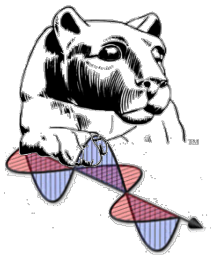
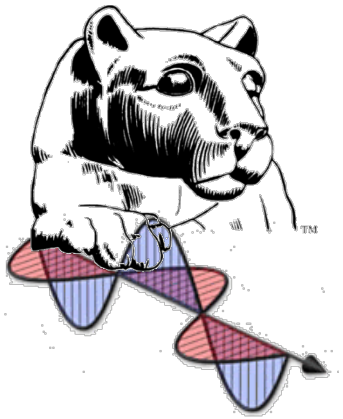


The New Arecibo Ionospheric Modification HF Facility Dual Array Cassegrain Antenna – History and Design

Prof. James K. Breakall, WA3FET
Señor "Rompe Todo"
Electrical Engineering Department
Penn State University



HamSCI Workshop
Case Western Reserve University
March 22-23, 2019

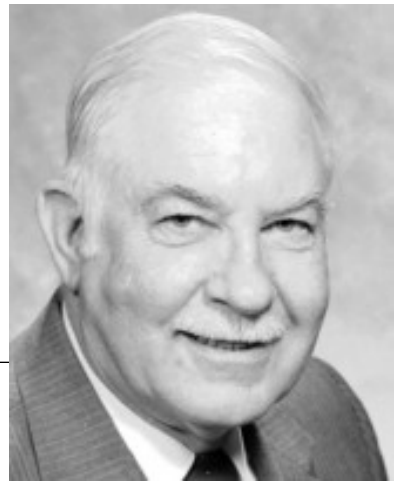
PENNSTATE

PENNSTATE 1855

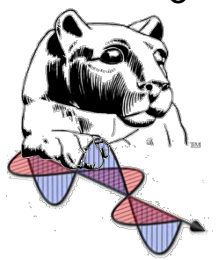
Breakall, James K., *On the absolute calibration and theoretical justification of high resolution ionospheric results obtained from Arecibo radar measurements*, Ph.D. - Case Western University, 1983.

- Prof. John D. Mathews – Arecibo Research – D-Region, Sporadic-E, Meteor Physics
- Prof. Robert E. Collin – Antennas, EM, Microwaves
- *Field Theory of Guided Waves*
- *Foundations for Microwave Engineering*
- *Antennas and Radiowave Propagation*
- *Principles and Applications of Electromagnetic Fields* (coauthored with R. Plonsey)

CASE SCHOOL OF ENGINEERING
CASE WESTERN RESERVE UNIVERSITY

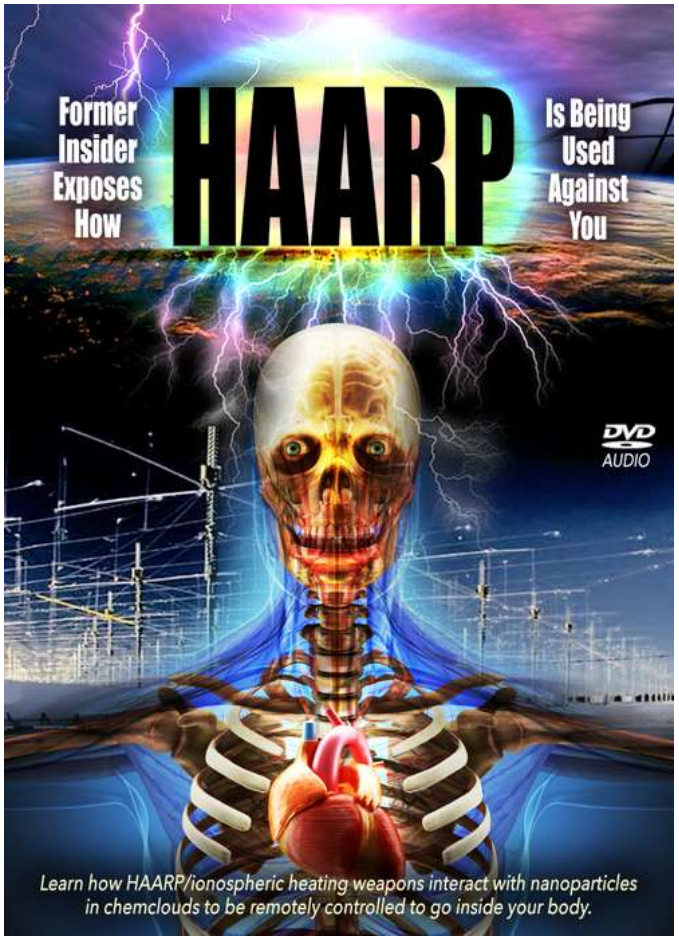


Ionospheric Modification (Heating) Science



- HF ionospheric heaters can turn the ionosphere into a plasma-physics laboratory
- Electron acceleration processes
- Ionospheric structure irregularities at meter to sub-kilometer scales
- Electron thermal balance
- Resonant ion oscillations
- Airglow optical emissions (artificial aurora)
- Generation of ELF and ULF (Submarine communication)
- Enhanced plasma lines

What Ionospheric Modification is Really For !!!!???



Famous Ionospheric Heating Facilities Around the World

Sura

- 4.5 to 9.3 MHz
- 144 crossed-dipoles
- 300 x 300 m
- 3 – 250 kW TXs
- Max gain 24 dBi
- ERP 80 – 190 MW

Tromso

144 crossed dipoles (12x12), 5.3-8.0 MHz

36 crossed dipole (6x6), 3.8-5.7 MHz

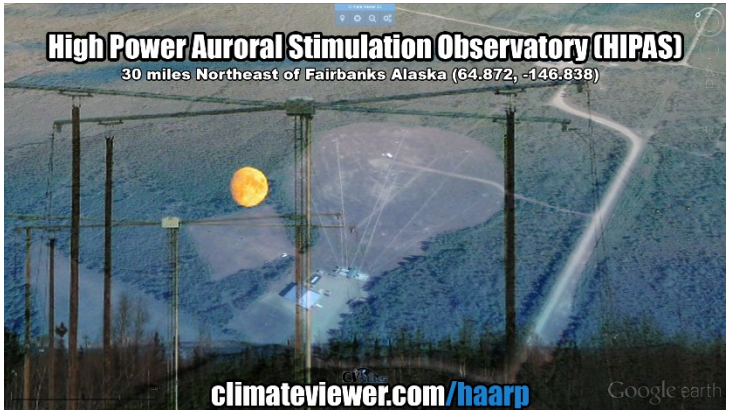
36 crossed dipole (6x6), 5.3-8.0 MHz

Frequency: 3.85 - 8 MHz

Power: 1,200,000 Watts (12 x 100 kW)

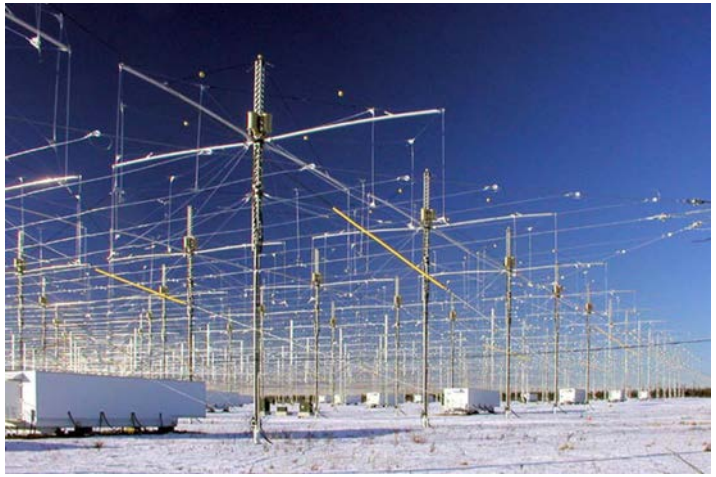
Crossed dipole (144 -1.2 GW) (36 -300 MW)

Famous Ionospheric Heating Facilities Around the World



- 8 crossed dipoles
- 2.85 - 4.53 MHz
- 1.2 MW, 150 kW x 8 TXs
- ERP: 70 MW

HAARP



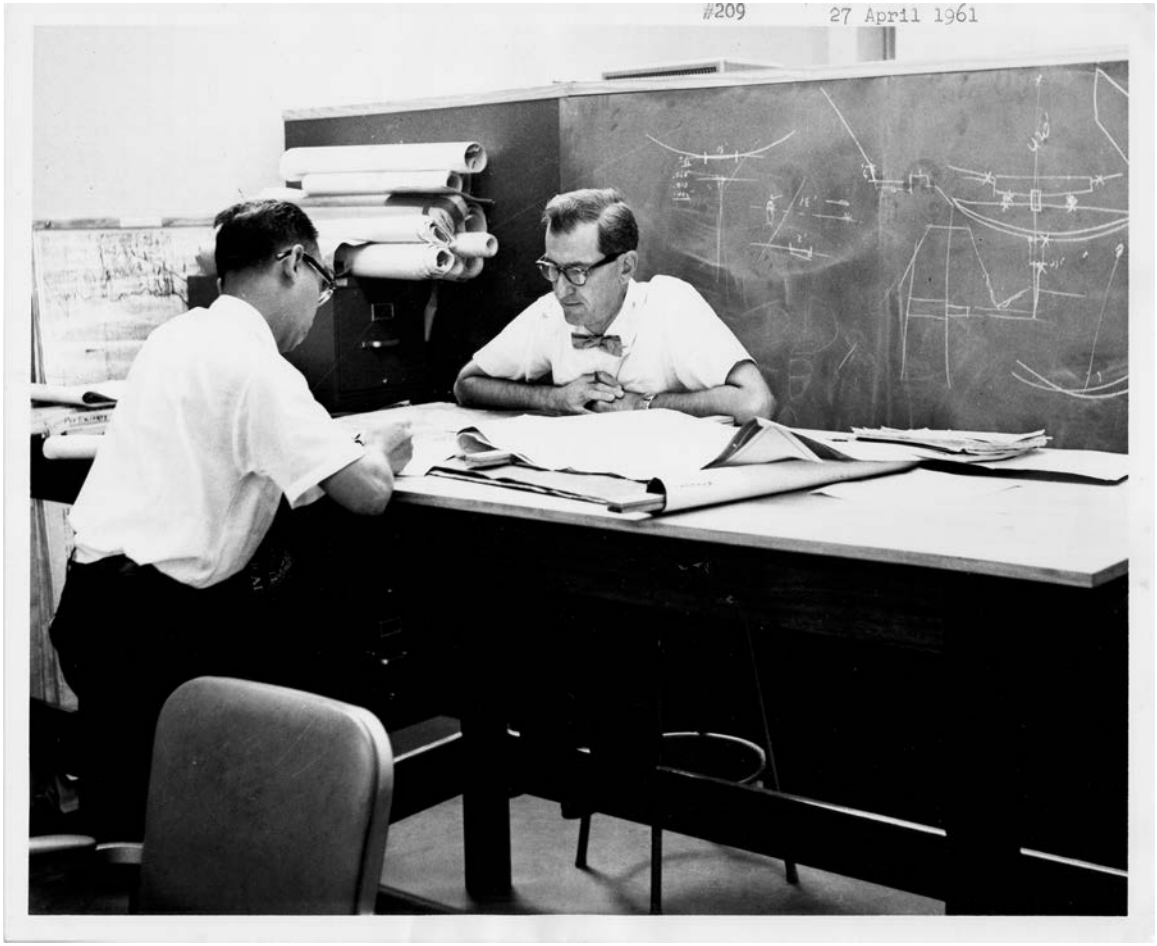
180 crossed dipole (12 x 15), 1040' x 1280'

2.8 - 10 MHz

3.6 MW, 360 10 kW TXs

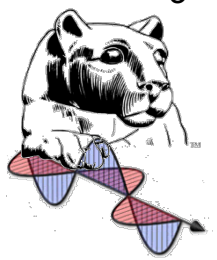
ERP: 5 GW

Dr. William Gordon in 1961




Smithsonian
CHANNEL

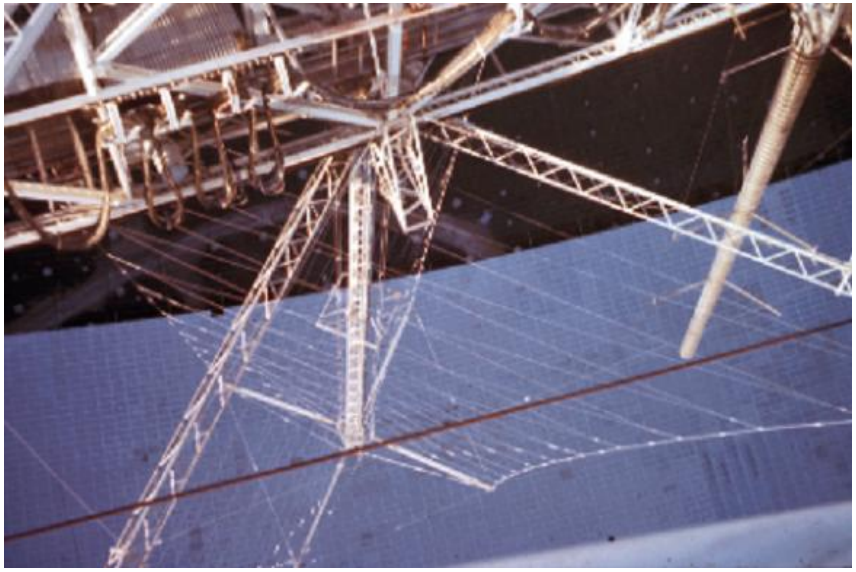
Previous HF Heating Facilities at Arecibo



- Crossed log-periodic antenna located on-site at the observatory
- Islote - Log-periodic array located off-site

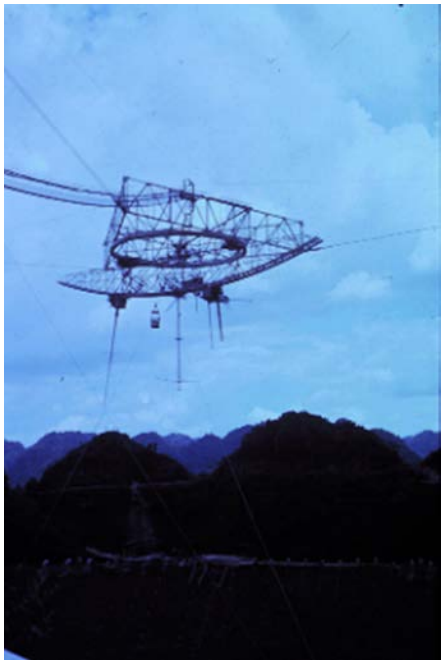
First HF Heating Facility

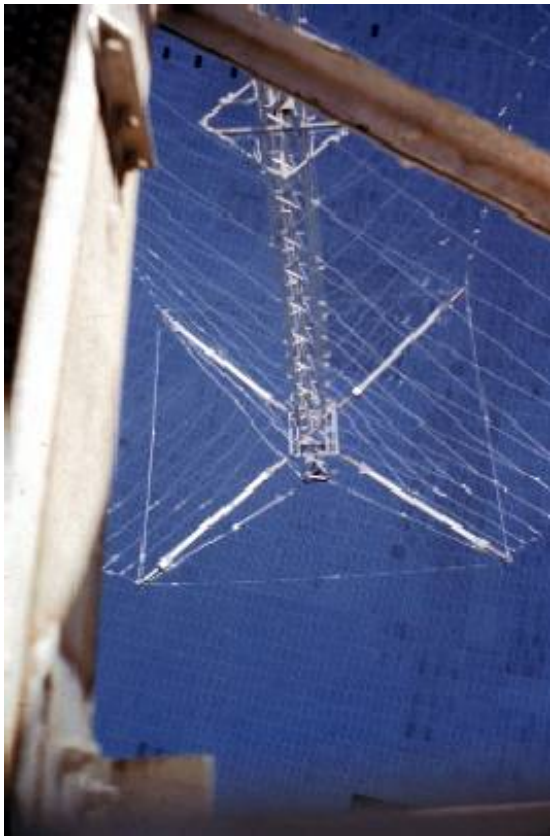
- Log-periodic antenna was located over the main dish, pointing downward
- Use was discontinued when the antenna developed arcing and corona problems



- Bandwidth from 3 – 10 MHz
- Fed with 100 kW source
- Gain Estimated 40% of Aperture
- ERP 3.7 MW at 3 MHz
- ERP 41 MW at 10 MHz

Past Log-Periodic Dish Feed





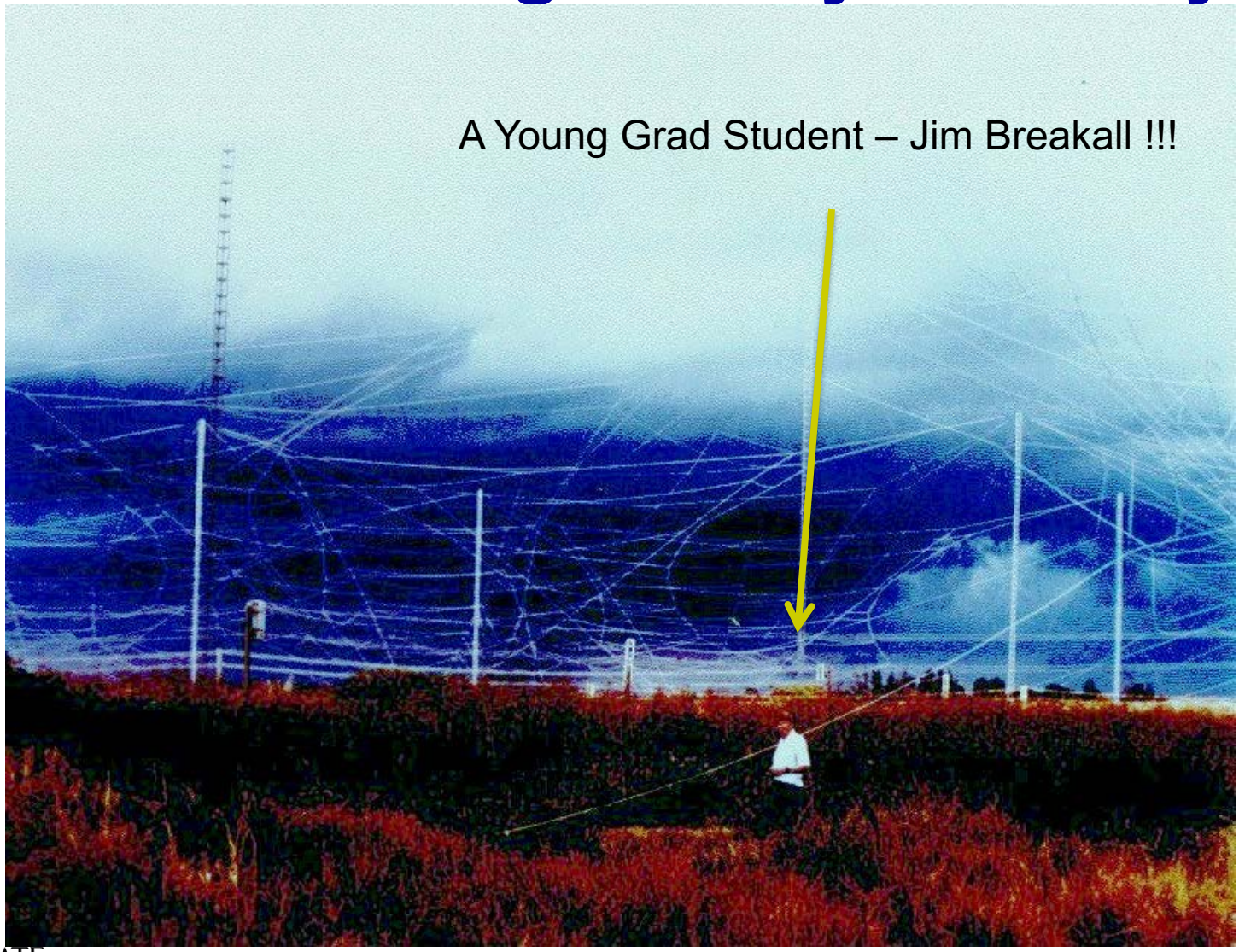
Second HF Heating Facilitv

- Consisted of a pyramidal log-periodic array with 32 elements

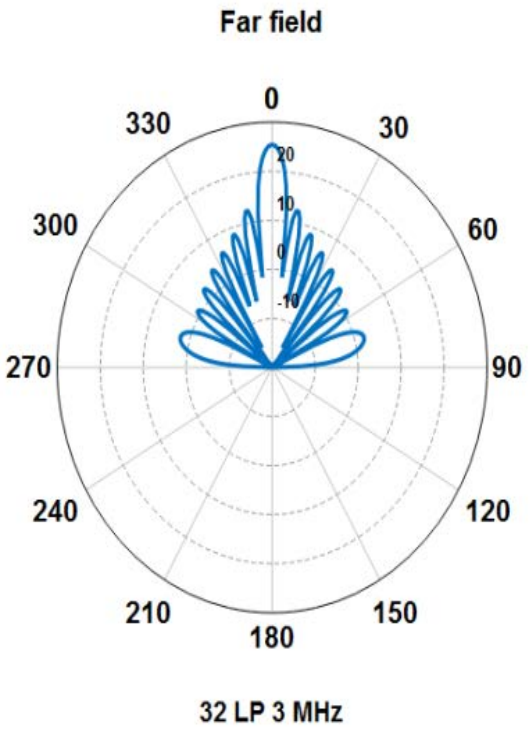
- Was destroyed in Sept. 1998 in Hurricane Georges

- Constant Gain: 23 dBi
- Bandwidth: 3 - 8 MHz
  BUT Grating Lobes!
- Radiated Power: 600 kW
- ERP: 120 MW

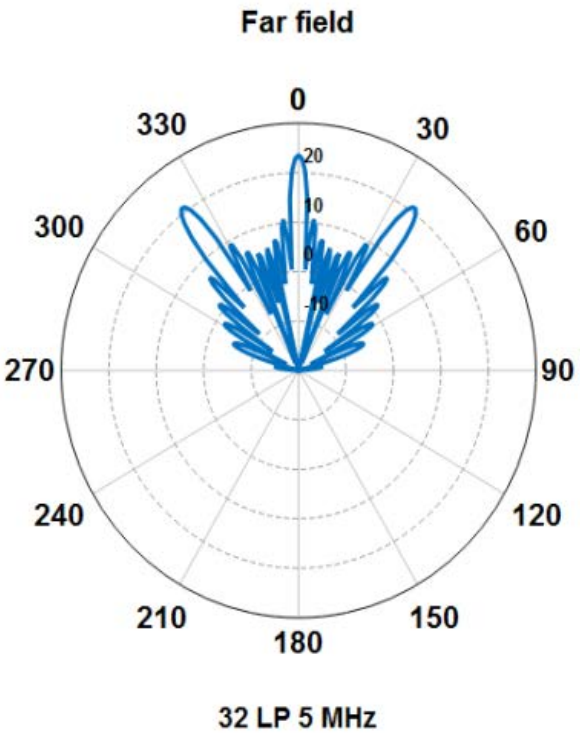
Islote Heating Facility LP Array



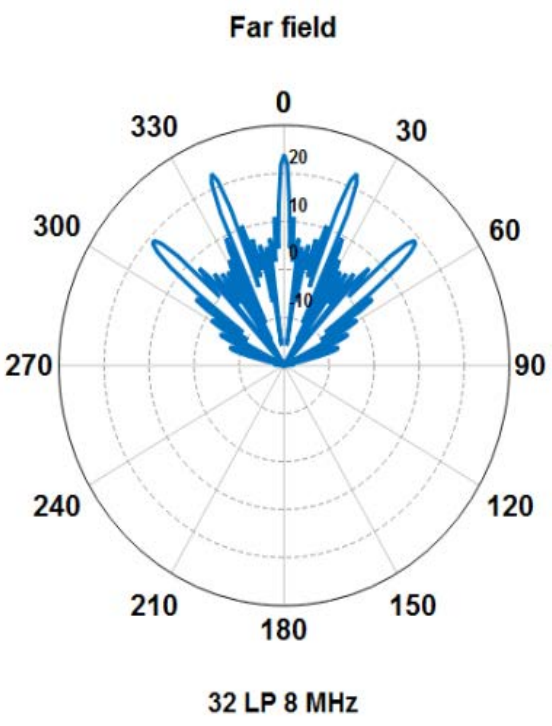
Radiation Patterns of Islote 32 Log Periodic Array – Grating Lobes



32 LP 3 MHz

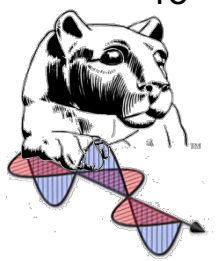


32 LP 5 MHz



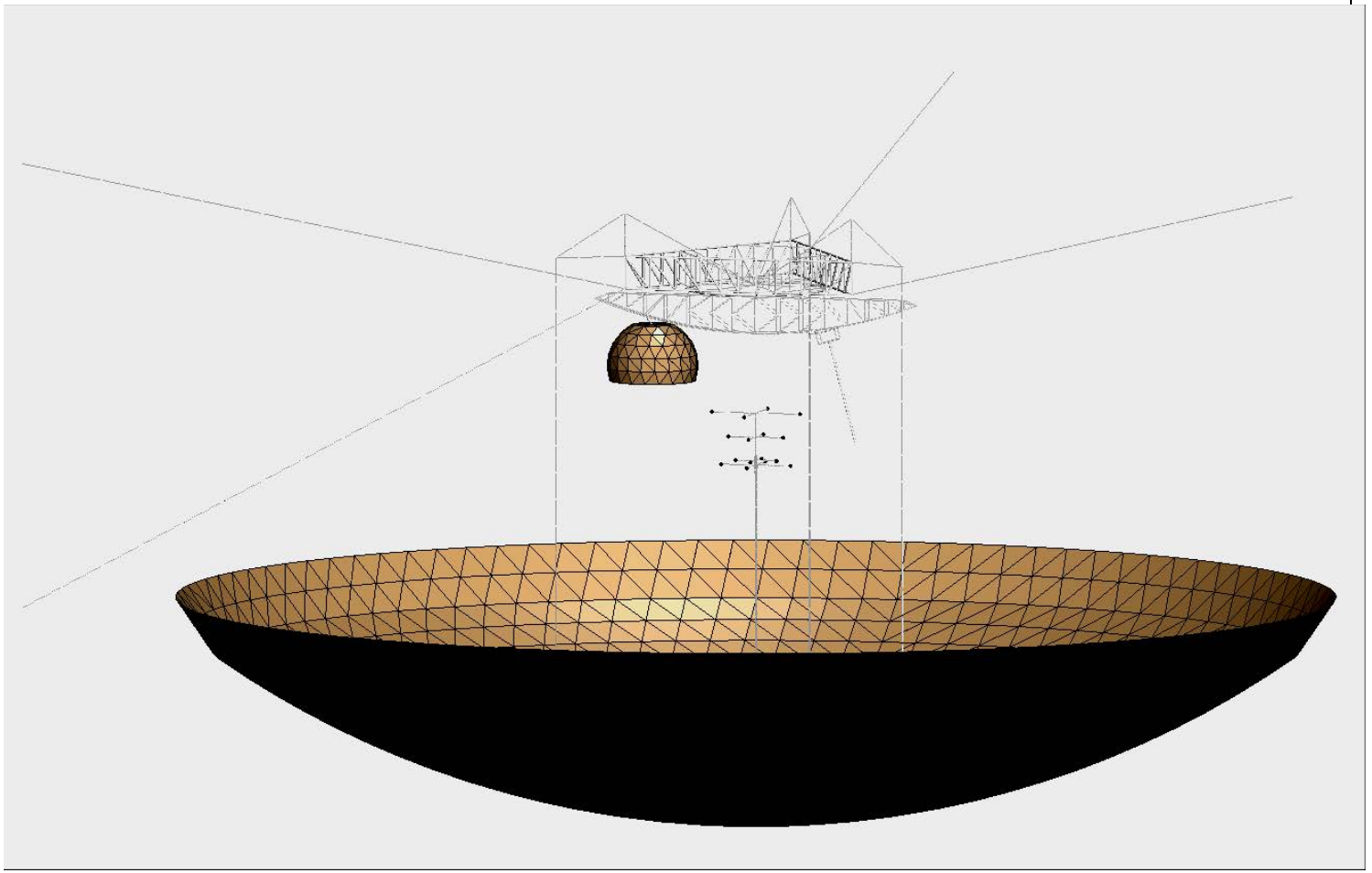
32 LP 8 MHz

A New HF Facility was Needed to be Built at and use the 1000 foot Dish



- Cost - $2.5M
- Air Force Research Lab - $500K
- Office of Naval Research - $500K
- National Science Foundation - $1.1M
- Transmitters and their power supplies, heat exchangers, and 3 inch Heliax coax lines were free – Decommissioned Cold War Over-the-Horizon (OTH) Radar from Maine and Alaska

First Design of Full HF Interactions Facility Simulation Model



Full Crossed-Dipole Yagi Feed Simulation Model

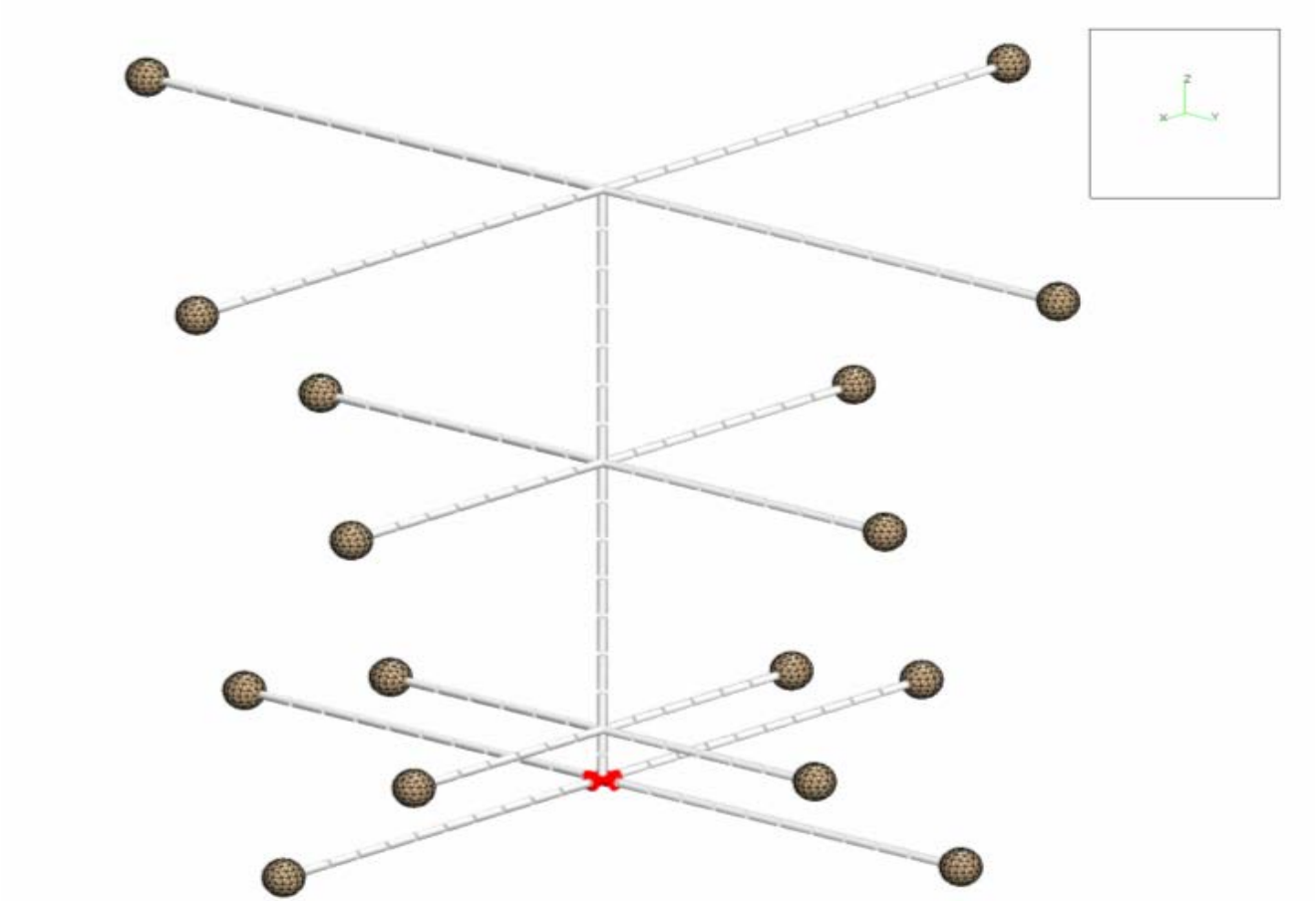
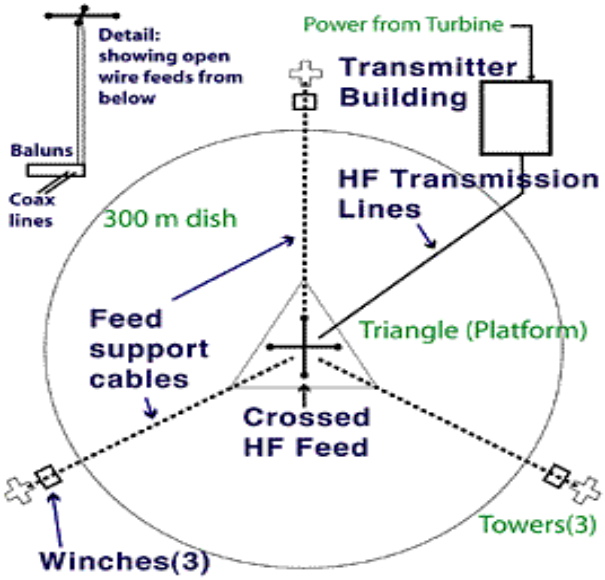
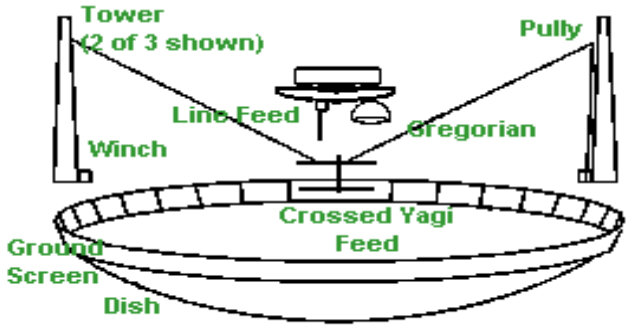
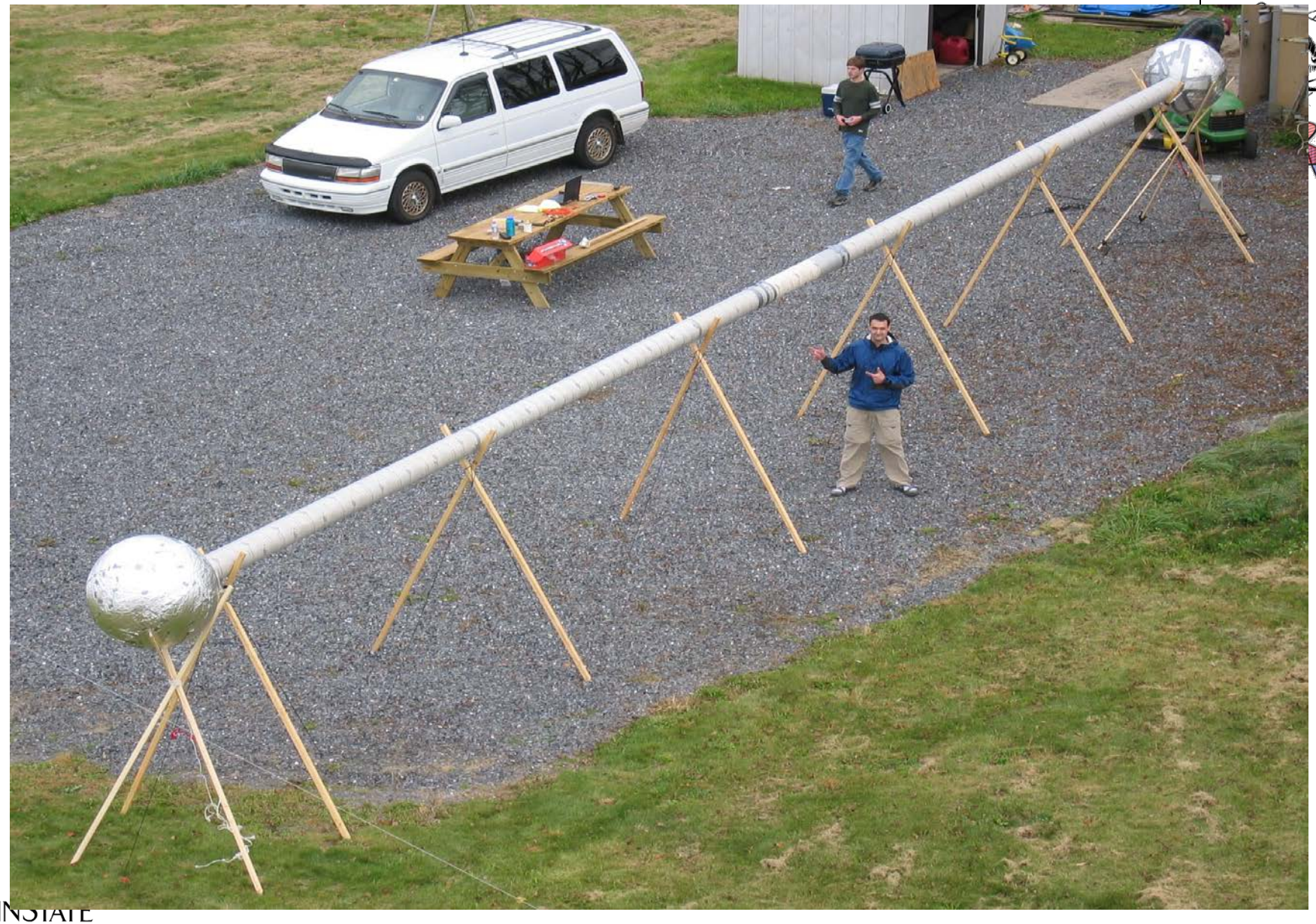


Diagram of Proposed Antenna

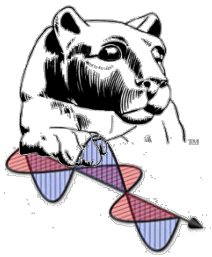




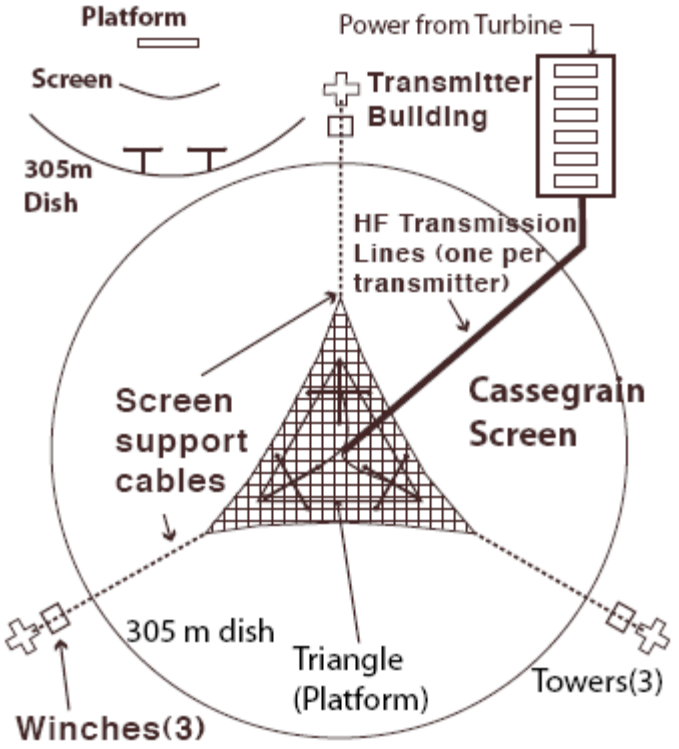
Near Electric Field Measurements
Construction of Full Size Prototype Dipole



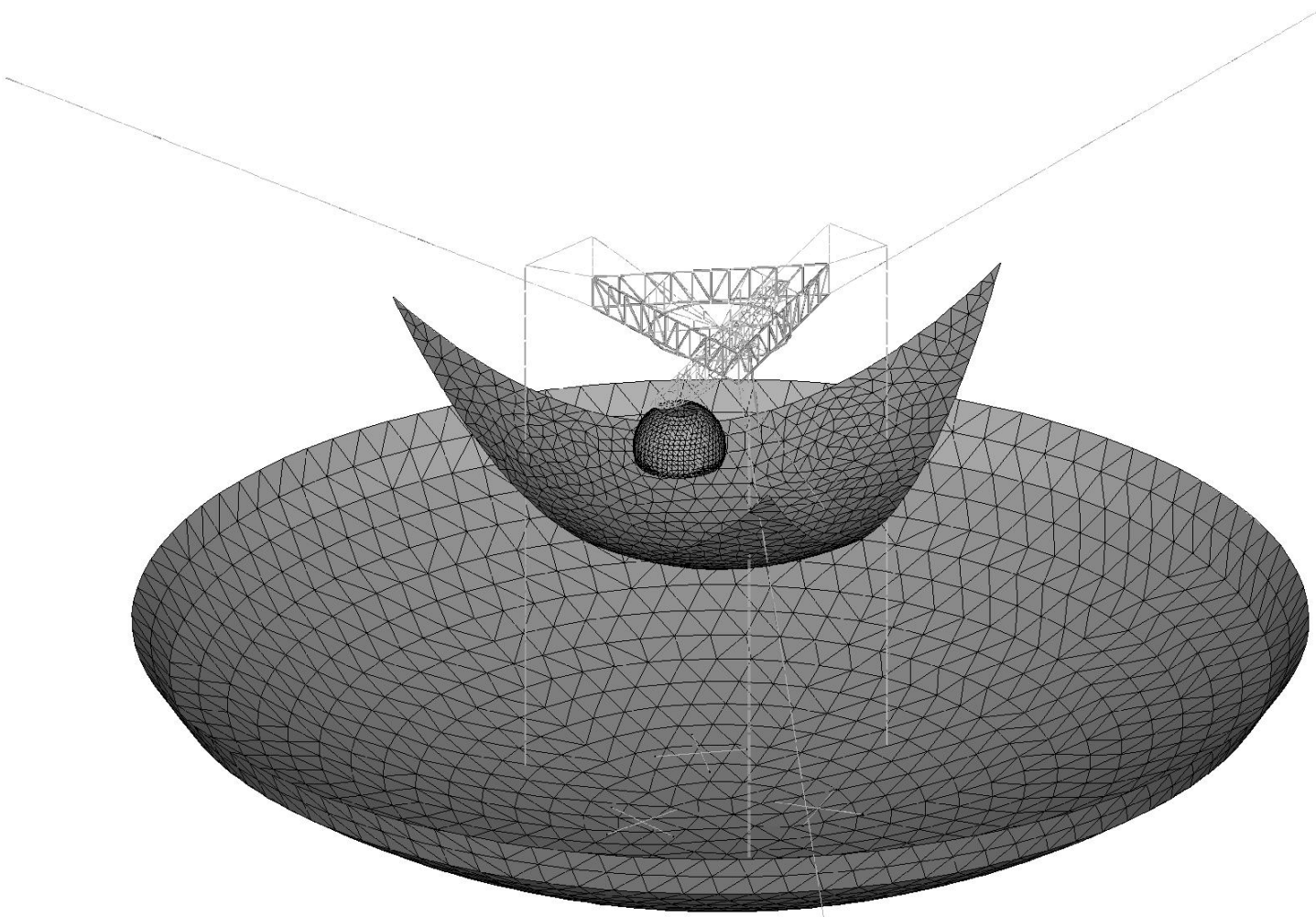
Proposed New HF Heating Facility



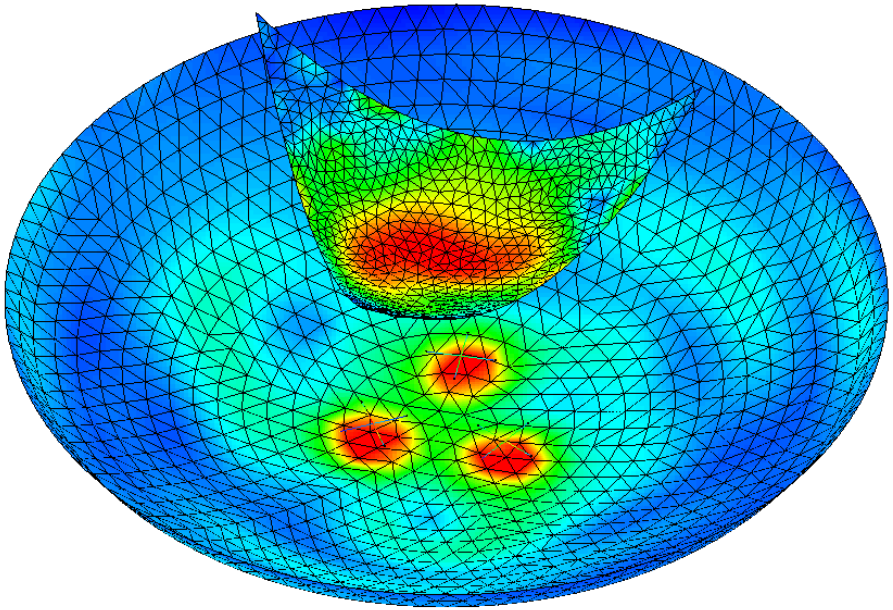
- Located on-site at the observatory
- New antenna design uses a Cassegrain system with a subreflector suspended from the upper platform
- Cassegrain will be fed with a phased array of crossed dipoles located close to the main dish
- Operating frequencies centered at 5.1 and 8.175 MHz



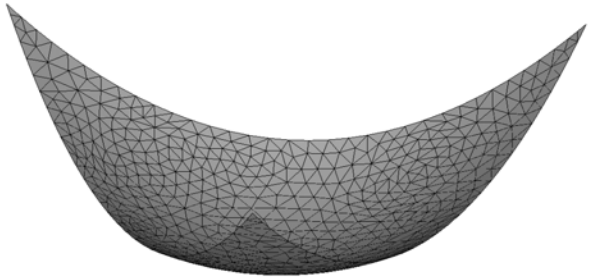
Full FEKO Original Subreflector Model

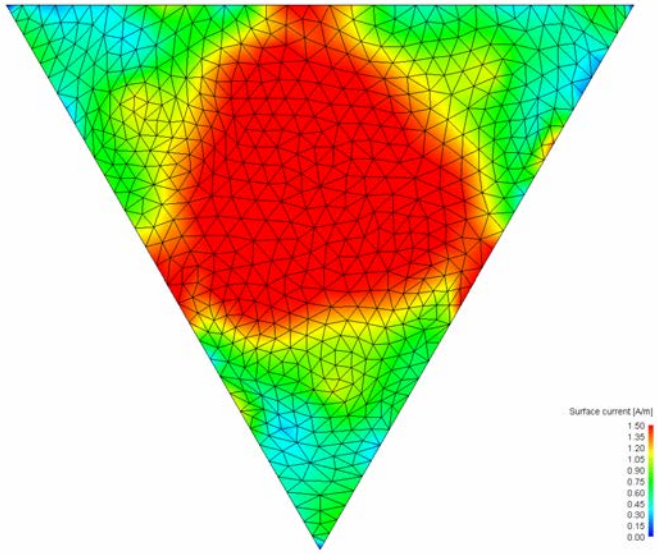


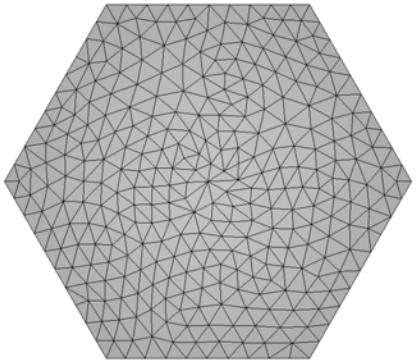
Surface Current Animation

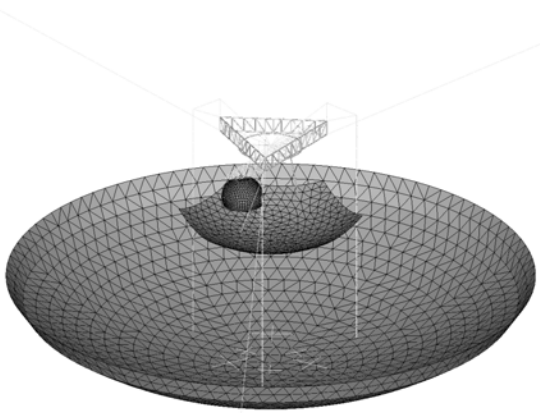


Re-design of Subreflector

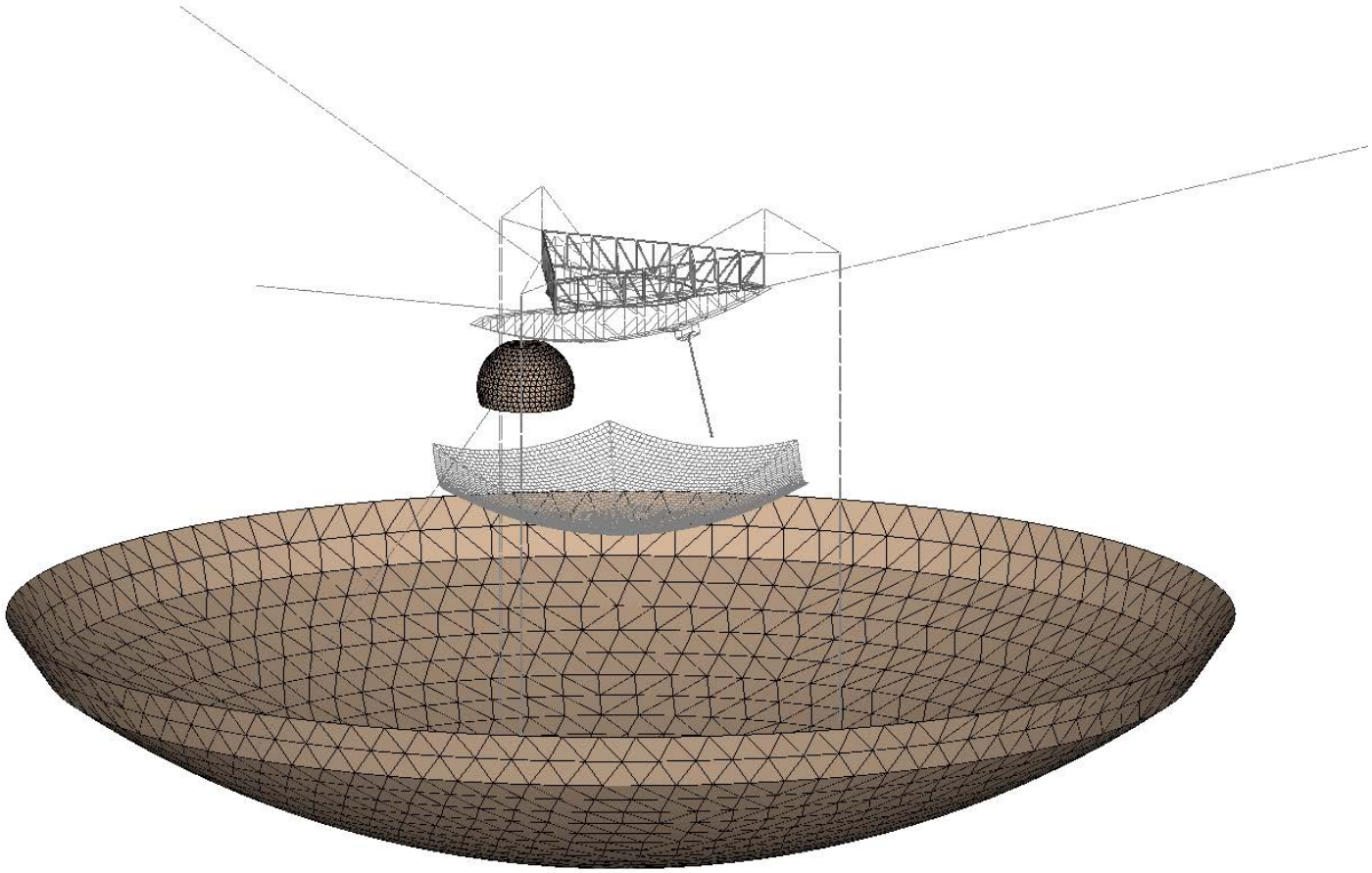




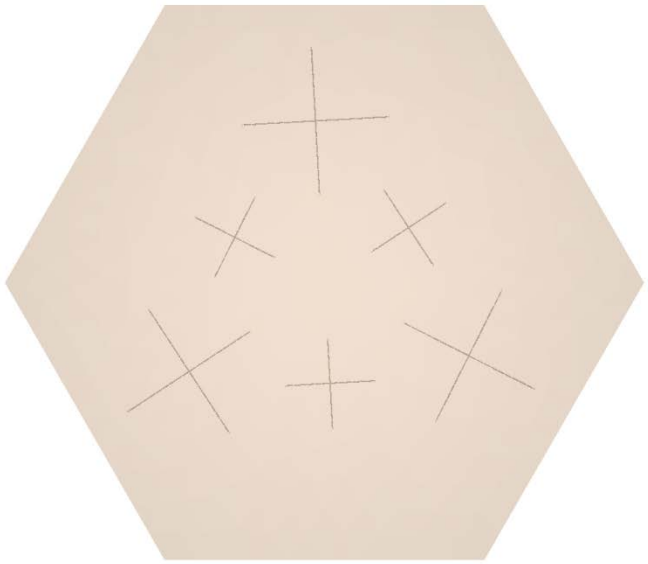


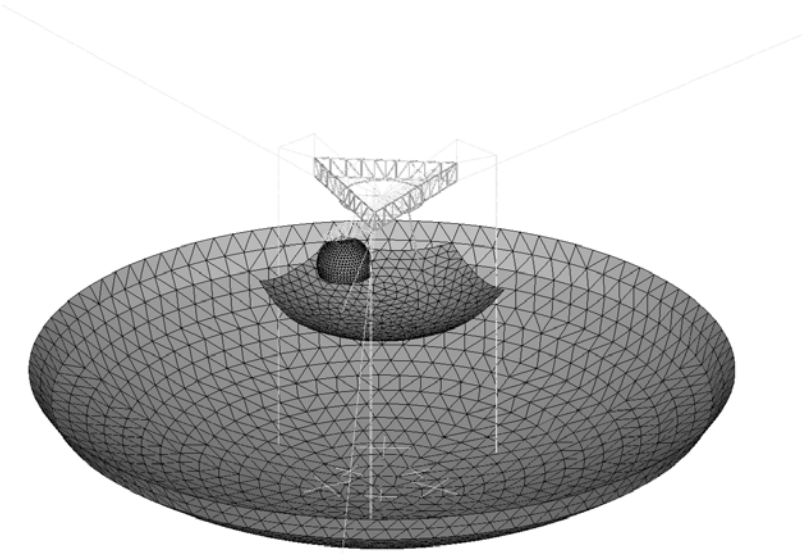


FEKO Model with Wire Subreflector



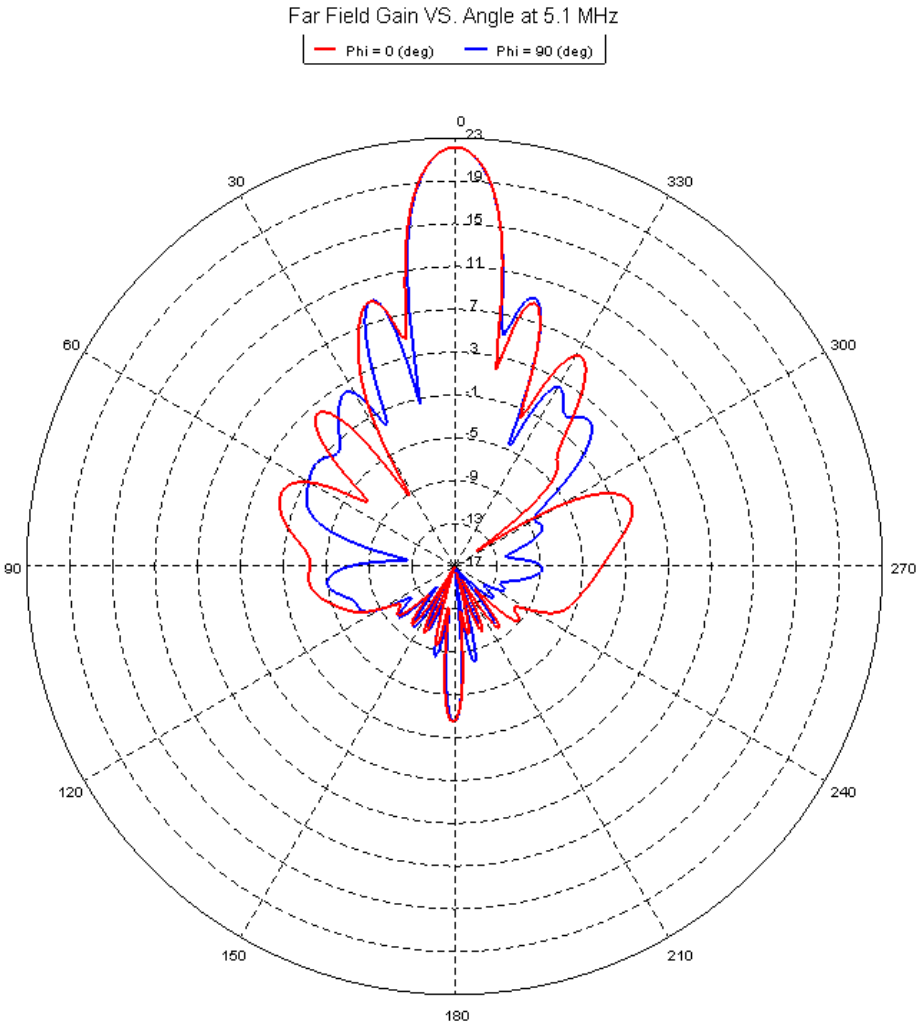
Final Design





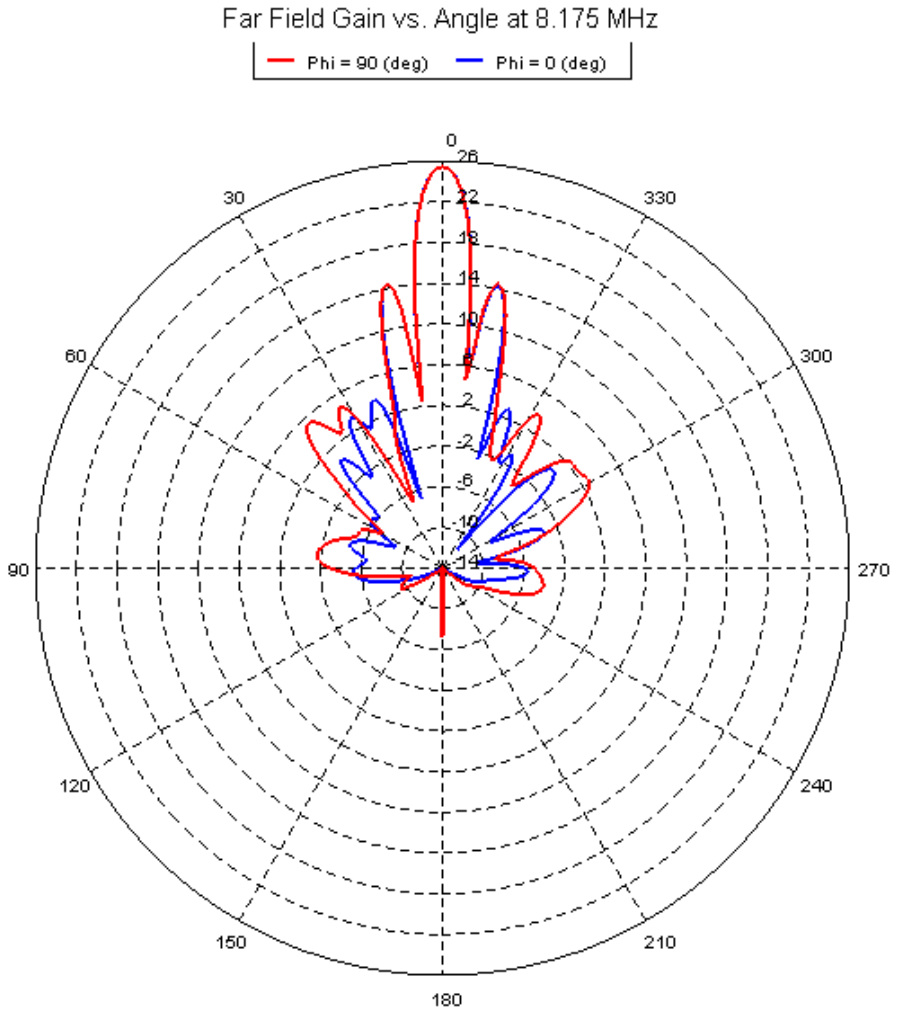
Final Design Gain 5.1 MHz

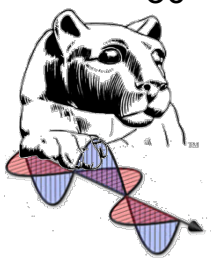
- **Main beam gain 22.16 dBi**



Final Design Gain 8.175 MHz

- **Main beam gain 25.46 dBi**





In Terms of ERP

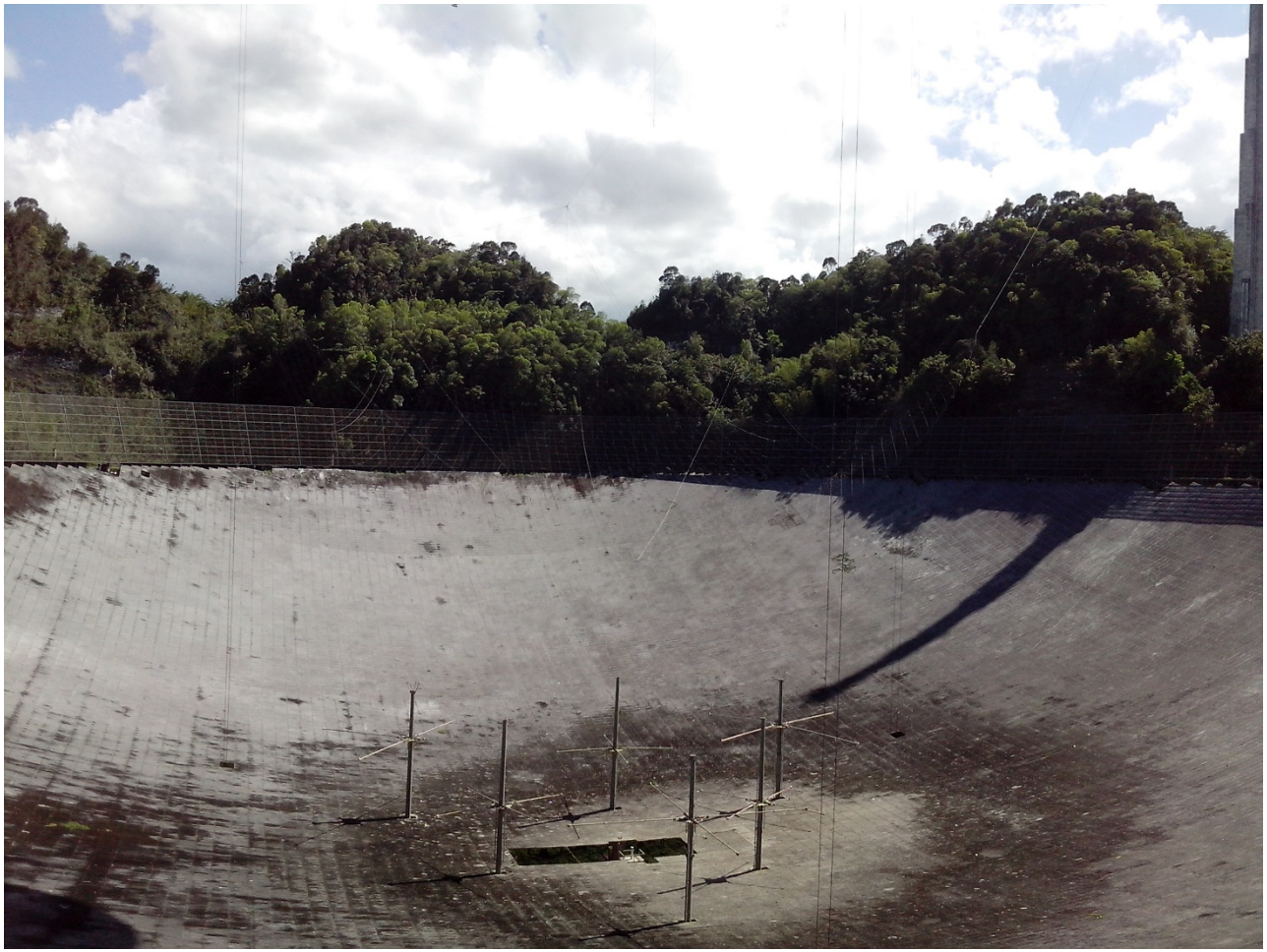
- Old Log-periodic dish feed(est. 40% of Aperture)
- ERP(3 MHz) = 3.7MW (100kW transmitter power)
- ERP(5.1 MHz) = 10.6MW (100kW transmitter power)
- ERP(8.175 MHz) = 27.3MW (100kW transmitter power)

- Islote 32 Log-periodic array
- ERP(3 to 8 MHz) = 79.8MW (400kW transmitter power)

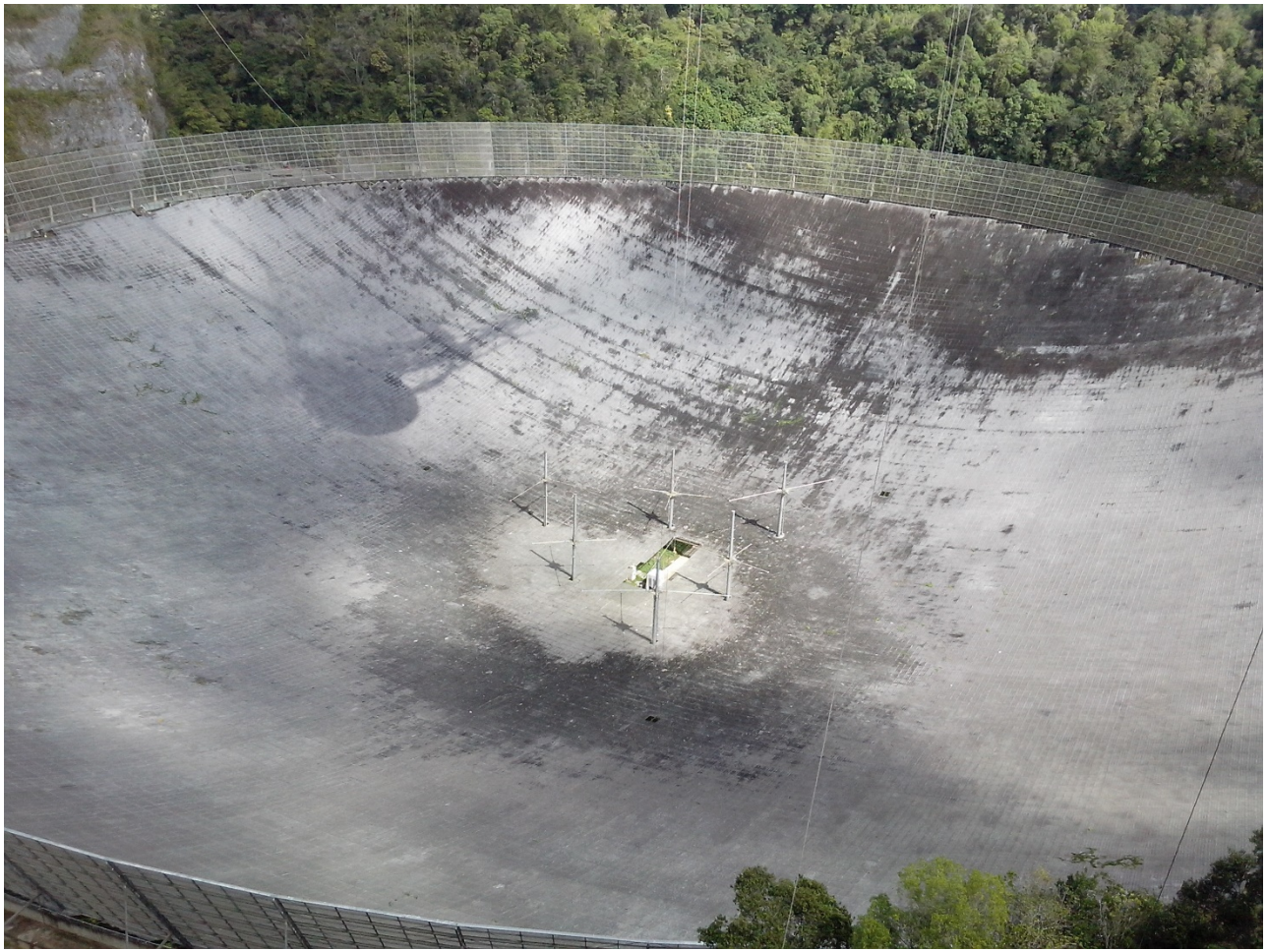
- New HF Design
- ERP(5.1 MHz) = 99.6 MW (600kW transmitter power)
- ERP(8.175 MHz) = 212.9 MW (600kW transmitter power)

New HF Array at Bottom of Dish (Still Under Construction)

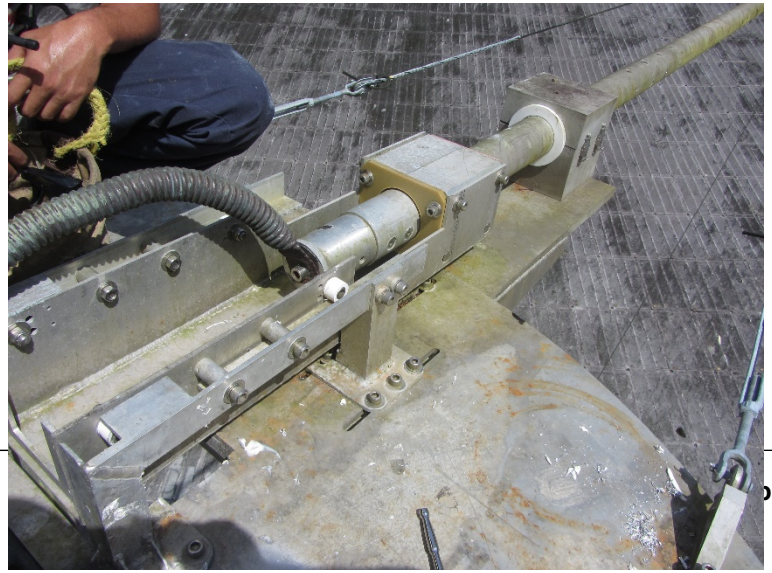
New HF Array at Bottom of Dish (Completed)



New HF Array at Bottom of Dish (Completed)



HF Crossed Dipoles



The Cassegrain Mesh (or should it be called “Mess”)

The Cassegrain Mesh (or should it be called “Mess”)

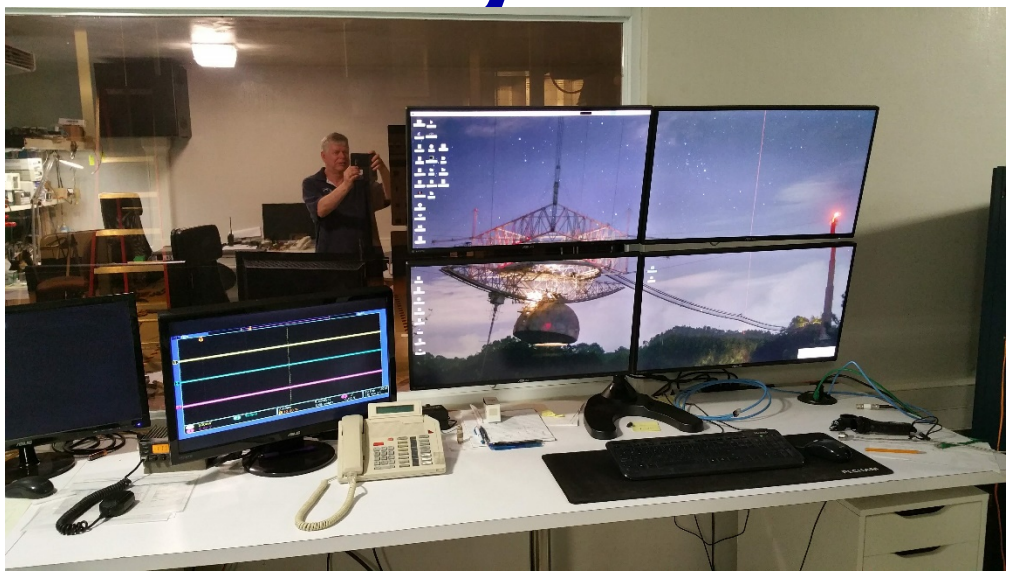
Cassegrain Mesh Finally Starts to Look Like a Reflector for HF

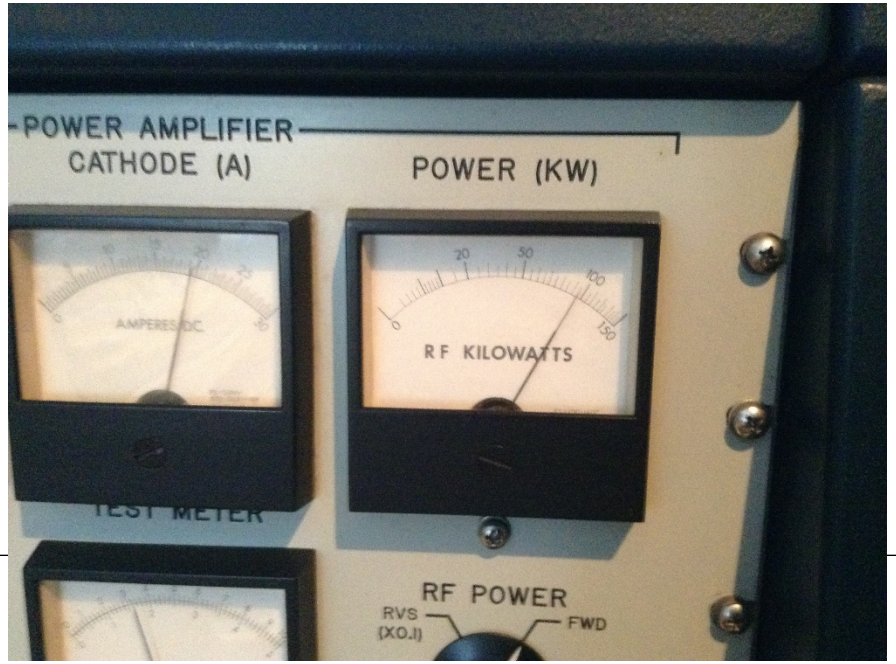
HF 100 kW Transmitters (Or Future 6 Band Contest Station)

HF Facility

HF Facility

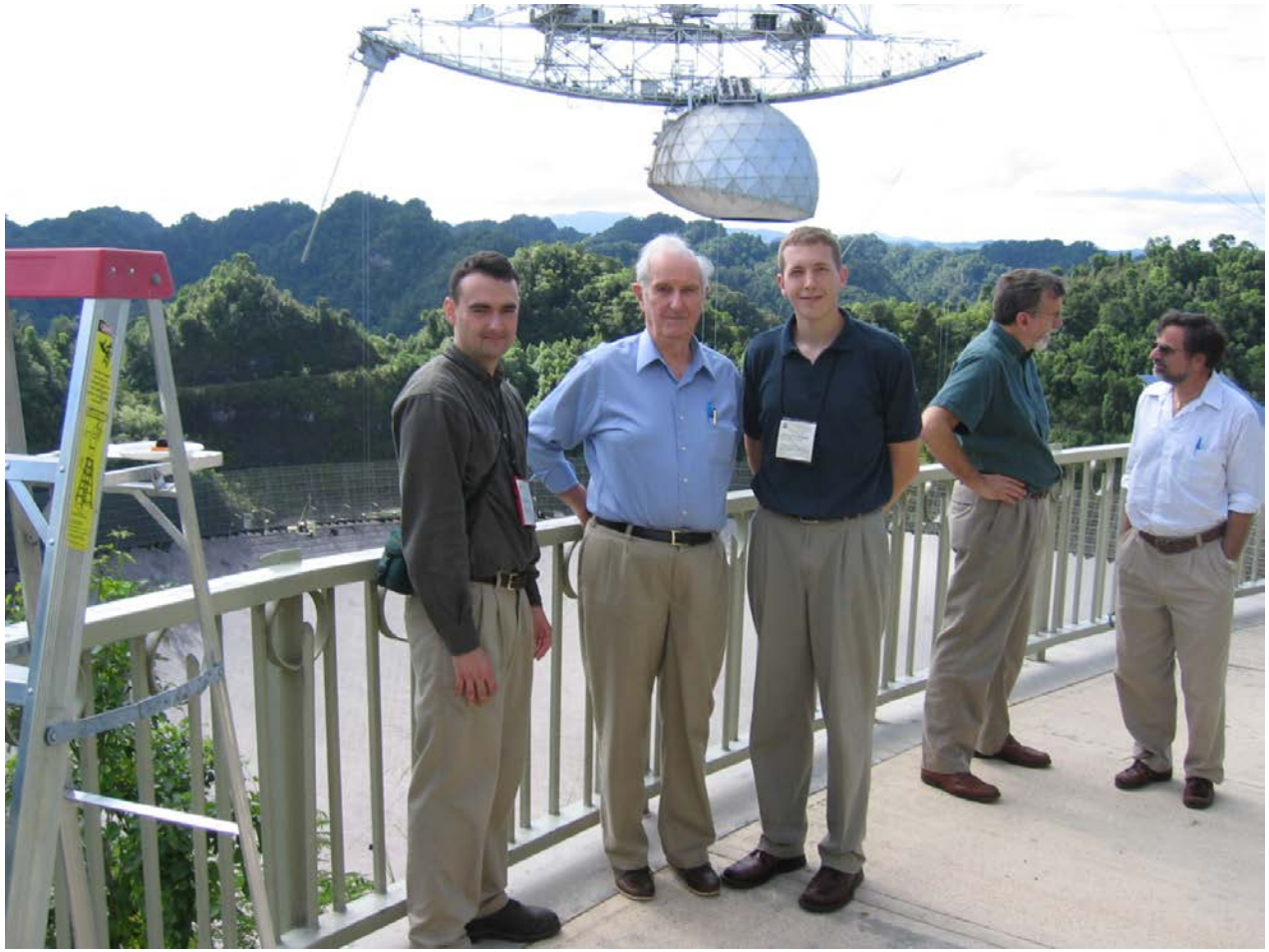
HF Facility




POWER AMPLIFIER
CATHODE (A)
POWER (KW)
AMPERES DC
RF KILOWATTS
TEST METER
RF POWER
RVS
(X0.1)
FWD

Dr. Bill Gordon, Rey Velez, and me (21 years old!) working on original HF Heating Design

Dr. Bill Gordon with Penn State Graduate Students at 40th Anniversary



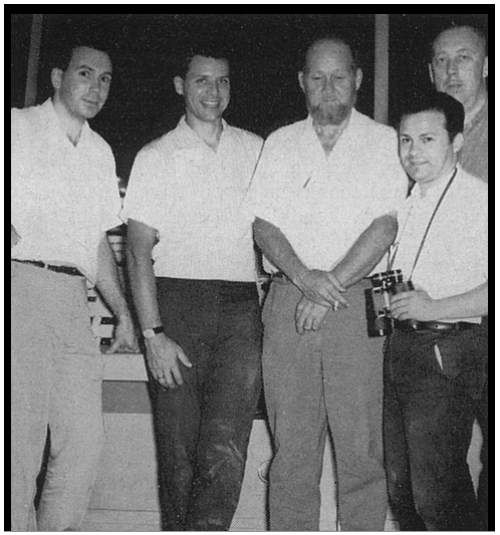
Señor Rompe Todo with PR Mafia

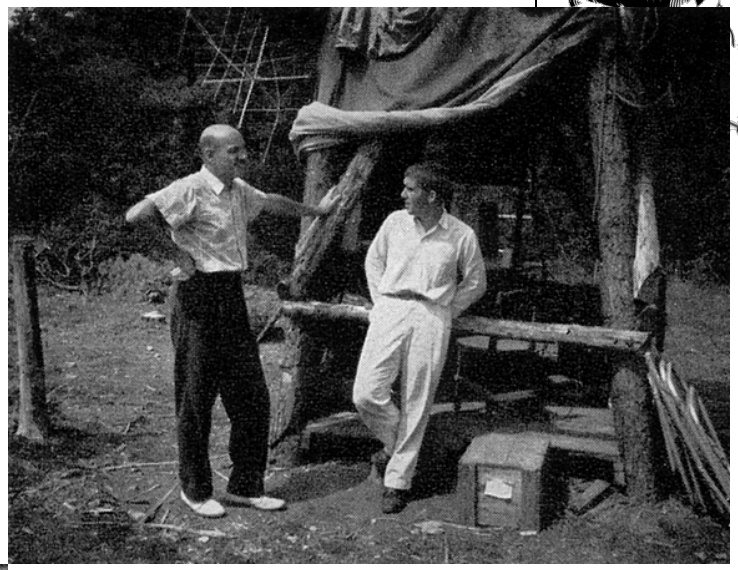
PR Godfather

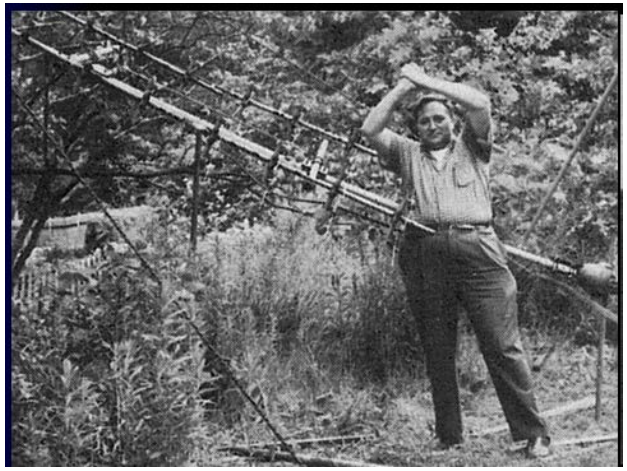
Here I am on New England Public TV about Ham Radio from 100 ft Dish

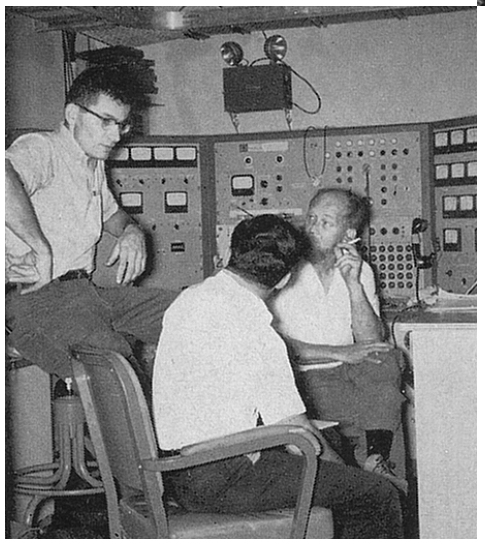
John Denver look in 1977

More Arecibo Hams

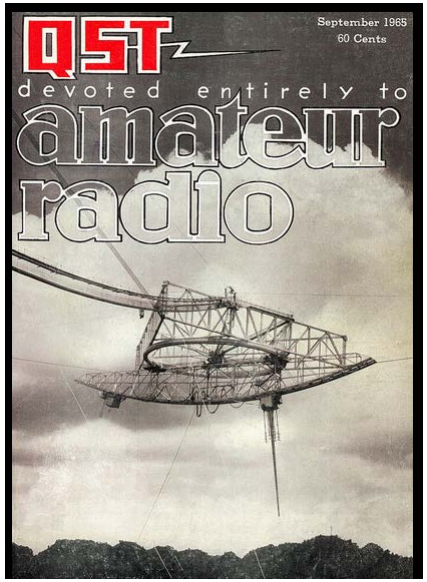








Moonbounce at Arecibo



Mi Hermano – Angel Vazquez – Crowd-Source Funding and Pay to Observe