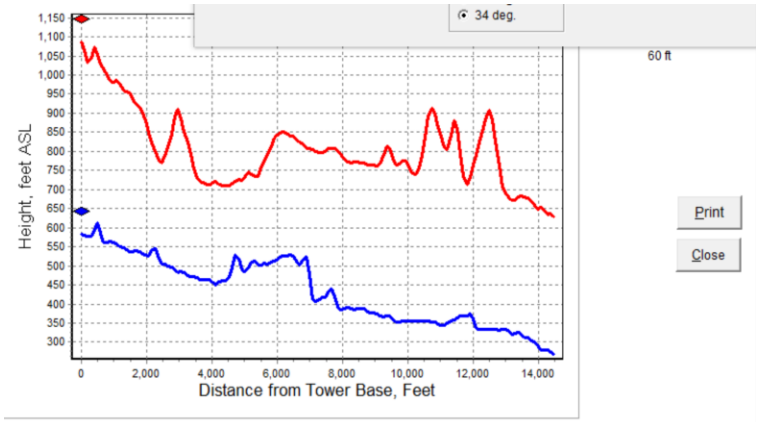
ICOM

Following to USA (330 deg bearing) 15m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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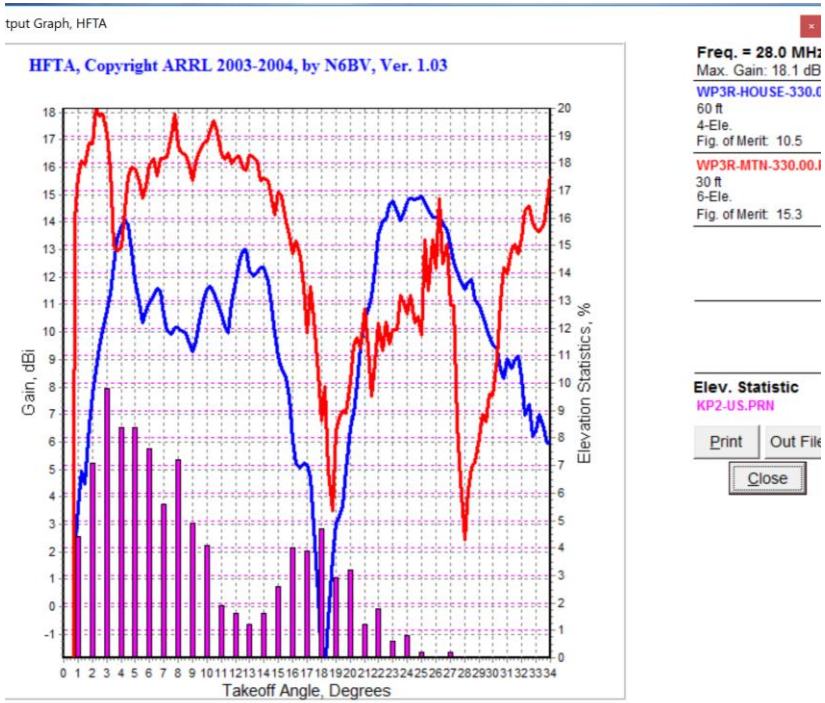
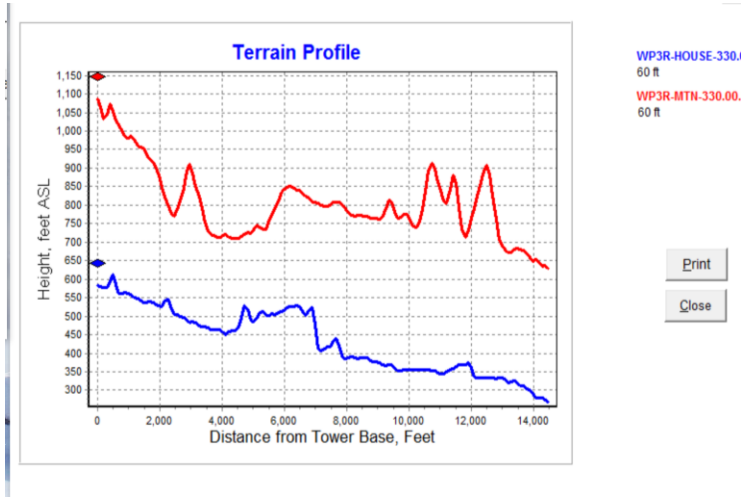
ICOM

Following to USA (330 deg bearing) 10m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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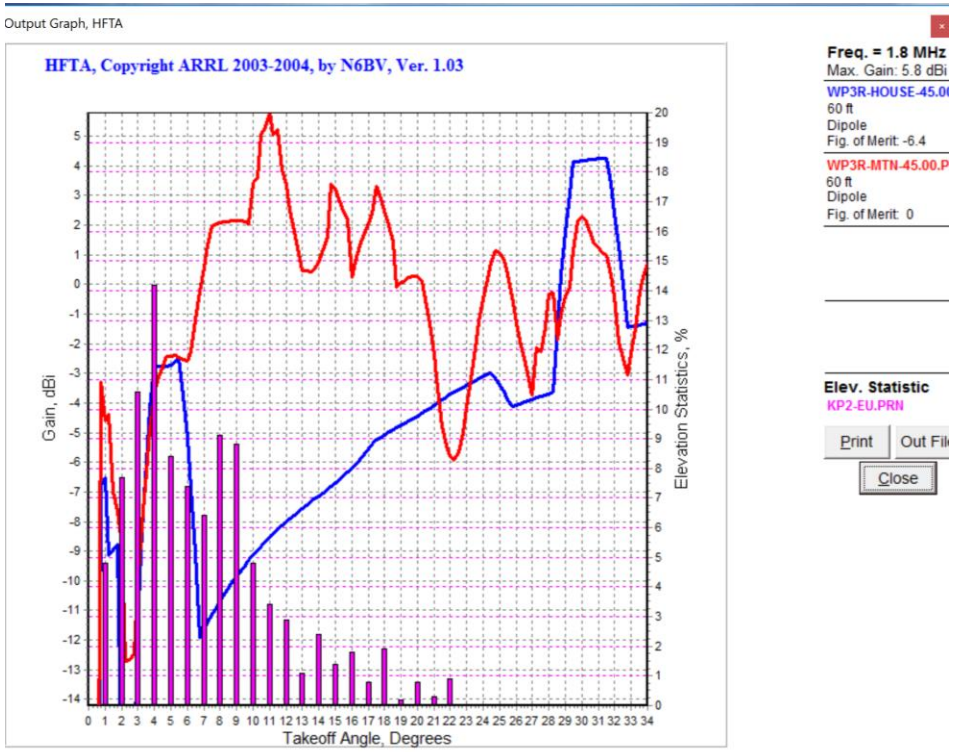
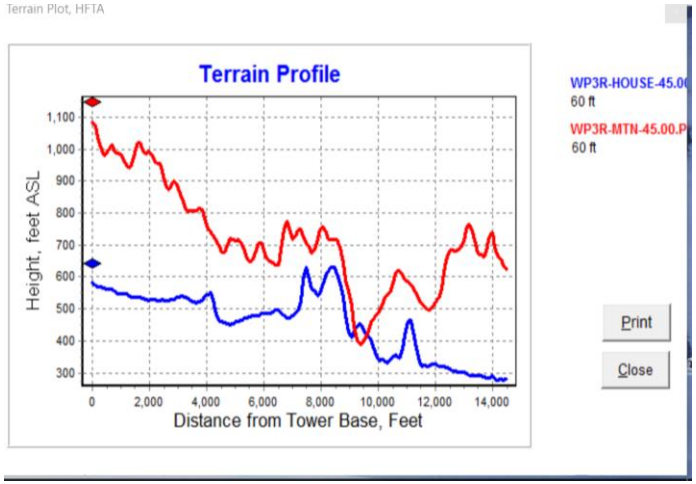
ICOM

Following to Europe (45 deg bearing) 160m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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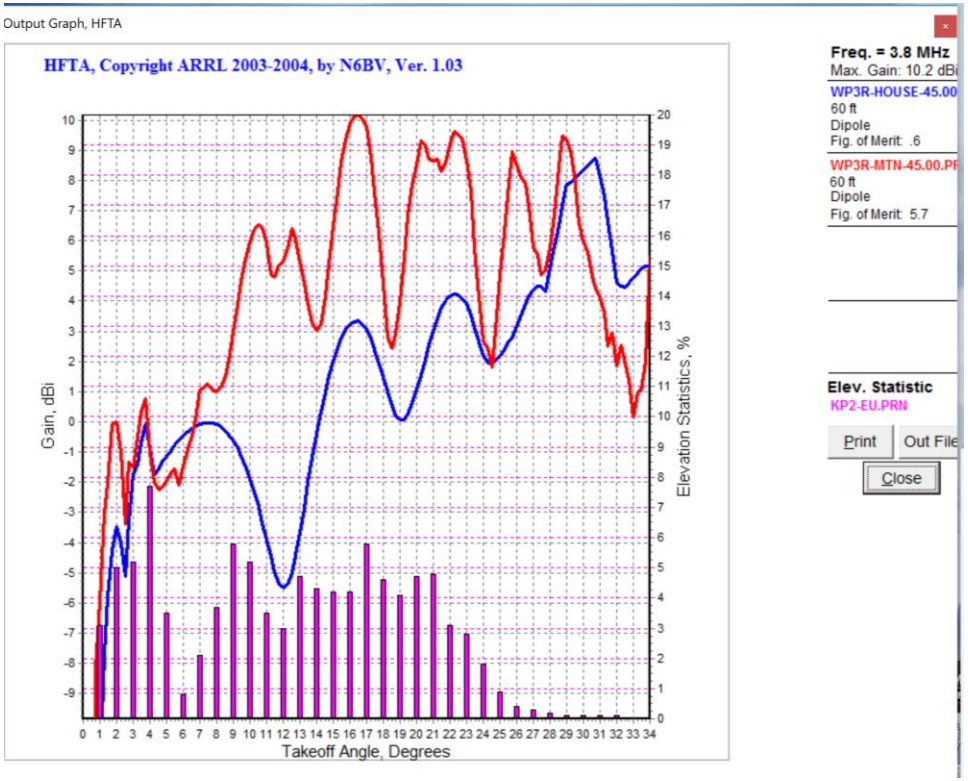
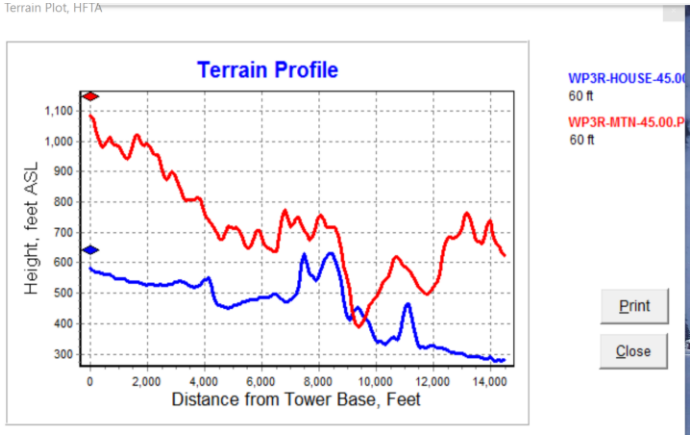
ICOM

Following to Europe (45 deg bearing) 80m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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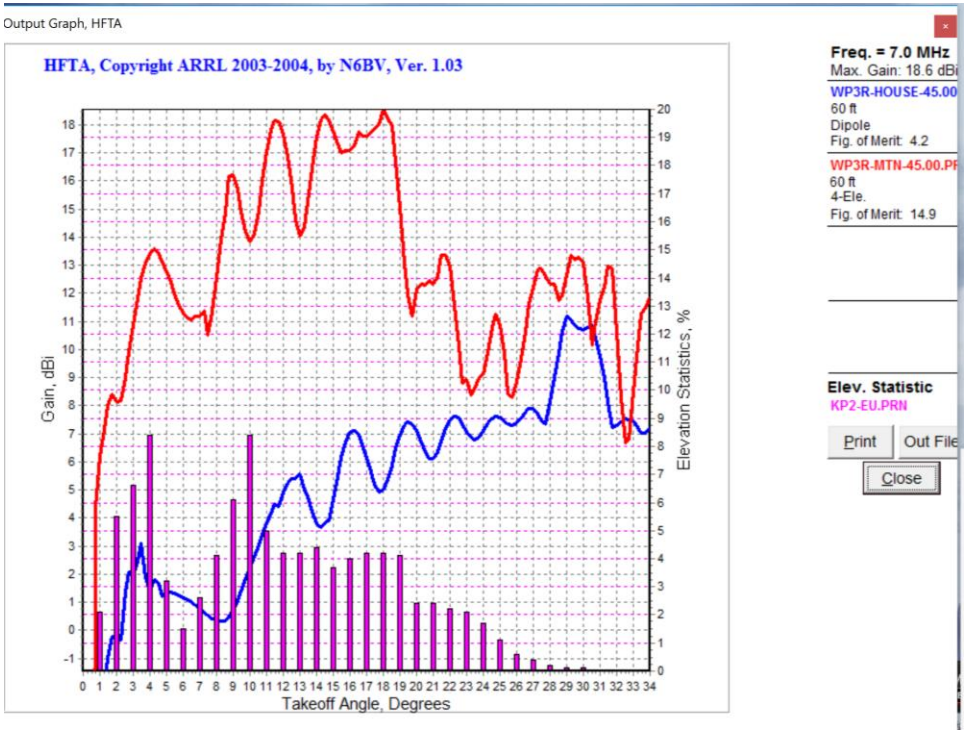
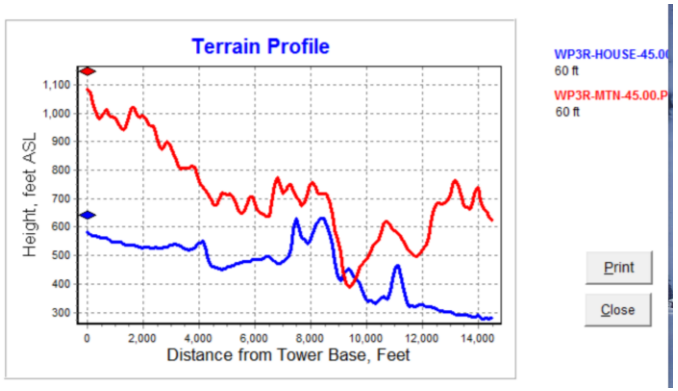
ICOM

Following to Europe (45 deg bearing) 40m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station

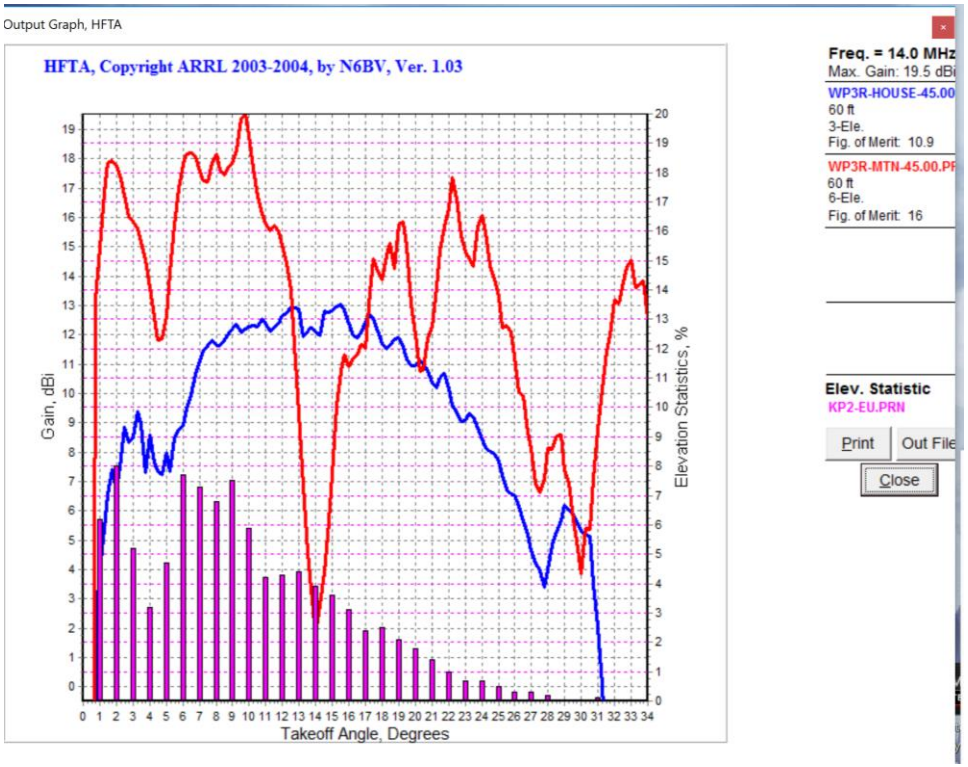


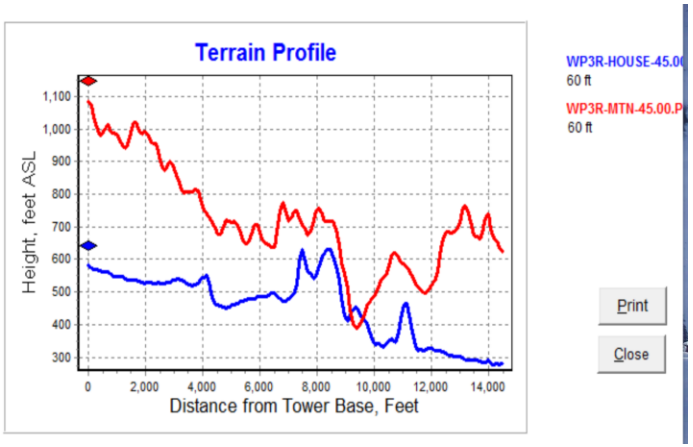


CTU CONTEST UNIVERSITY

ICOM

Following to Europe (45 deg bearing) 20m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station

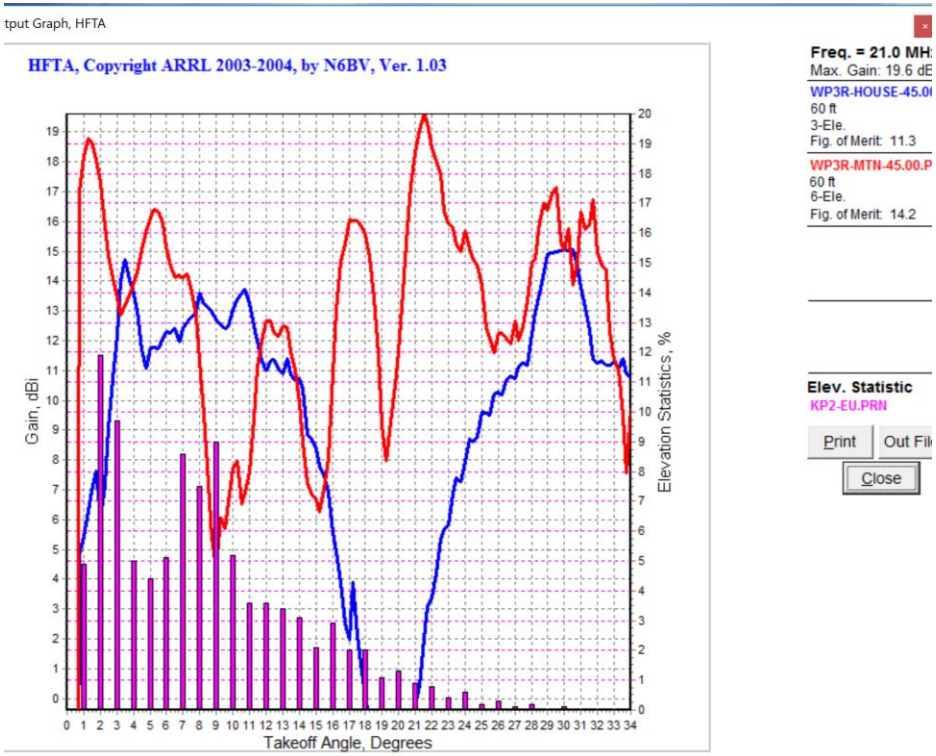


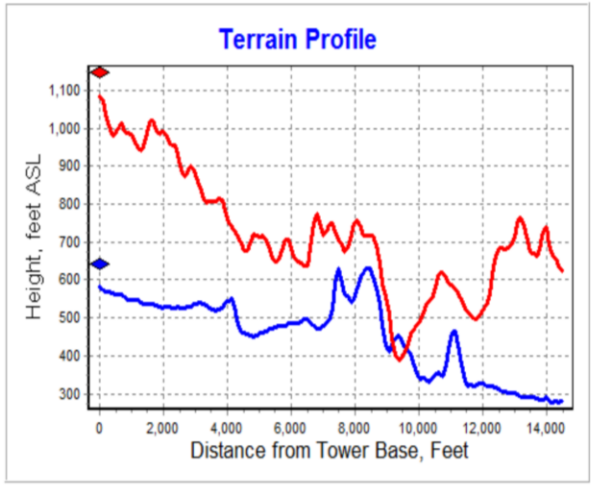


CTU CONTEST UNIVERSITY

ICOM

Following to Europe (45 deg bearing) 15m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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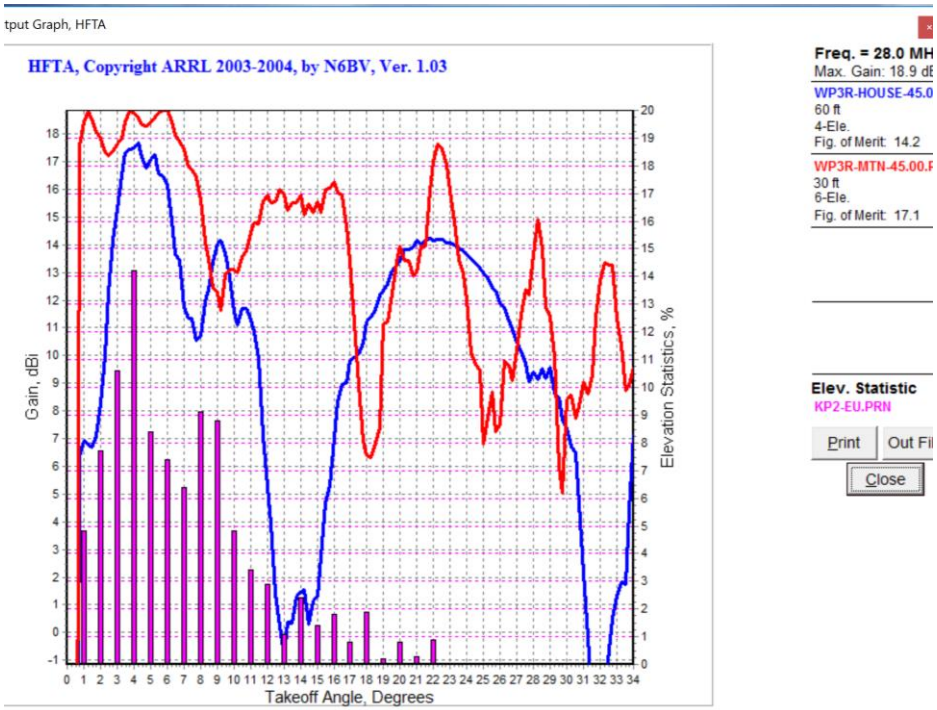
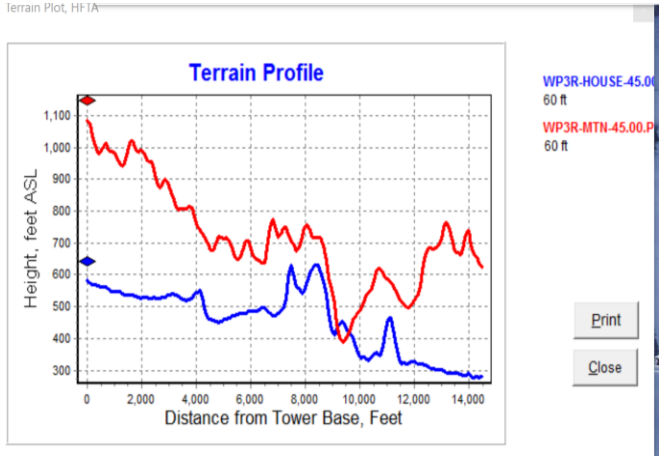
ICOM

Following to Europe (45 deg bearing) 10m
Red – WP3R/WA3FET Contest Station
Blue – WP3R New Home Station





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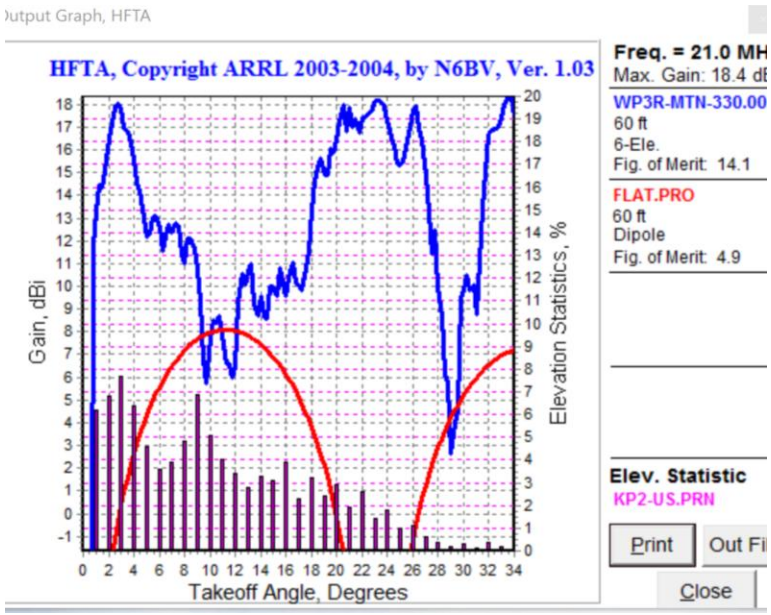
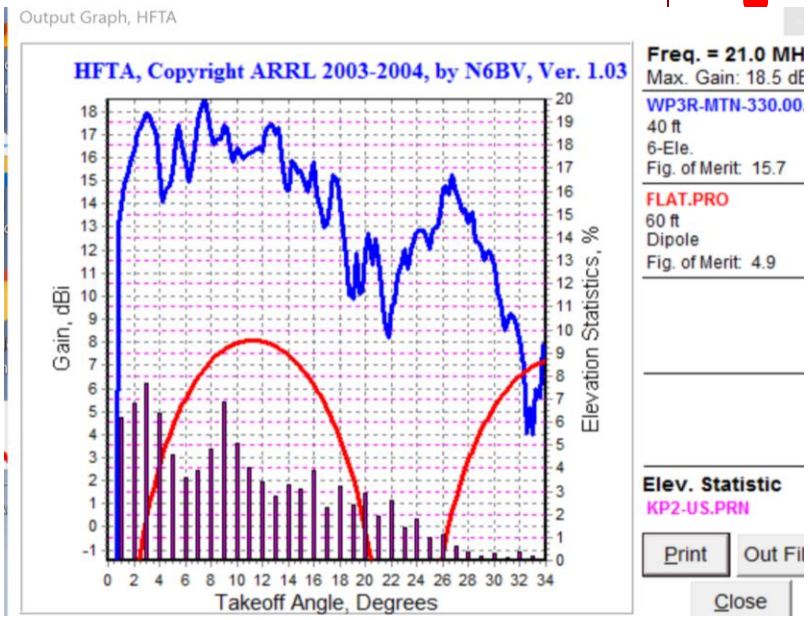
ICOM

Following to USA (330 deg bearing) 15m
WP3R/WA3FET Contest Station
60 ft vs 40 ft





On 15m, the height of 60ft is too high

On 15m, a height of 40 ft would be better

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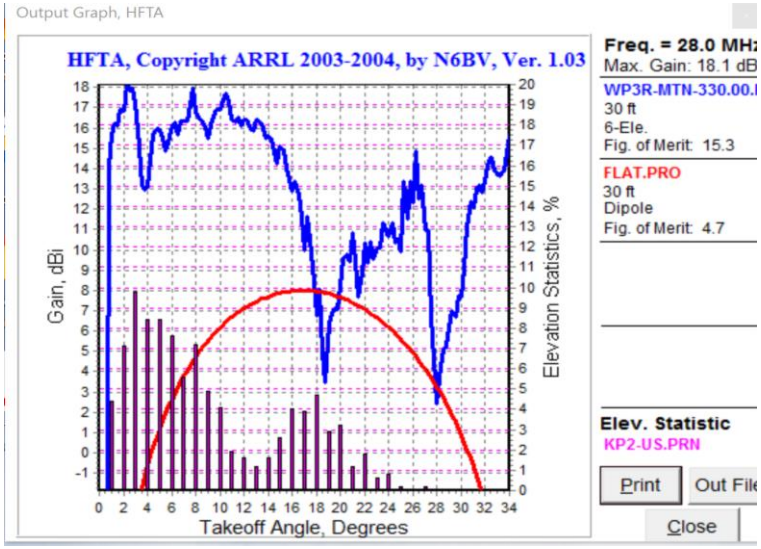
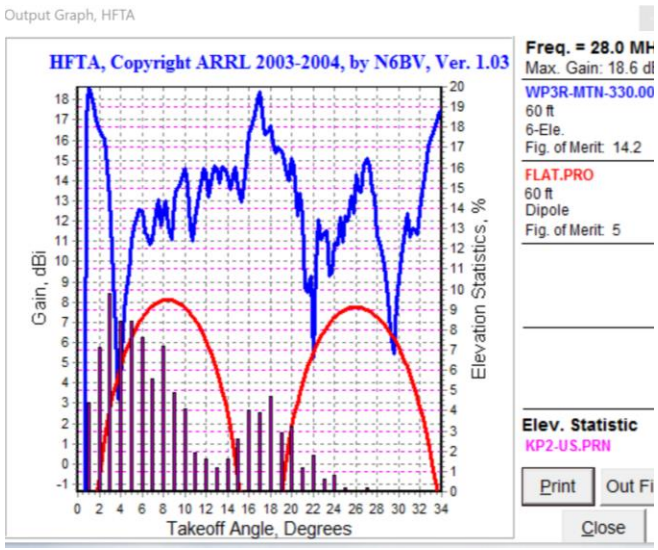
ICOM

Following to USA (330 deg bearing) 10m
WP3R/WA3FET Contest Station
30 ft vs 60 ft





On 10m, 30 ft was a good choice for height

On 10m, a height of 60 ft would have been too high

We certainly guessed correctly for the signals to USA except for some reduced angle coverage on 15m

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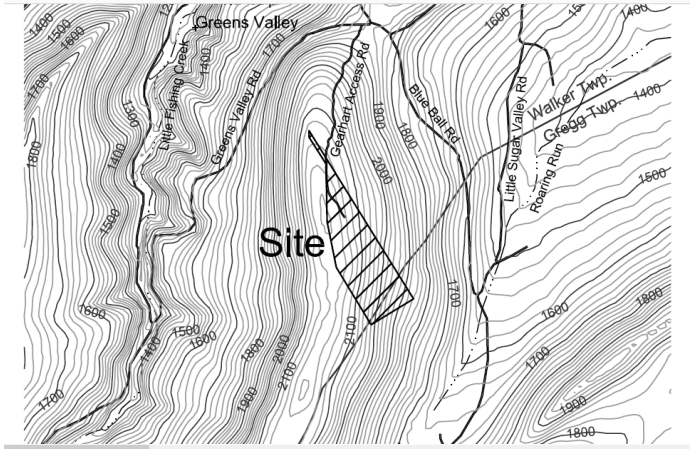
ICOM

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)



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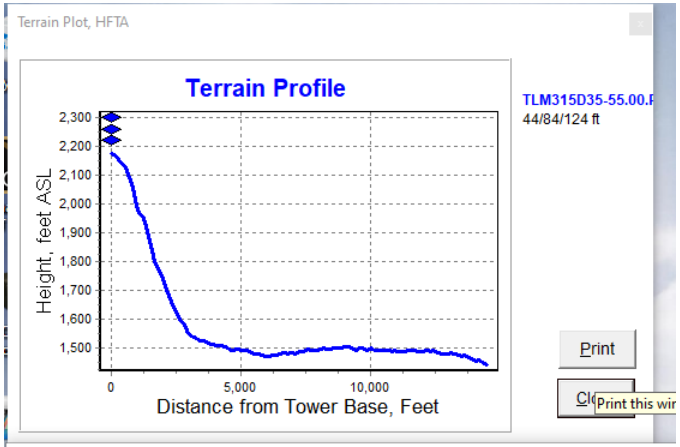
20m 6 Element OWA-ICE Design on 52 ft Boom Stack at 44 ft, 84 ft, and 124 ft All Turned by K0XG Ring Rotators

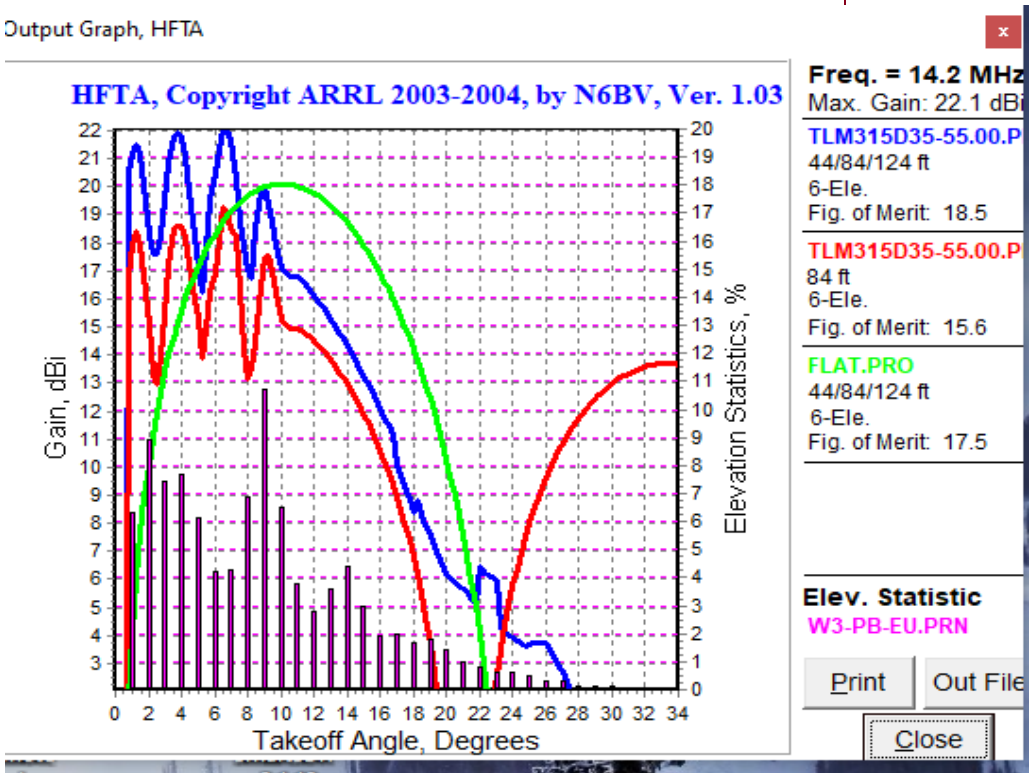
- K0XG Rings are Super Strong and Towers and Anchors at Camp K are too !!!

Camp K – More Photos

Camp K – More Photos

Camp K 20m 6 Element Stack with HFTA Modeling from the Magic Mountain to Europe





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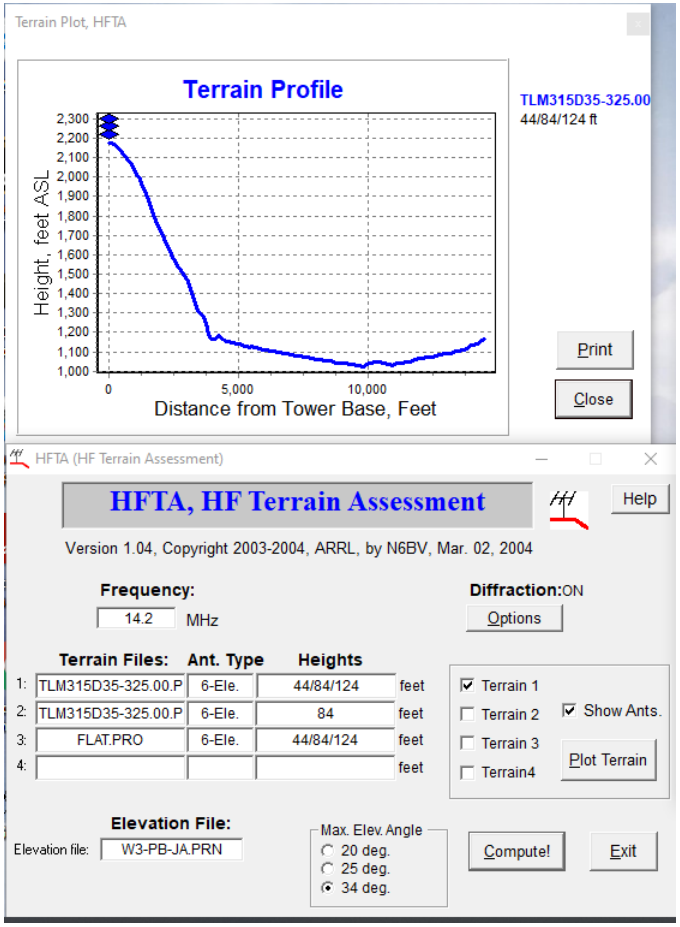
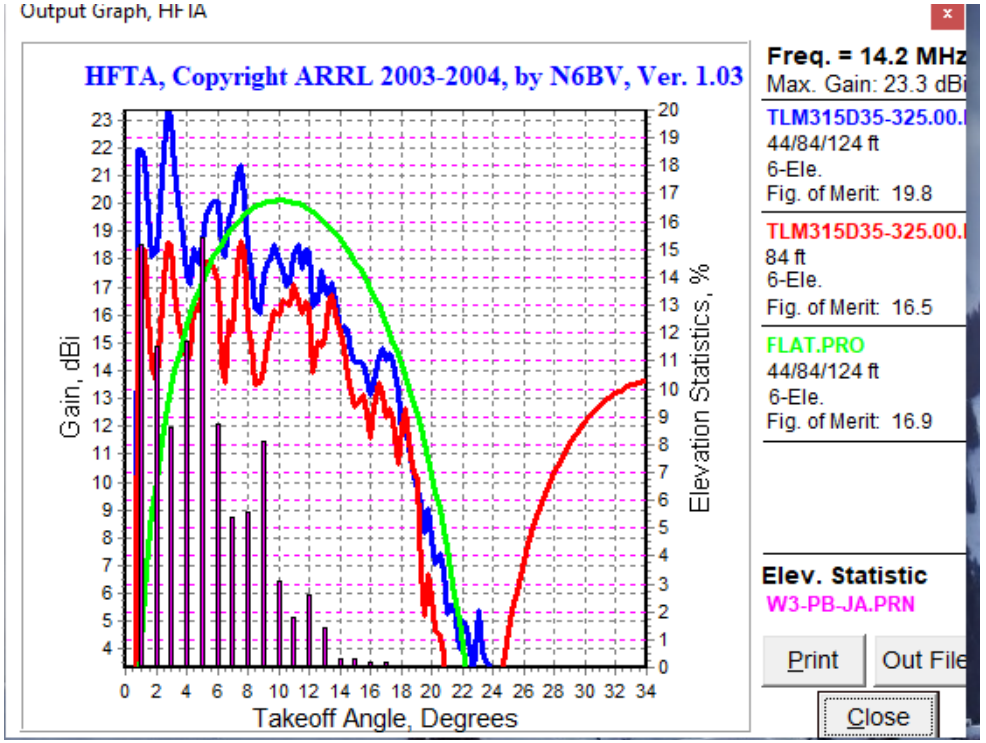
ICOM

Camp K 20m 6 Element Stack with HFTA Modeling from the Magic Mountain to Japan





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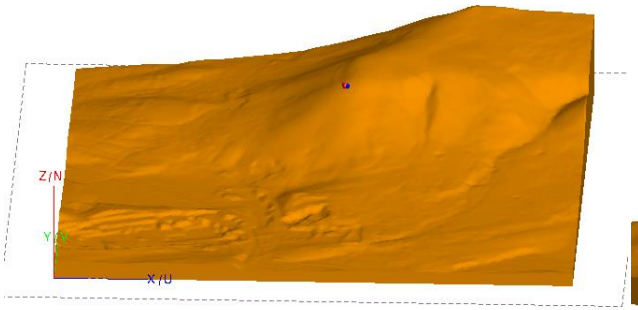
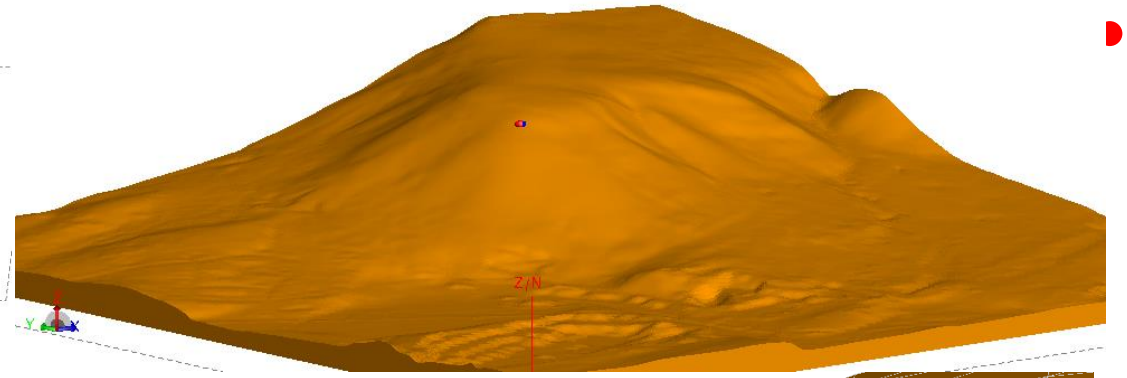
ICOM

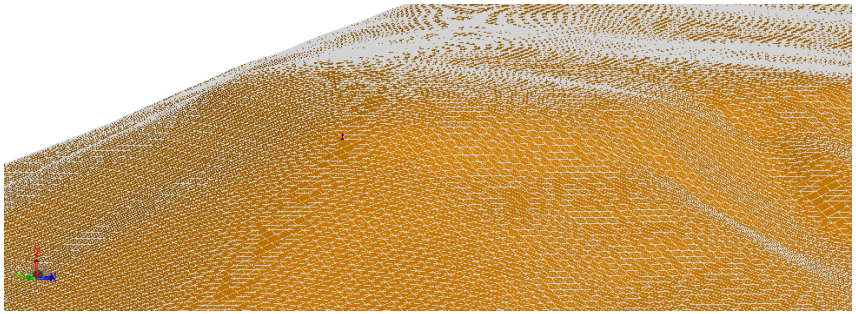
Video of Magic Mountain

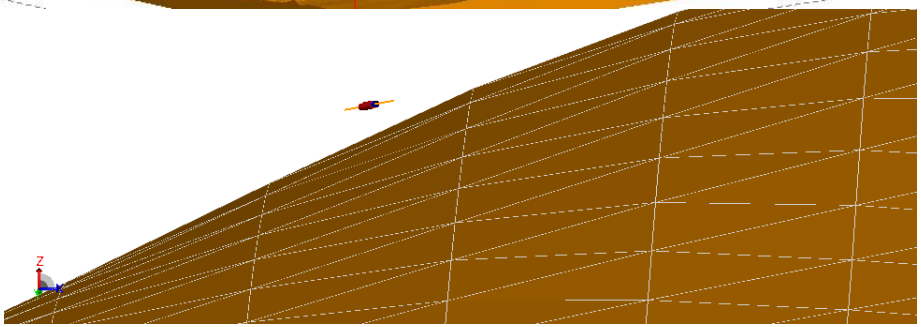
- Drone Flyover

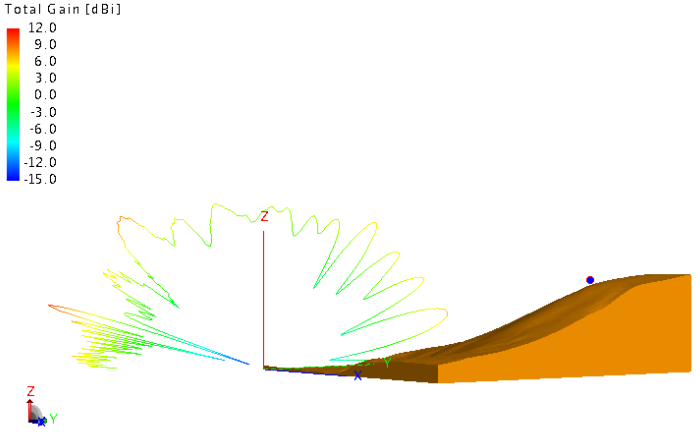
The Future – 3D Terrain Modeling












PENN STATE

Thank You!!!

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