Parabolic Cylinder Analysis

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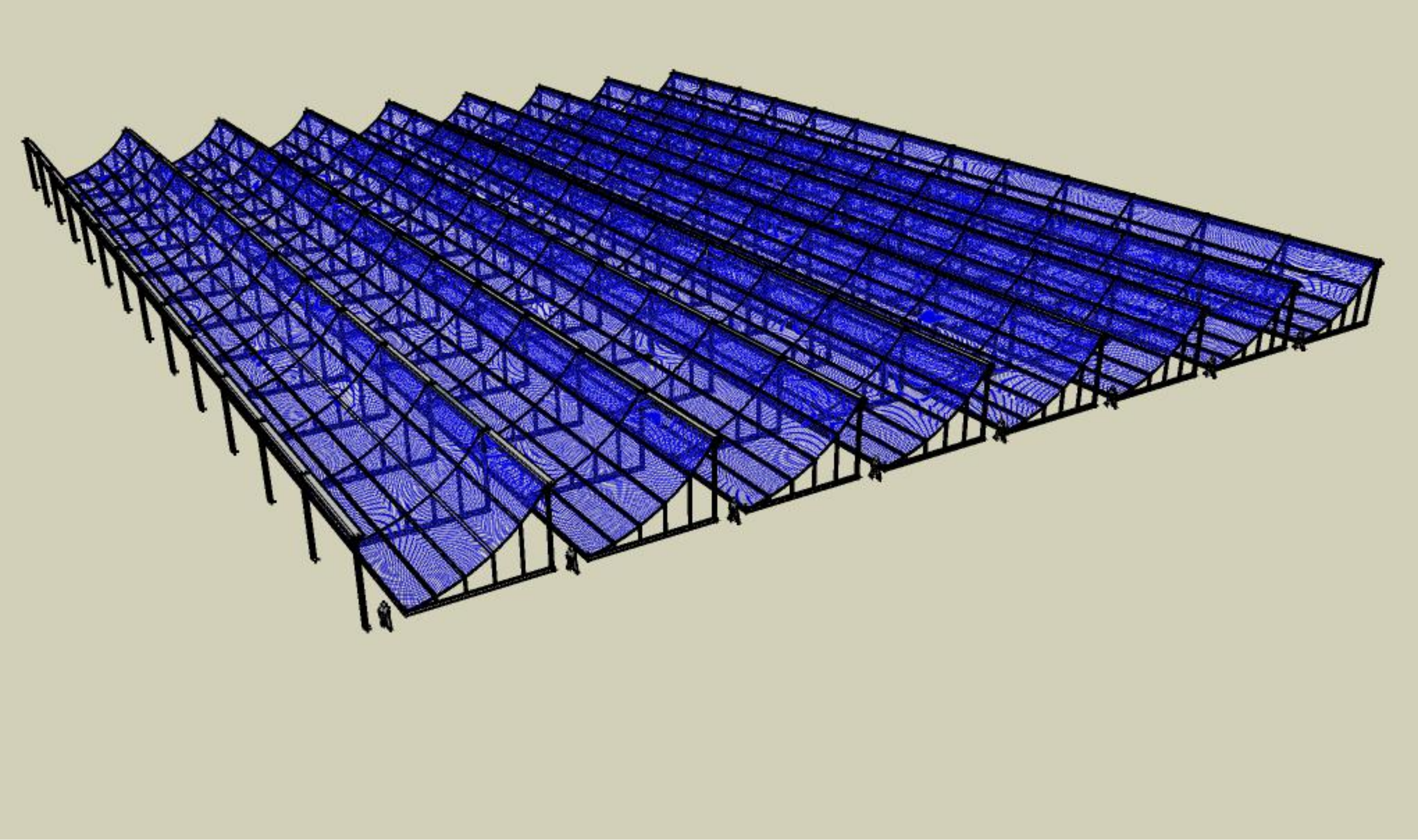
Fermilab
November 11, 2008

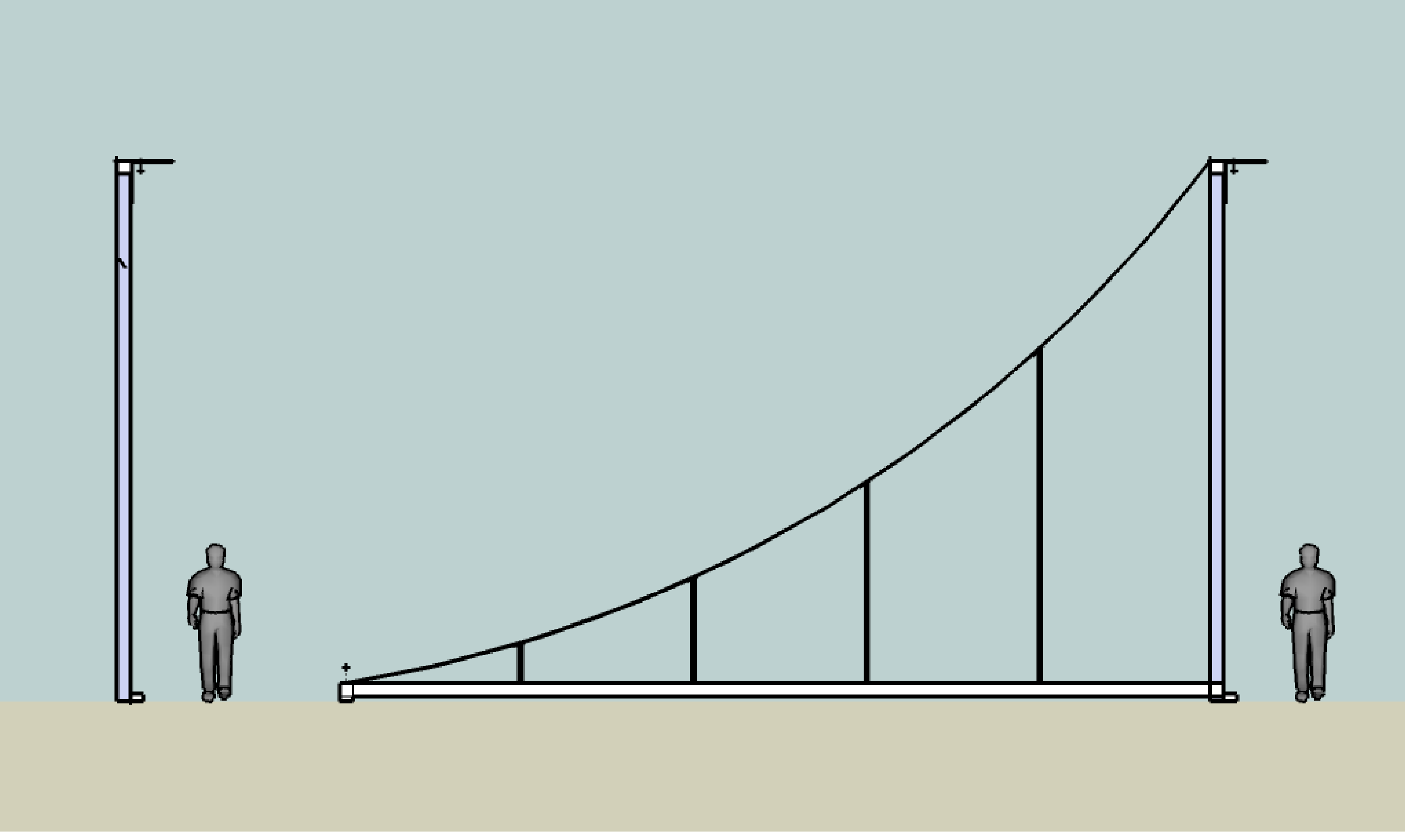
Design Parameters

- Number of cylinders = 8
- Cylinder length = 130 m
- Cylinder width = 12.5 m
- Cylinder Transverse beam width < 8 x 15 arc-min

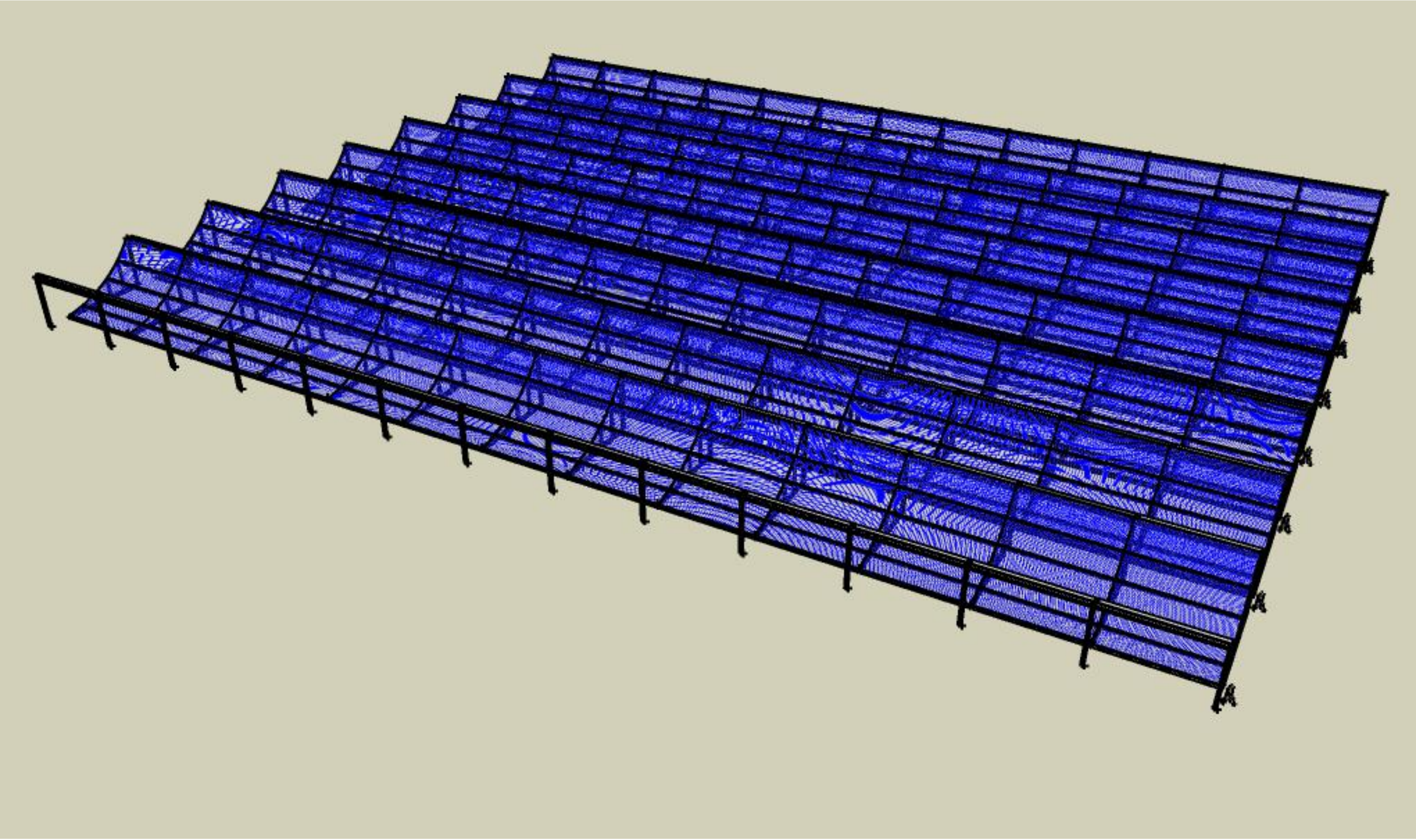
Telescope Layout



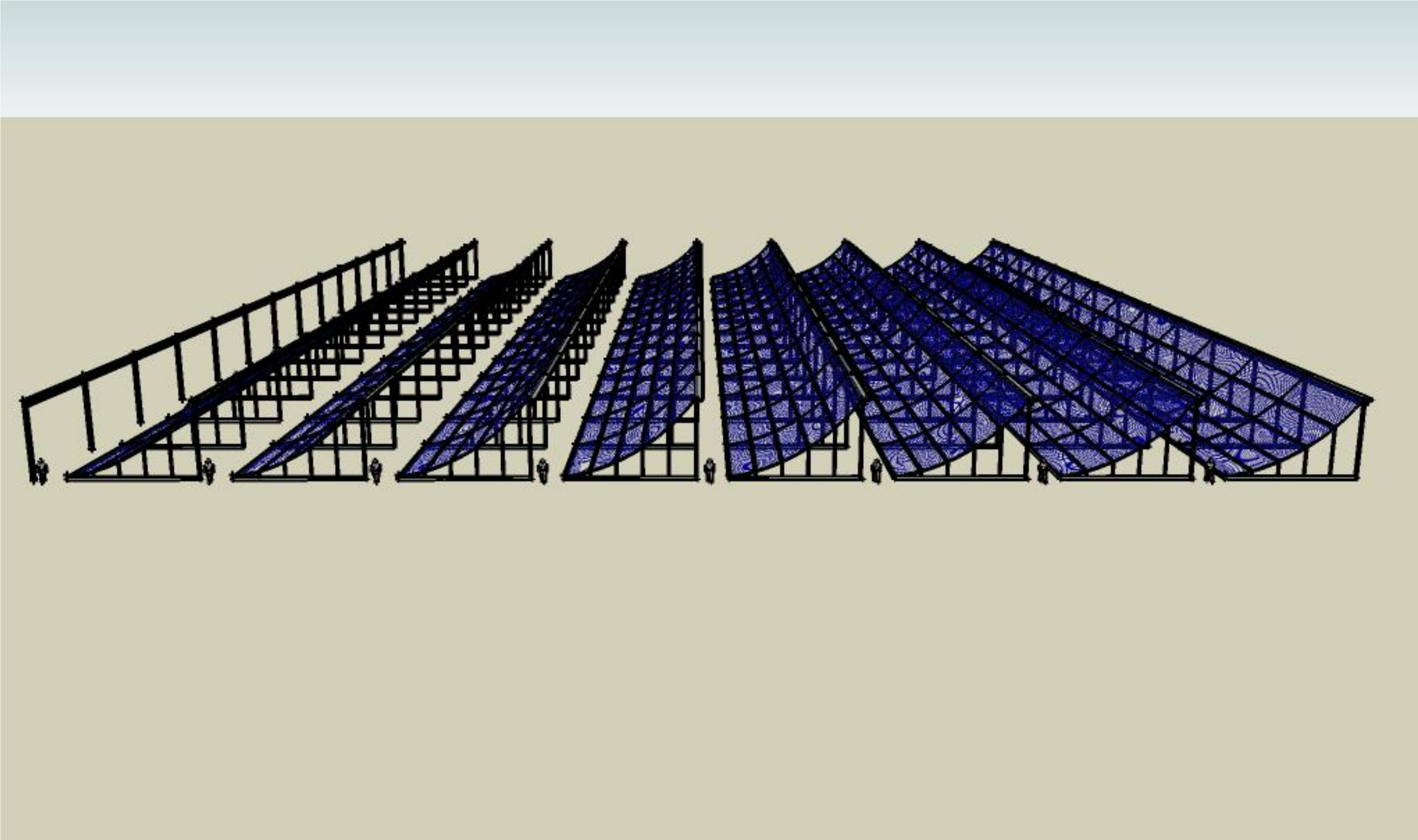
Cylinder Cross-Section



Telescope Layout



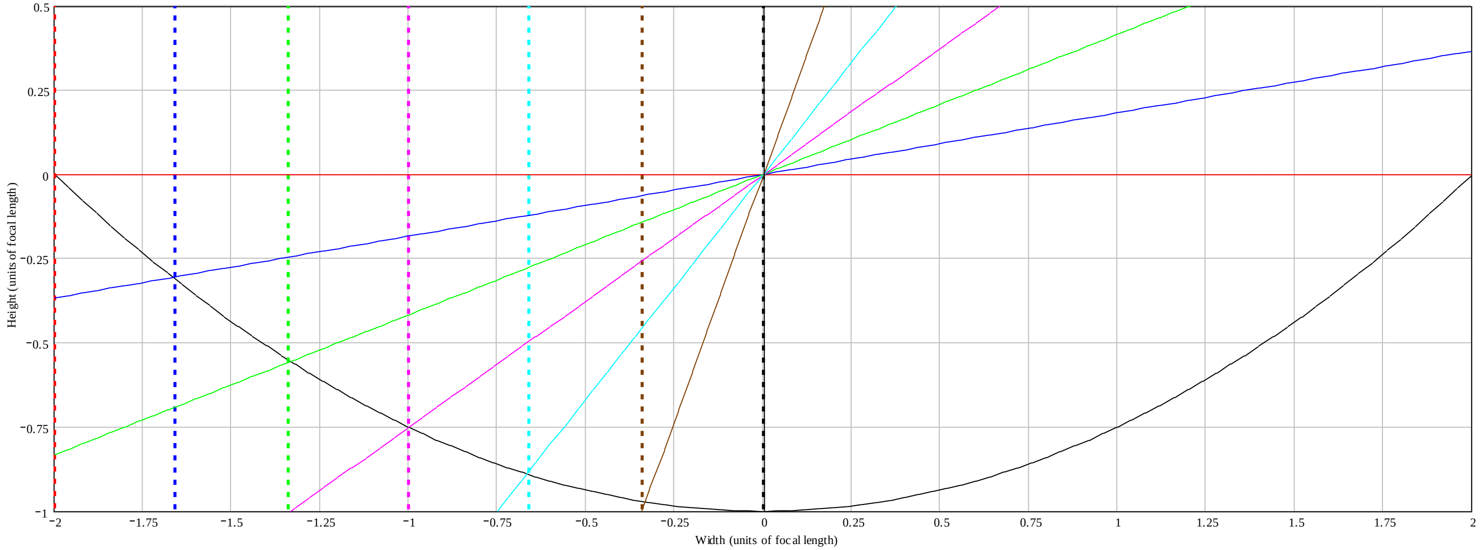
Telescope Layout

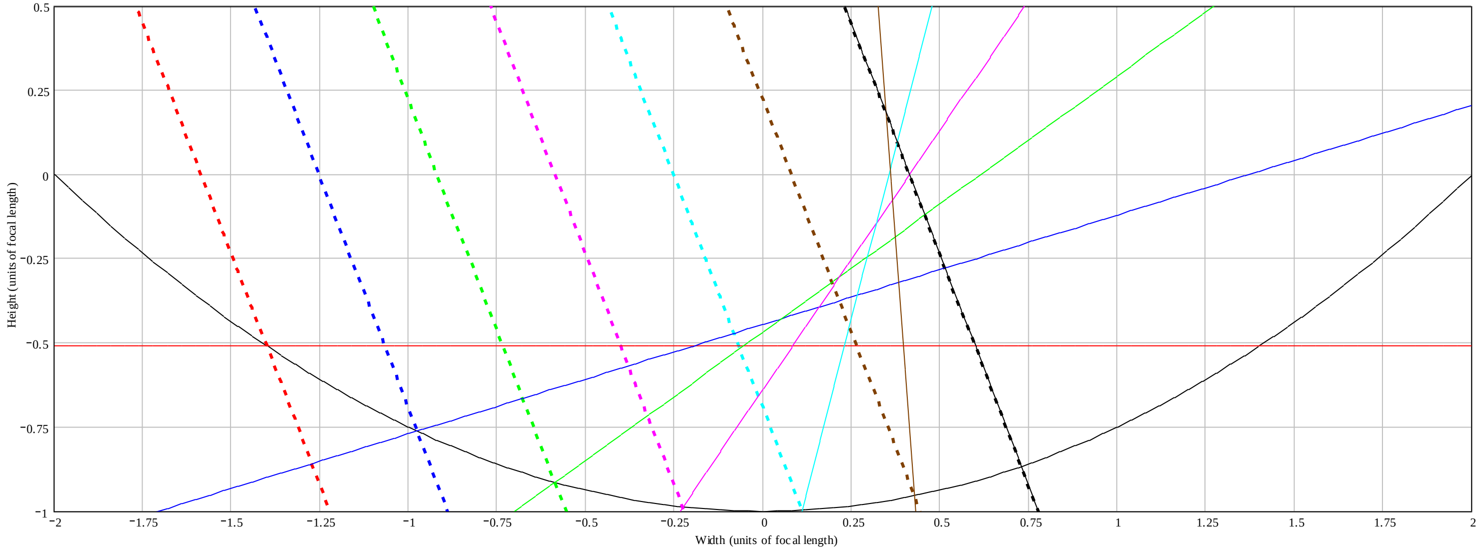


Offset-Fed Telescope

- Concern about double bounce modulation between dish and feed will cause significant ripple in the antenna pattern.
- Would like feed to be hidden by dish to shield from RFI sources.
- Small f-ratio exaggerates focus errors
  - Beam must be parallel to primary axis
  - Cut >50% of dish away

Offset-Fed Telescope

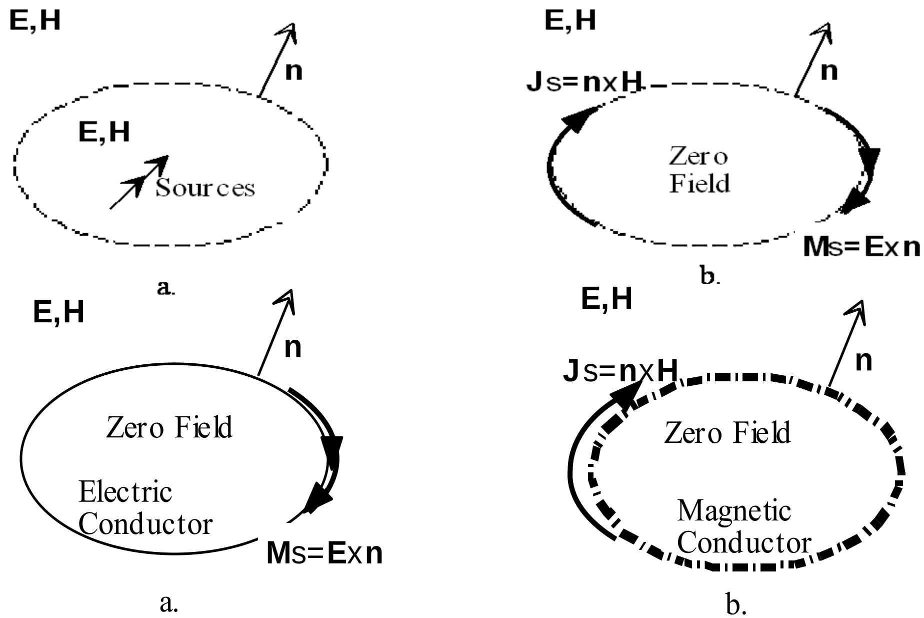


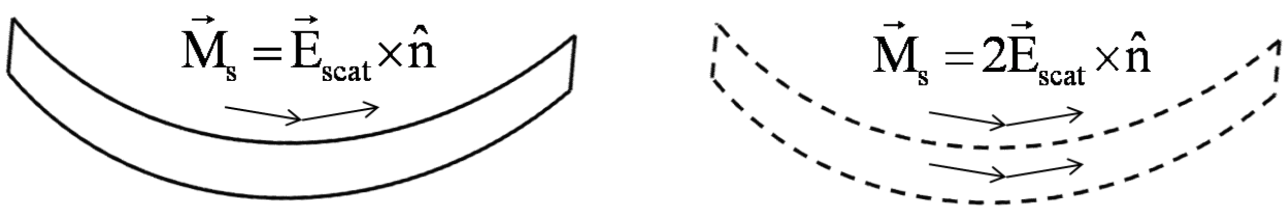


Cylinder Simulations

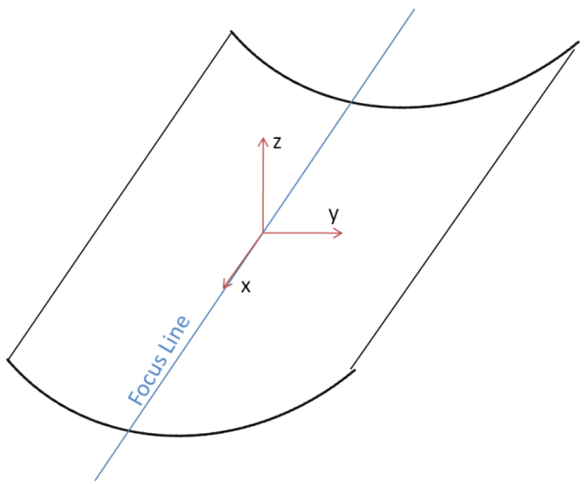
- Physical Optics Approximation
- The antenna dish reflects a scattered field so that the total tangential electric field on the dish is zero. $\vec{E}_{Total} = \vec{\mathrm{E}}_{\mathrm{inc}} + \vec{\mathrm{E}}_{\mathrm{scat}}$
- On the surface of the dish: $\hat{\mathrm{n}} \times \vec{\mathrm{E}}_{\mathrm{inc}} = -\hat{\mathrm{n}} \times \vec{\mathrm{E}}_{\mathrm{scat}}$
- If the incident field on the dish surface is known, then the scattered field on the dish surface is also known

Physical Optics Approximation



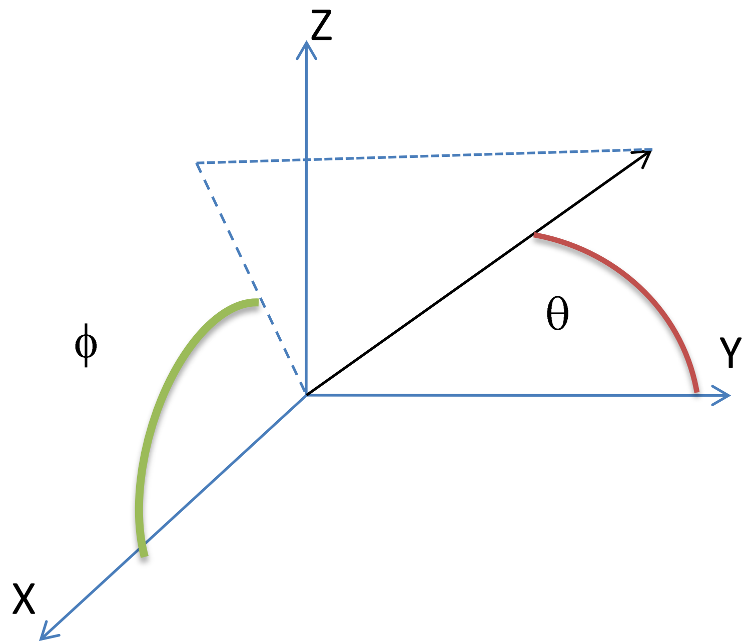


Telescope Coordinate System

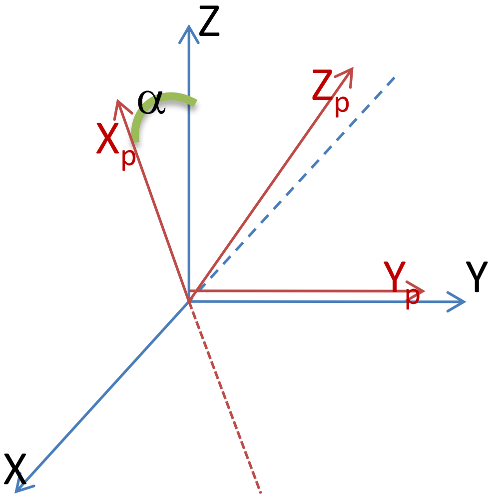


$$D(\phi,\theta) = \frac{U(\phi,\theta)}{\frac{1}{4\pi}\iint U(\phi,\theta)\sin(\theta)d\theta d\phi}$$

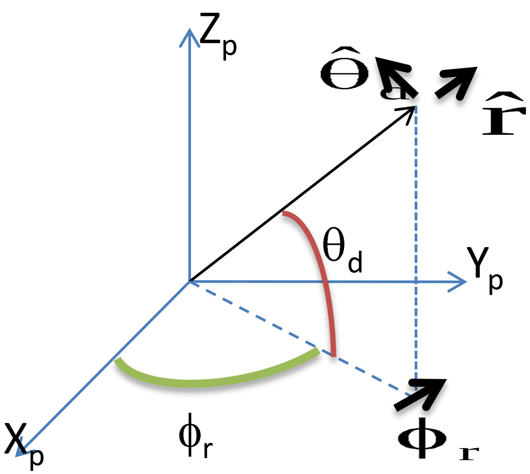
$$U(\phi,\theta) = \frac{1}{2}\mathrm{Re}\left\{\vec{E} \times \vec{H}^*\right\} \cdot \hat{r}R^2$$



Polarization



Celestial coordinate system (in red) with respect to telescope coordinate system. The angle a equal to the latitude of the telescope location



Celestial Coordinate system defined by declination angle, θ_d, and right ascension angle, ϕ_ρ.

$$\hat{\theta}_d = \begin{aligned} &-(\sin(\alpha)\sin(\theta_d)\cos(\phi_r) + \cos(\alpha)\cos(\theta_d))\hat{x} \\ &+(\sin(\theta_d)\sin(\phi_r))\hat{y} \\ &+(-\cos(\alpha)\sin(\theta_d)\cos(\phi_r) + \sin(\alpha)\cos(\theta_d))\hat{z} \end{aligned}$$

$$\hat{\phi}_r = \begin{aligned} &-(\sin(\alpha)\sin(\phi_r))\hat{x} \\ &+(\cos(\phi_r))\hat{y} \\ &-(\cos(\alpha)\sin(\phi_r))\hat{z} \end{aligned}$$

Directivity

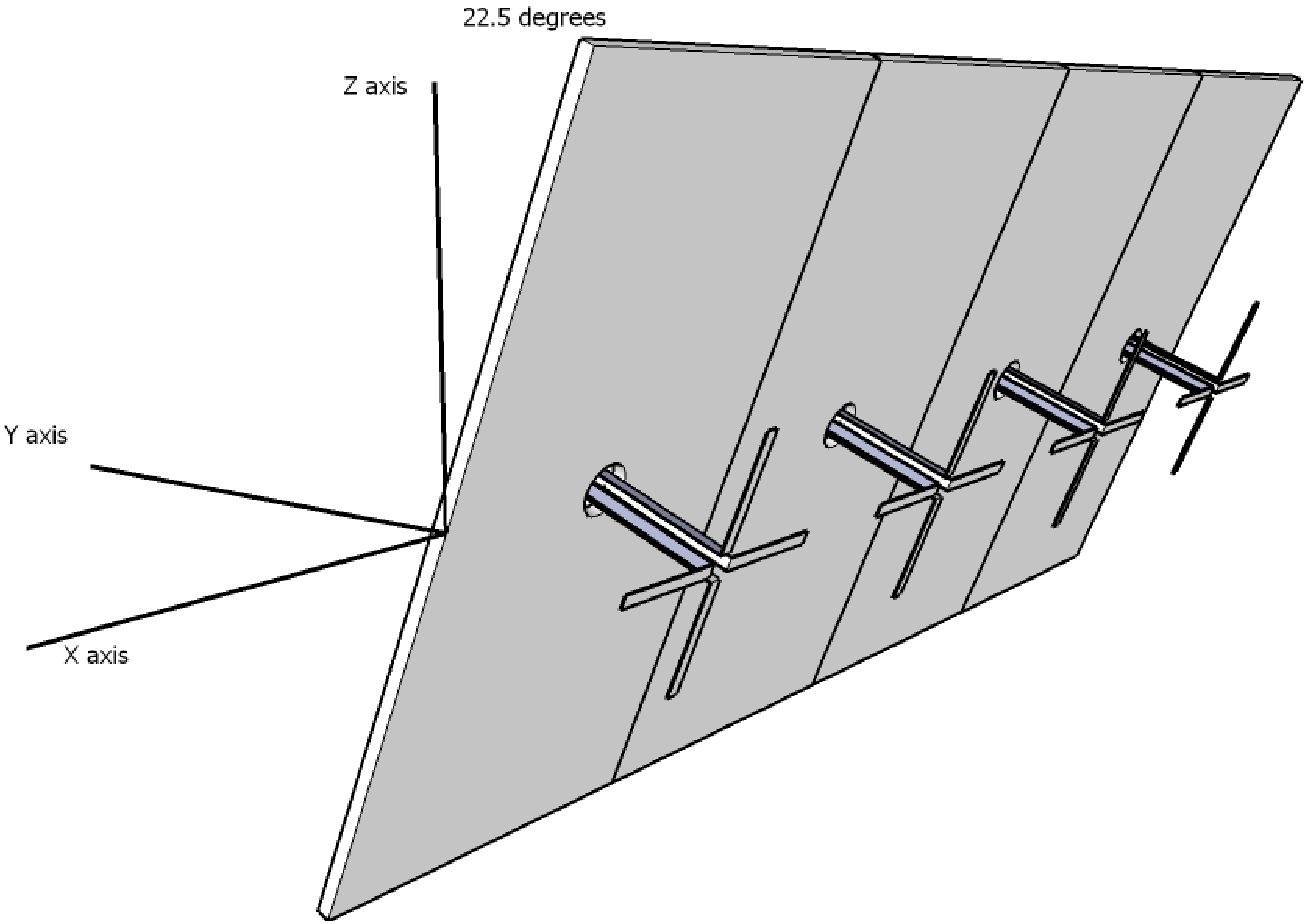
$$D(\phi,\theta) = \frac{U(\phi,\theta)}{\frac{1}{4\pi}\iint U(\phi,\theta)\sin(\theta)d\theta d\phi}$$

$$\Omega_A = \frac{4\pi}{D_{max}}$$

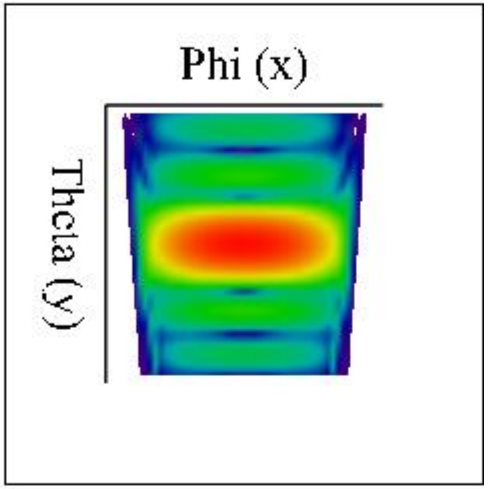
$$A_{em} = \frac{\lambda^2}{\Omega_A}$$

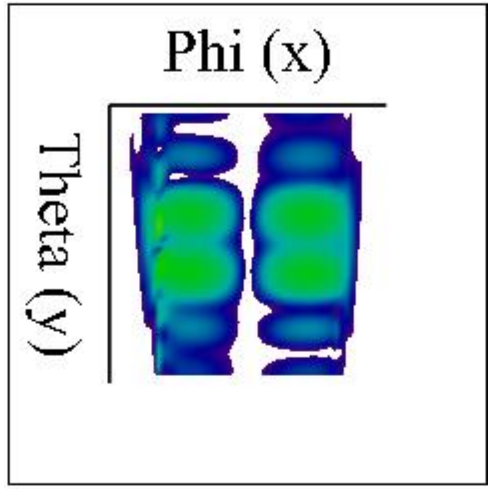
$$L_{em} = \frac{A_{em}}{W}$$

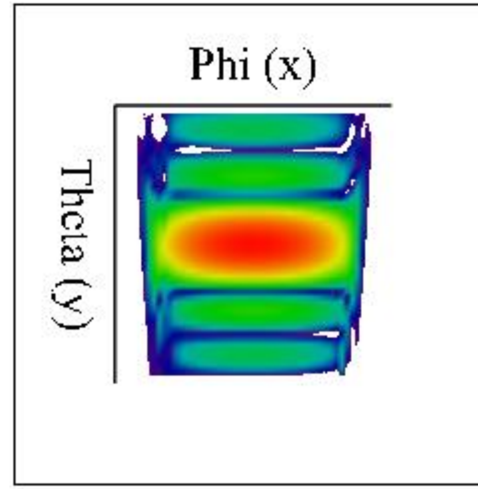
Simple Telescope Feed (first attempt)



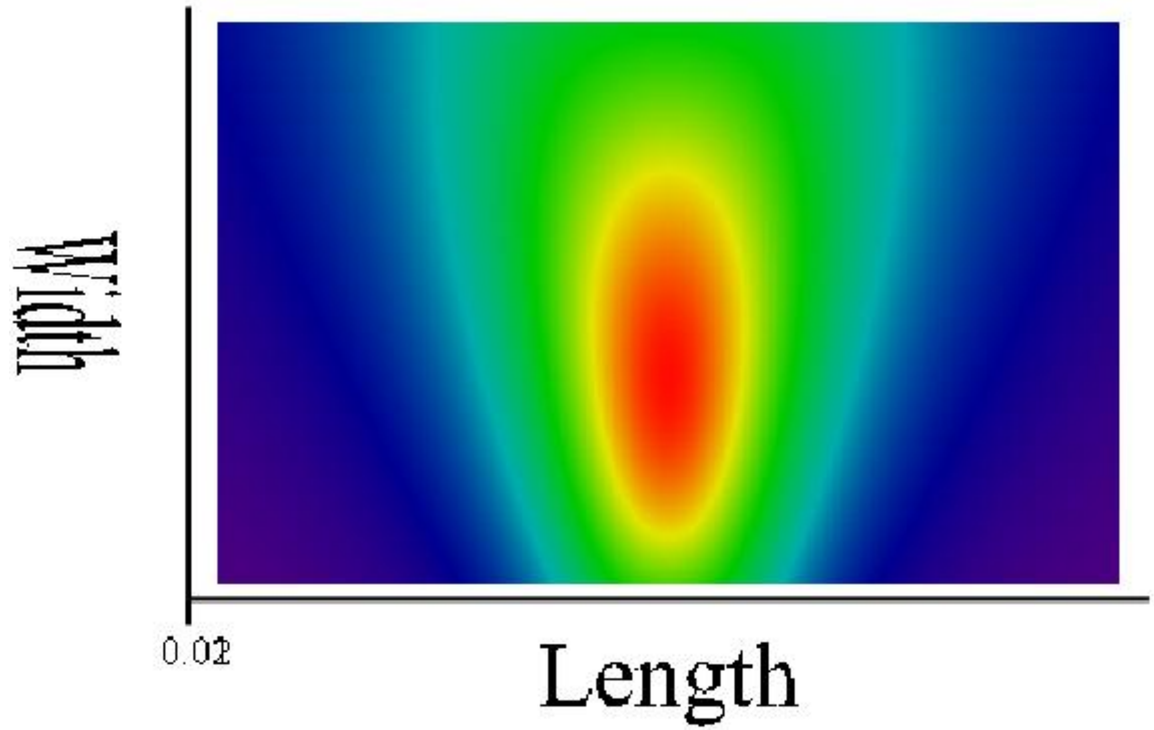
Y-Z Polarization Results



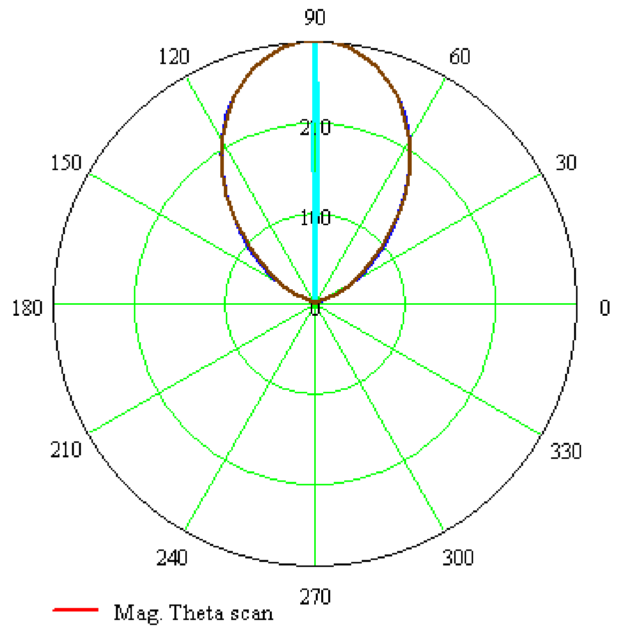




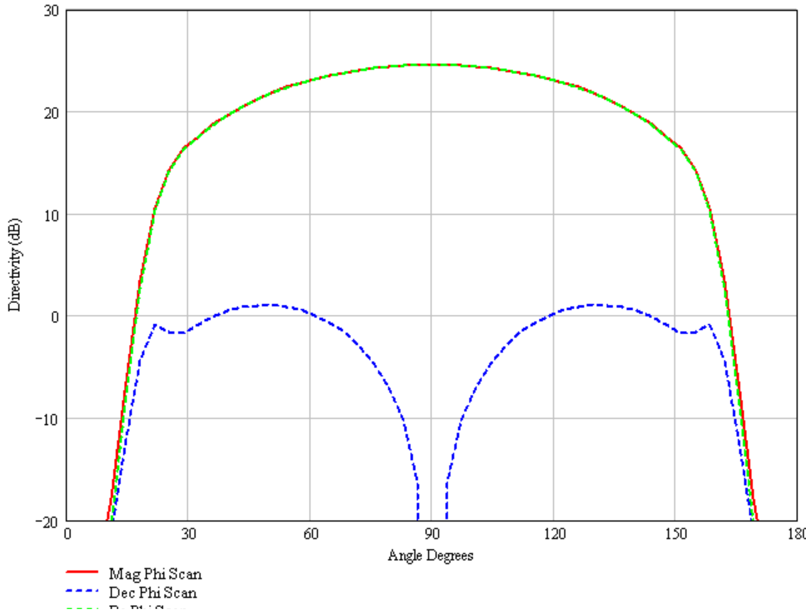
eMagLog

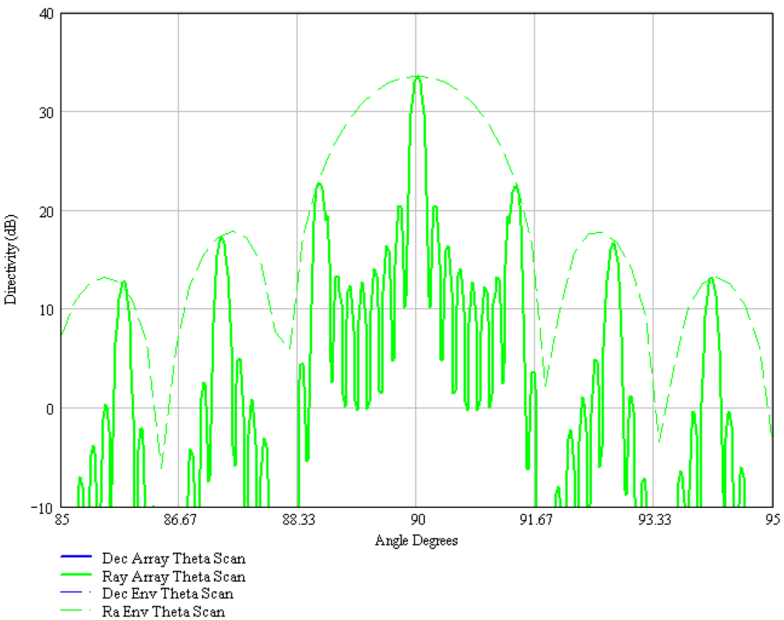


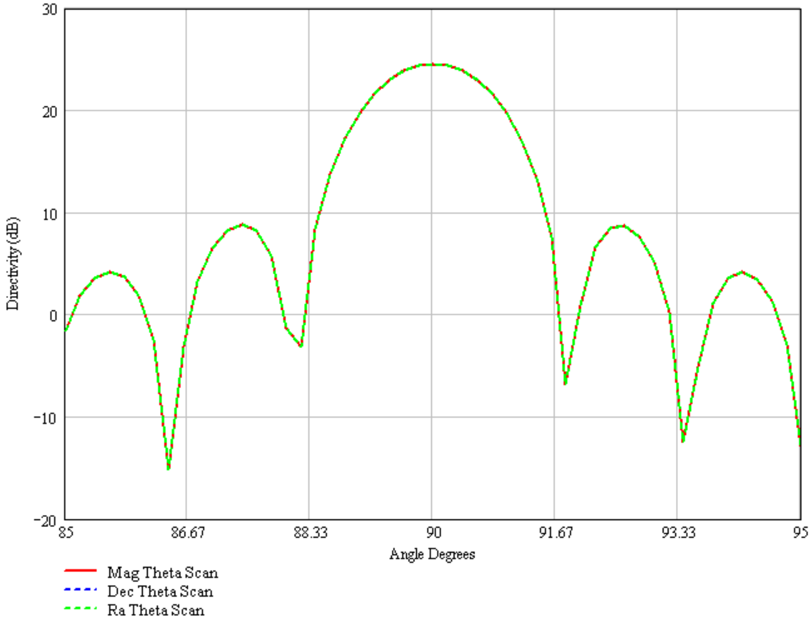
Y-Z Polarization Results



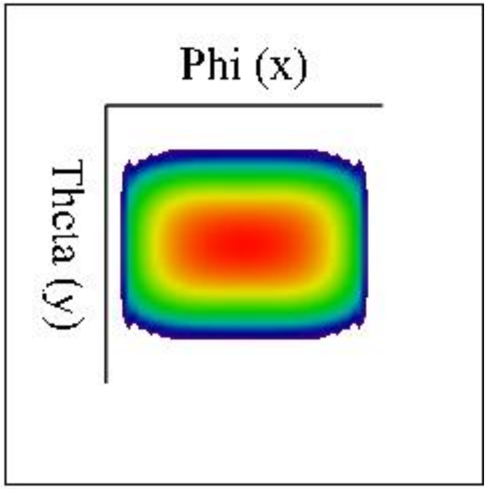
$$\frac{L_{em}}{\lambda} = 0.687$$







Y Polarization (Full Width)



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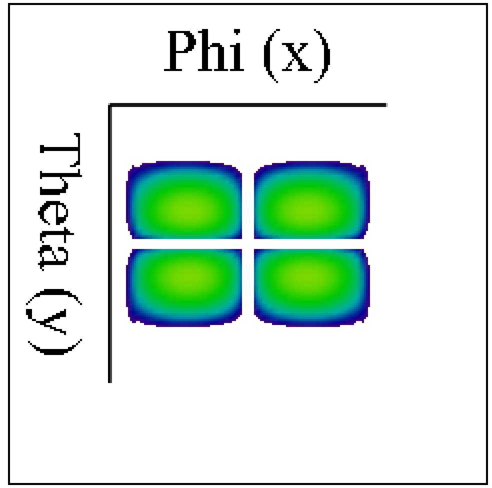
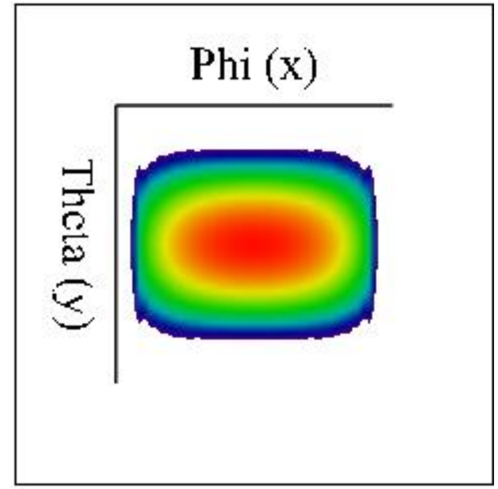
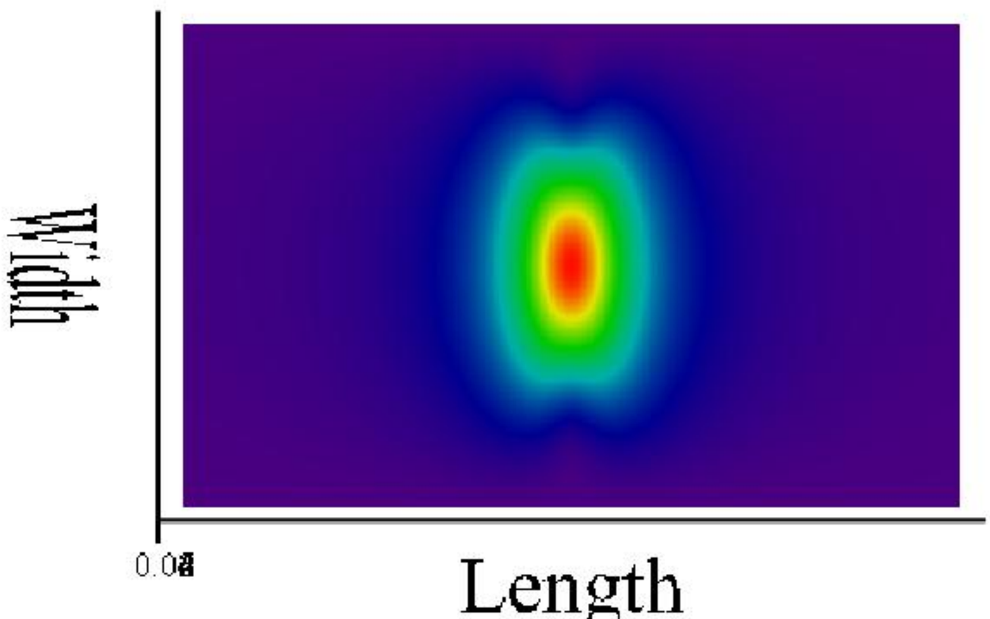


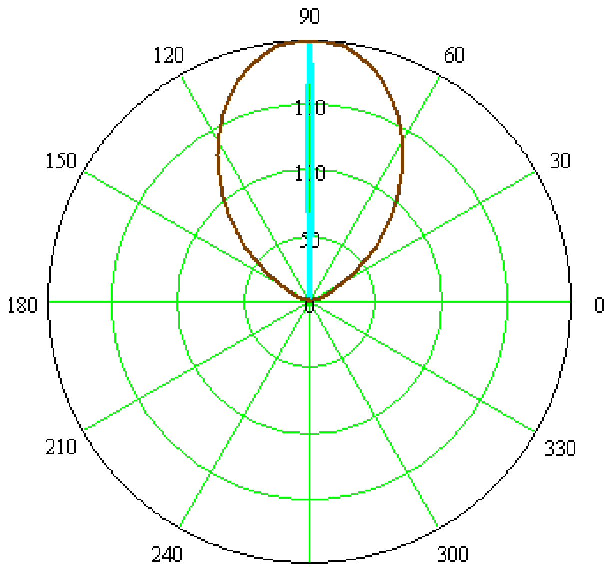
eDecLog



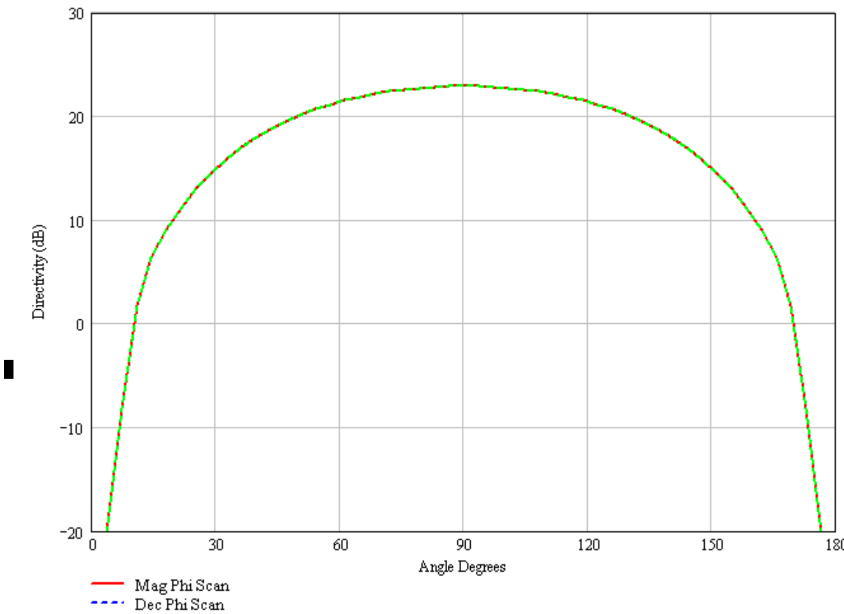
eRaLog

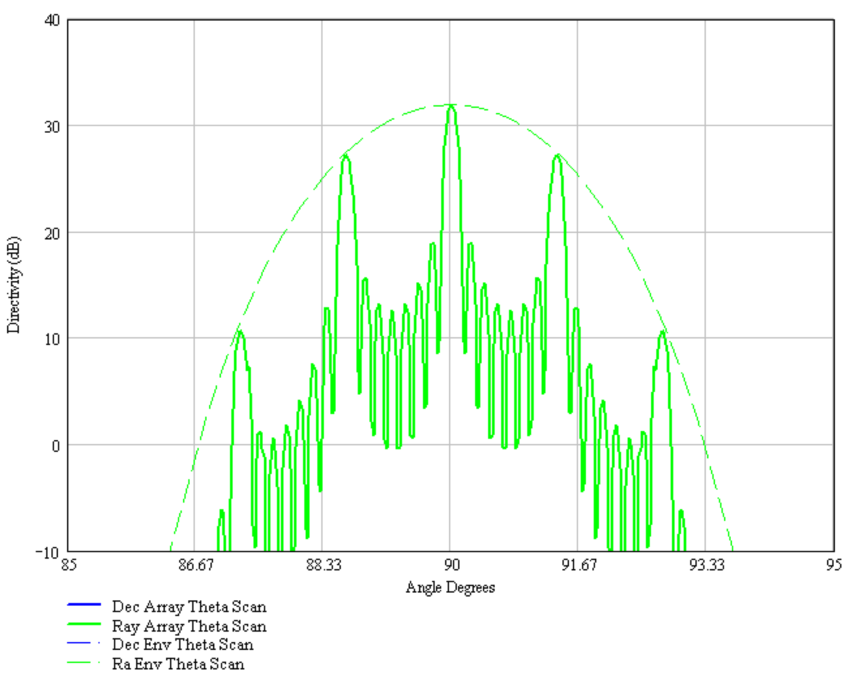


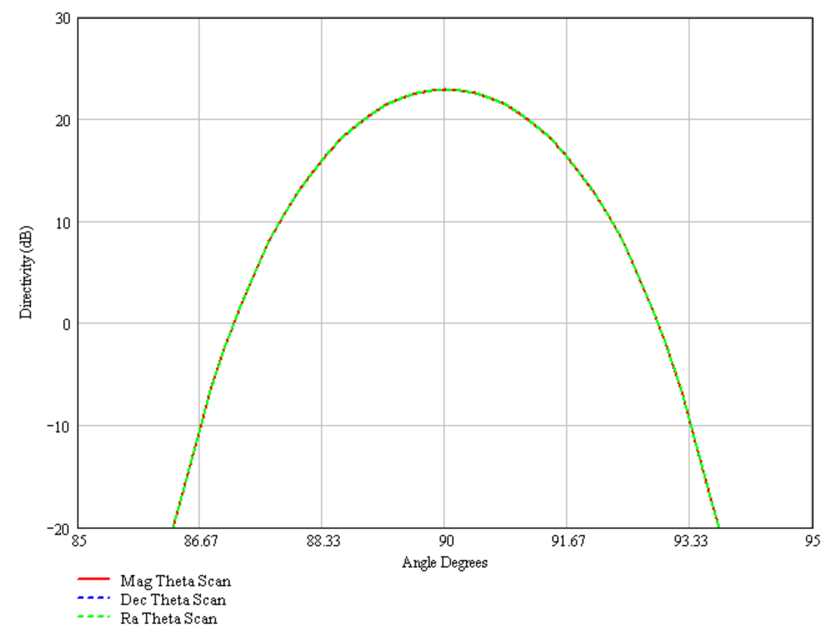
Y Polarization (Full Width)



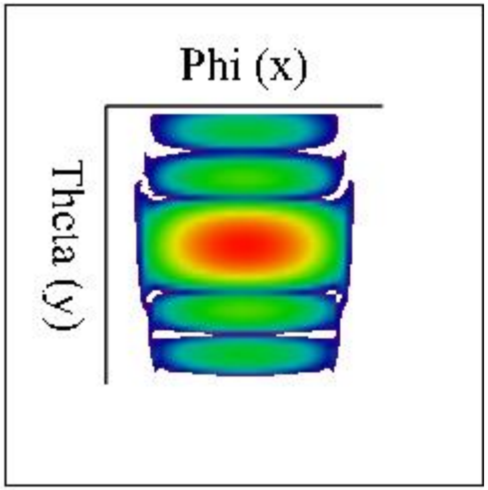
$$\frac{L_{em}}{\lambda} = 0.376$$



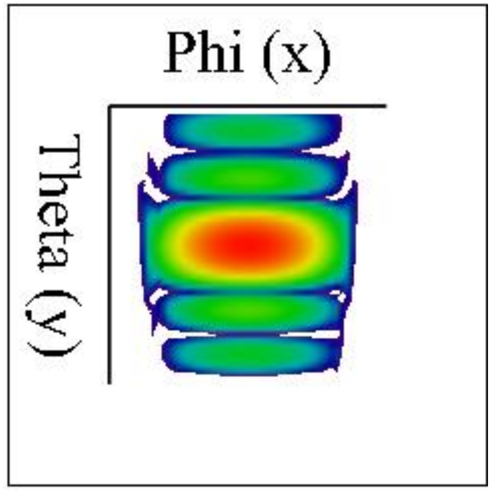




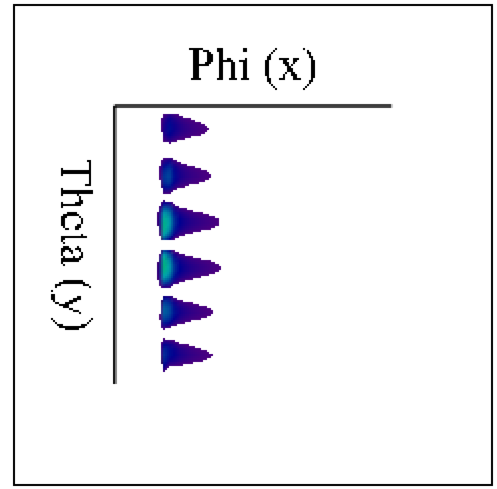
X-Polarization Results



eMagLog



eDecLog



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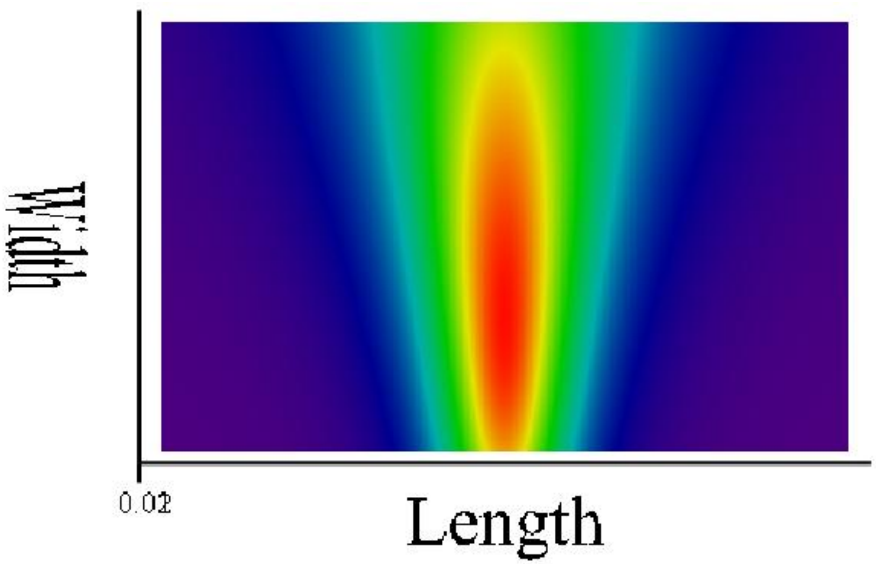
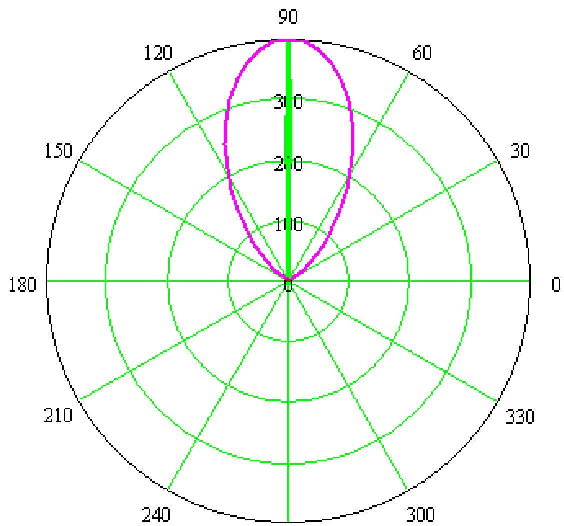
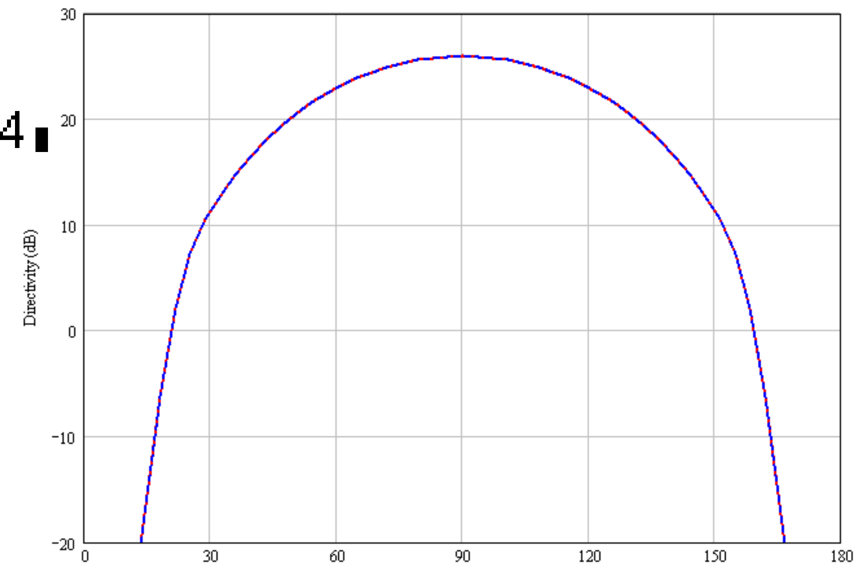
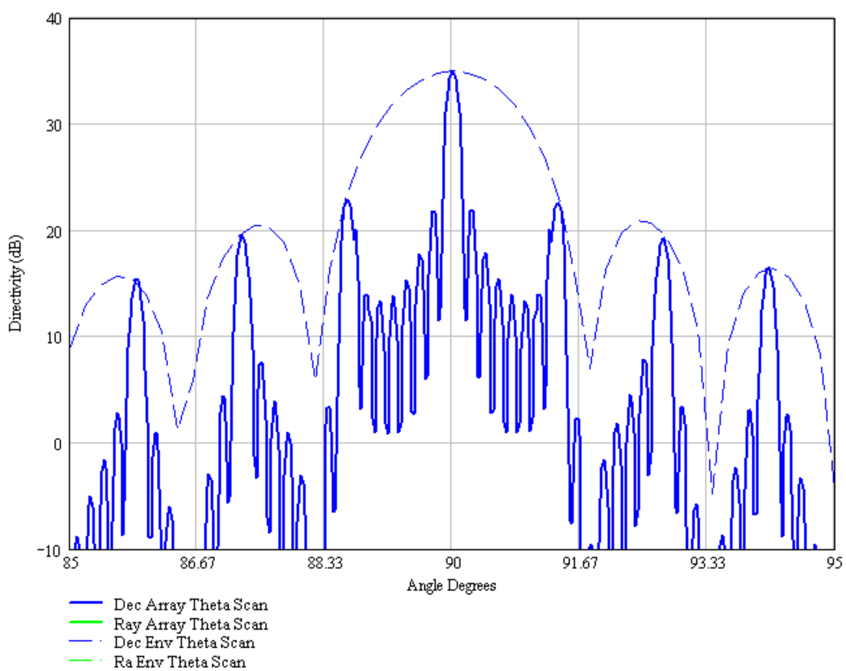


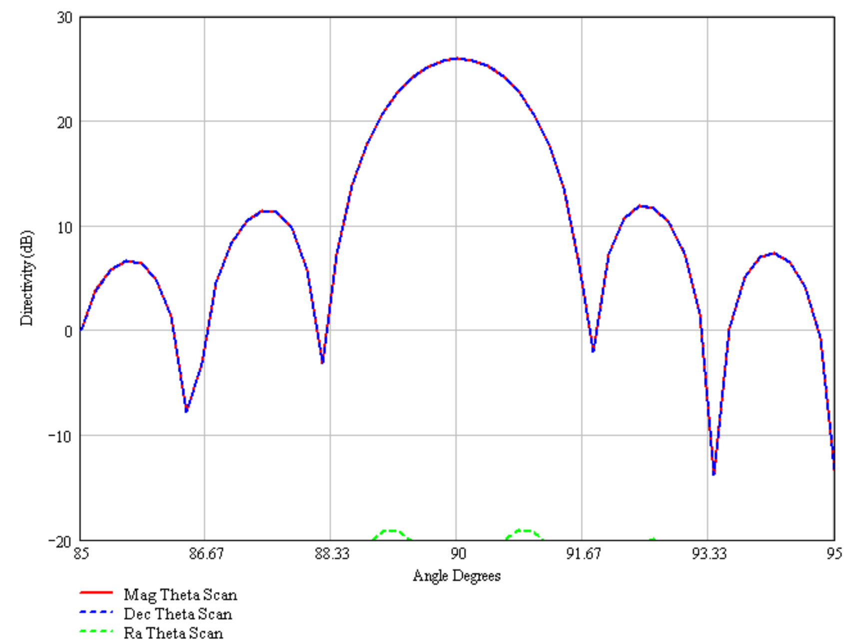
X-Polarization Results



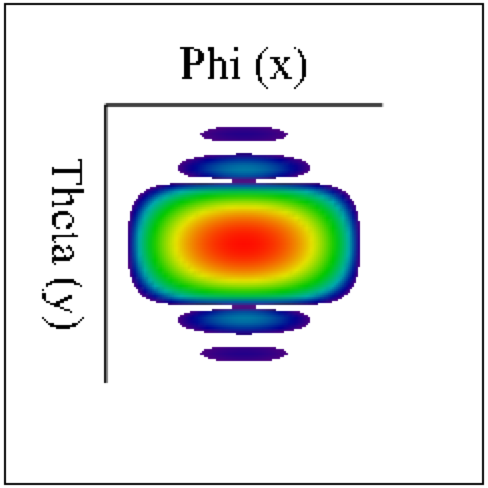
$$\frac{L_{em}}{\lambda} = 0.944$$



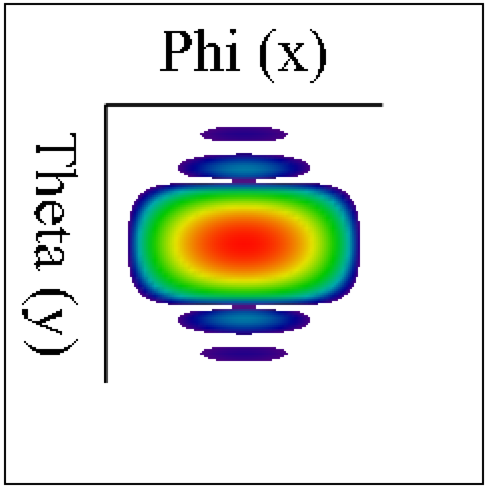




X Polarization (Full Width)



eMagLog



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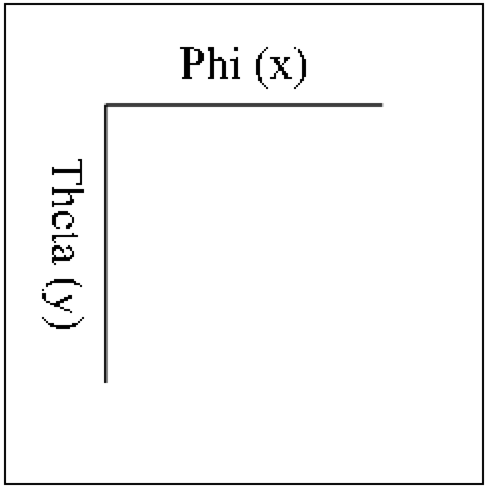

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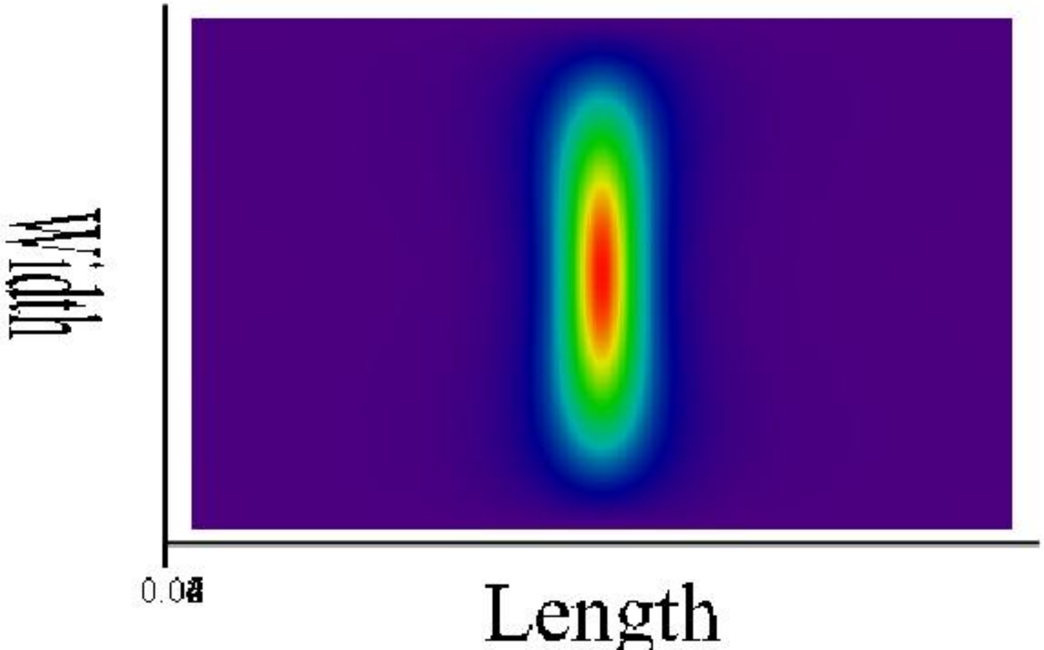
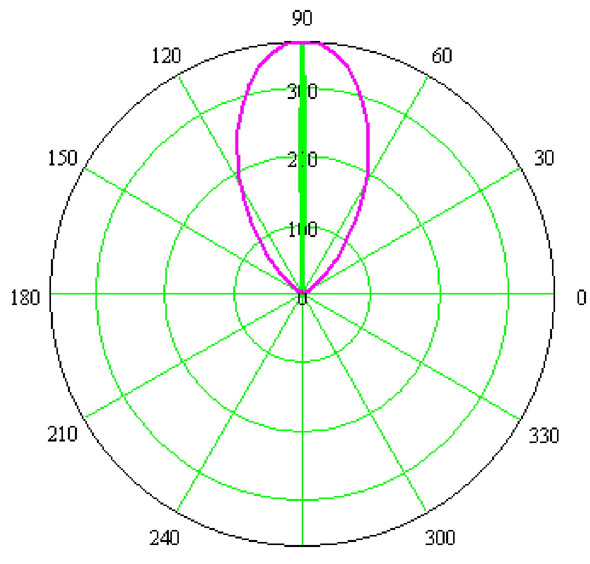
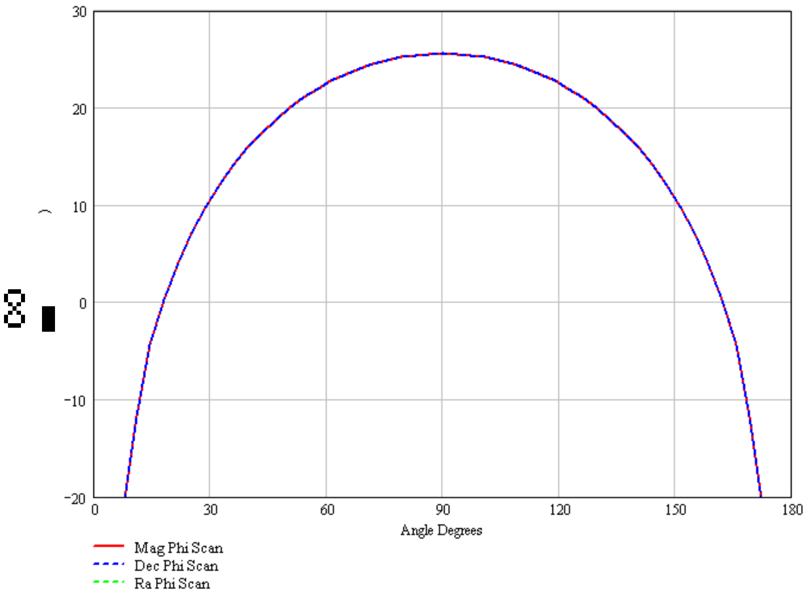
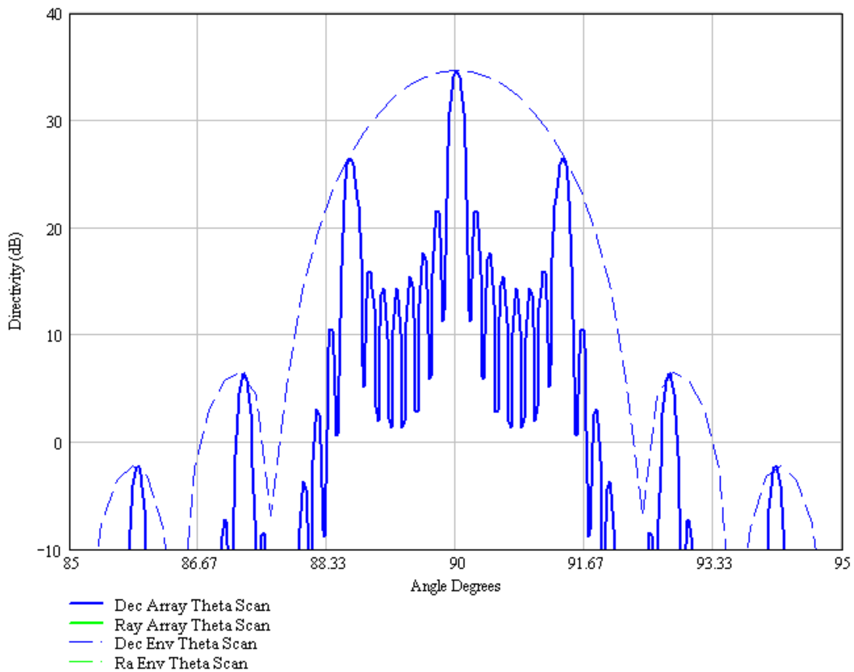


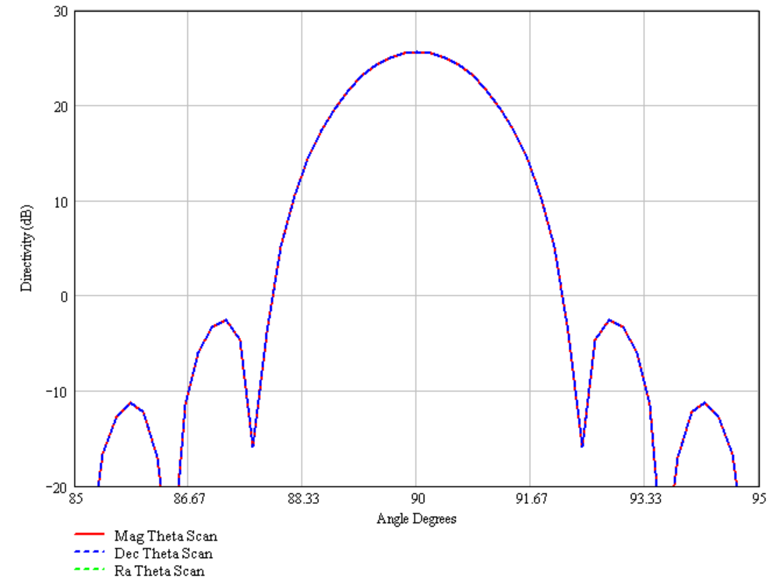
X Polarization (Full Width)



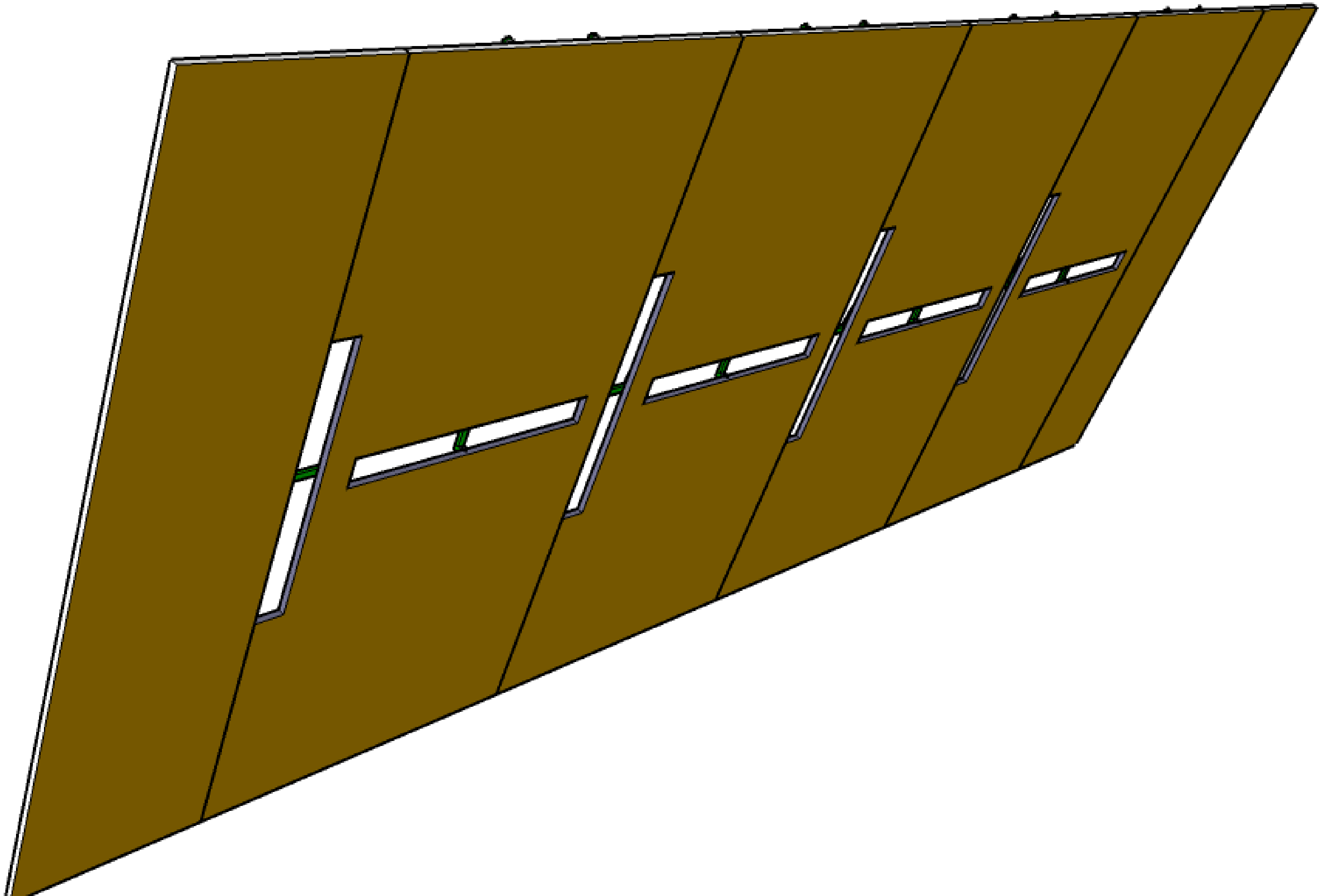
$$\frac{L_{em}}{\lambda} = 0.698$$



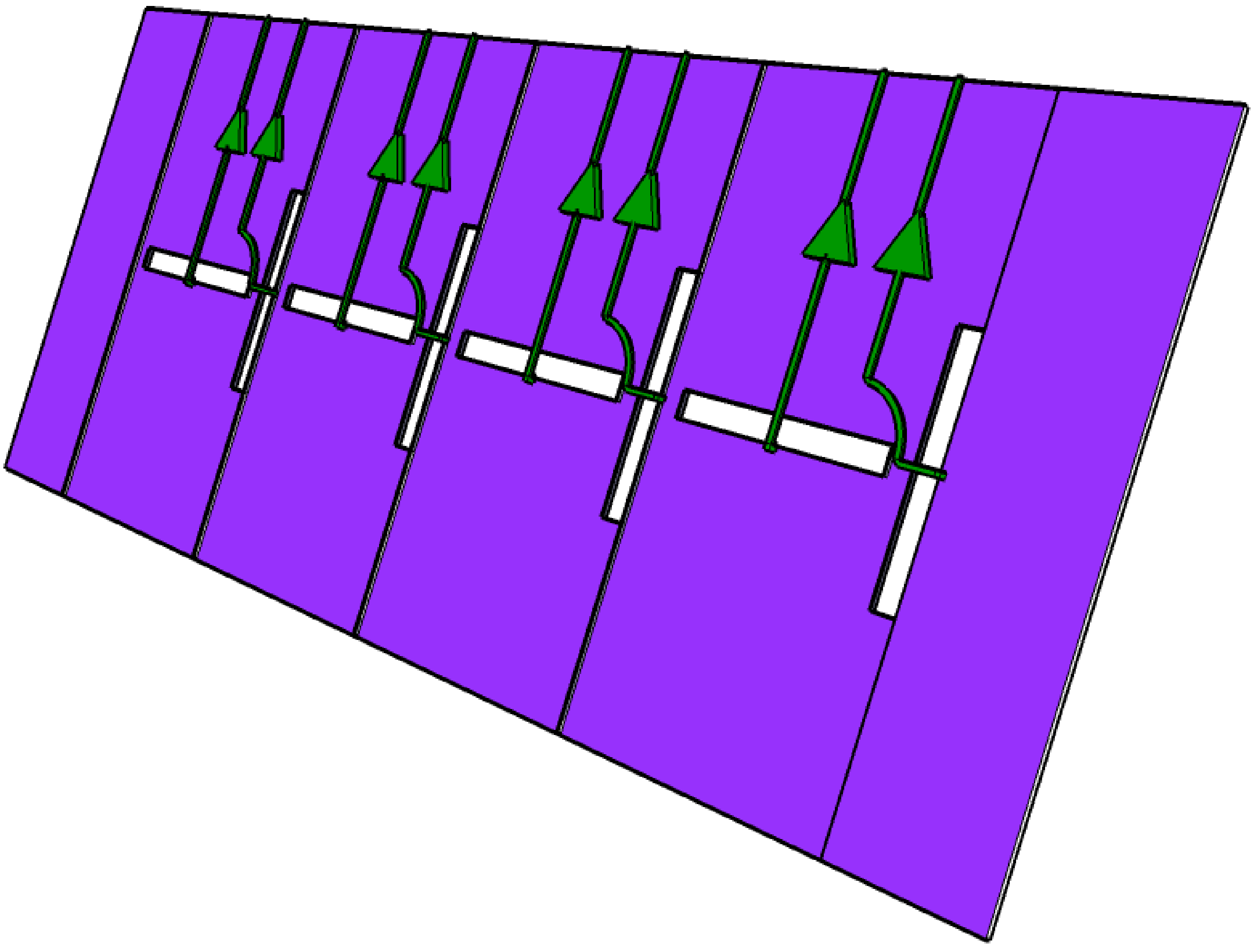




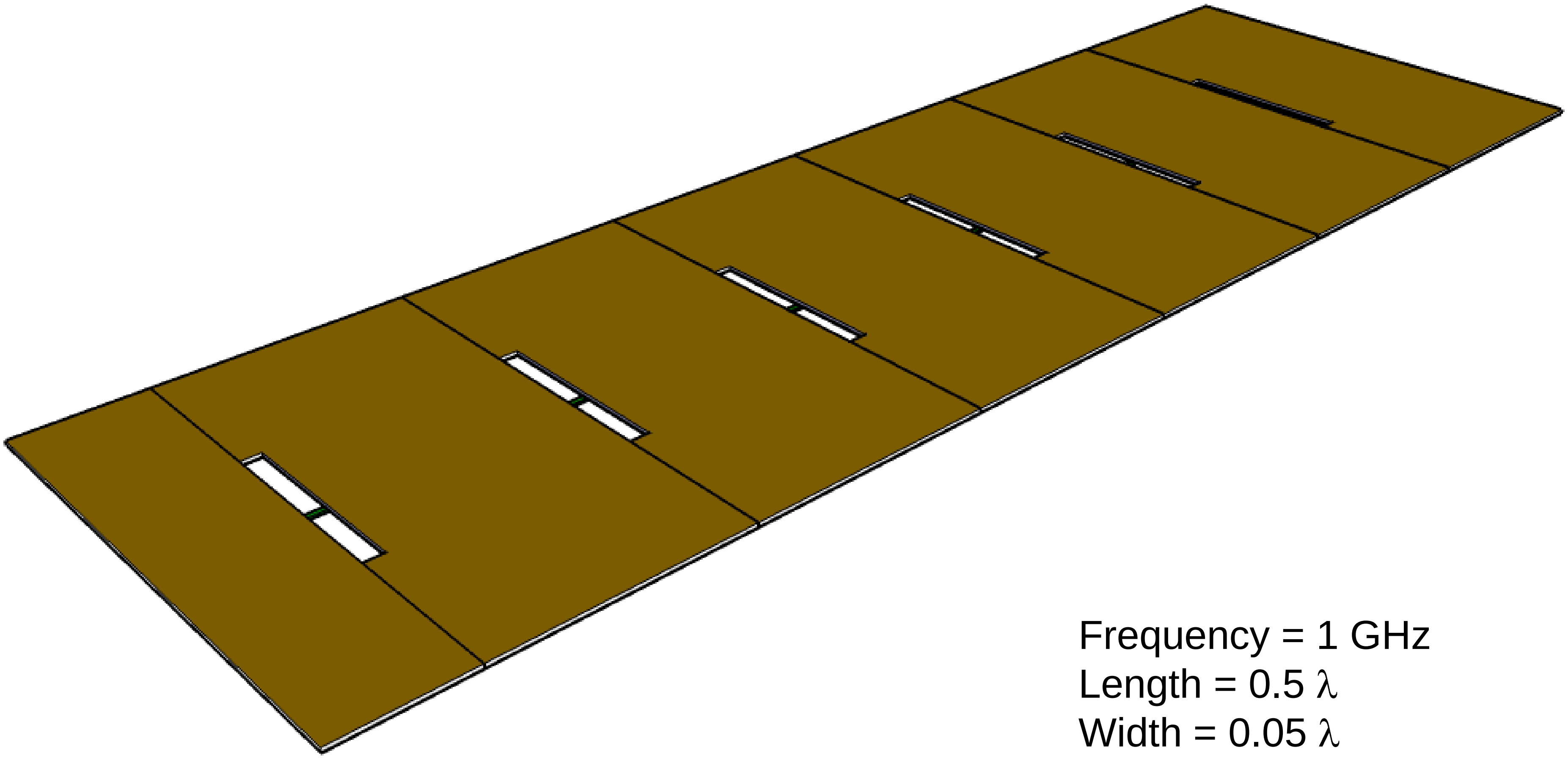
Slot Feeds



Slot Feeds

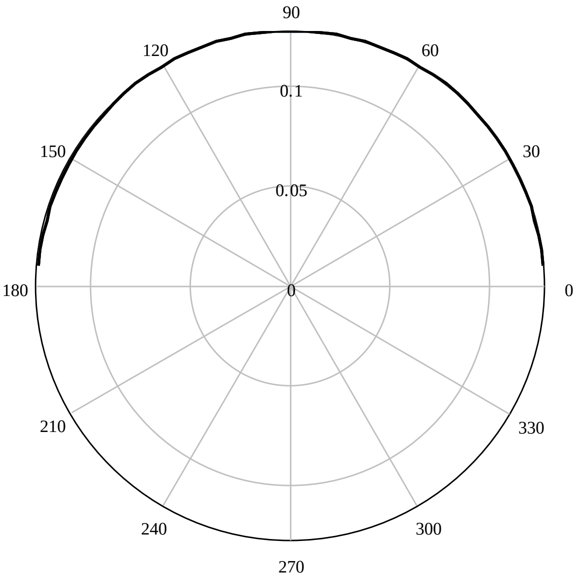


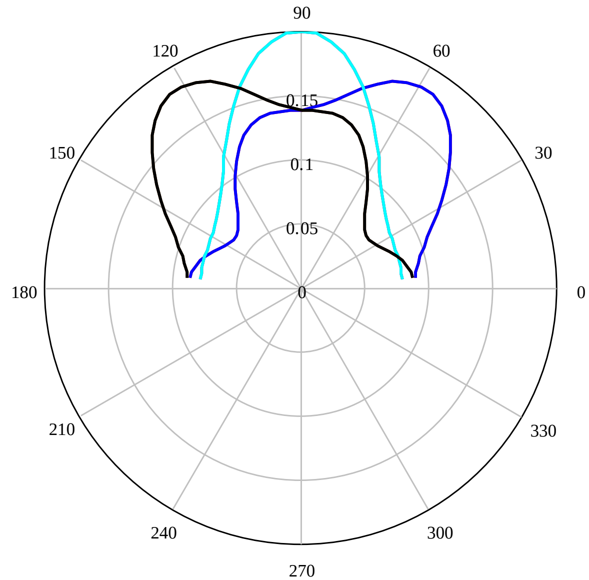
Broadside Coupling Simulation

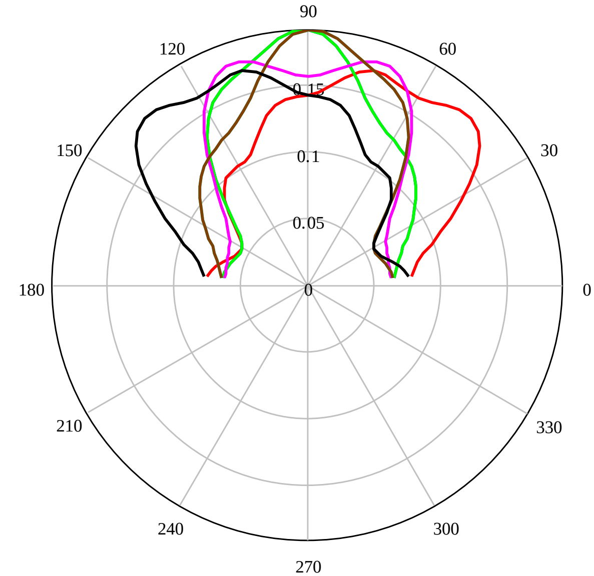


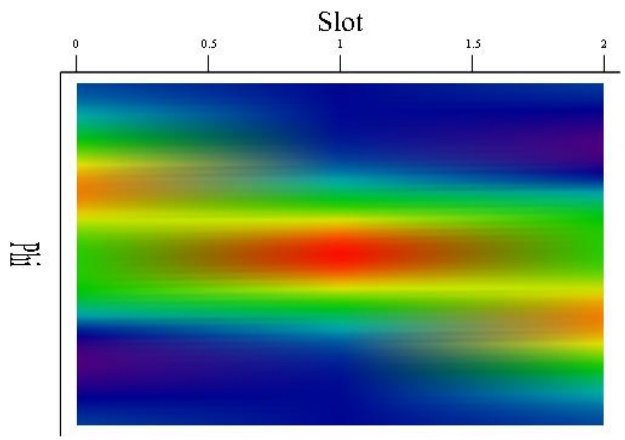
Frequency = 1 GHz
Length = 0.5 λ
Width = 0.05 λ
Spacing = 0.5 λ

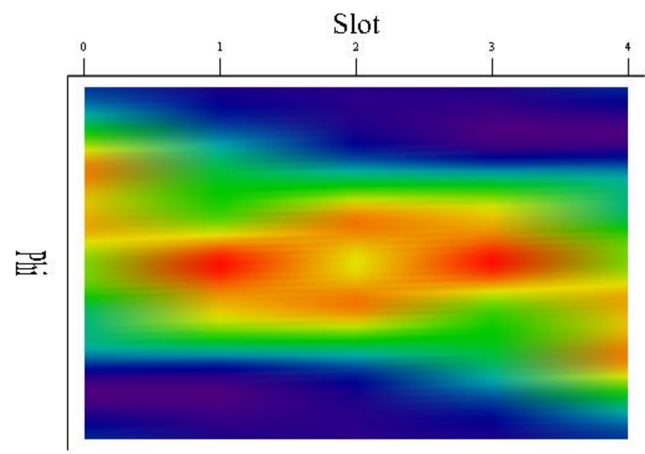
Simulated Array Pattern



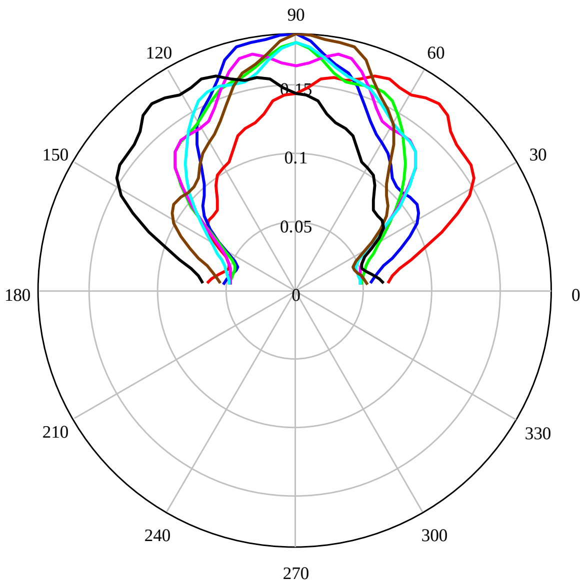


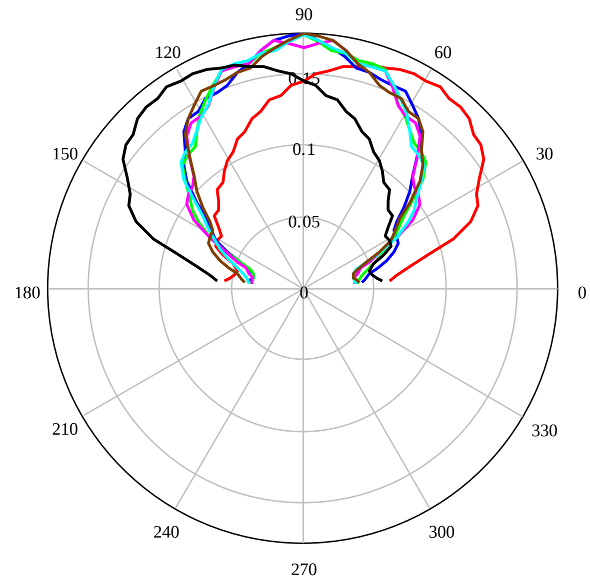


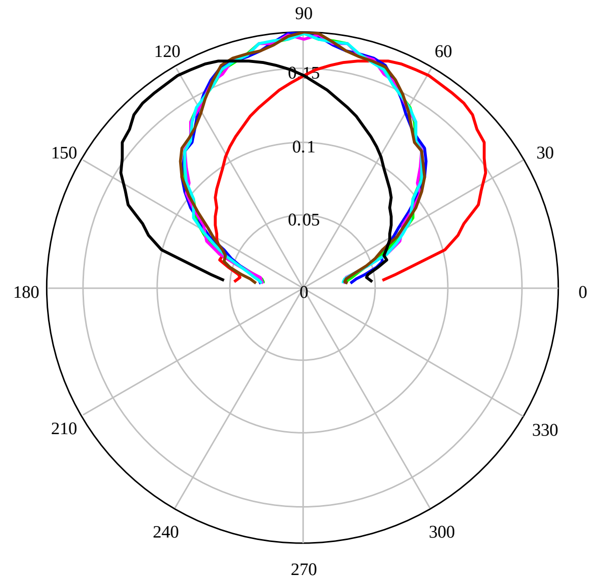


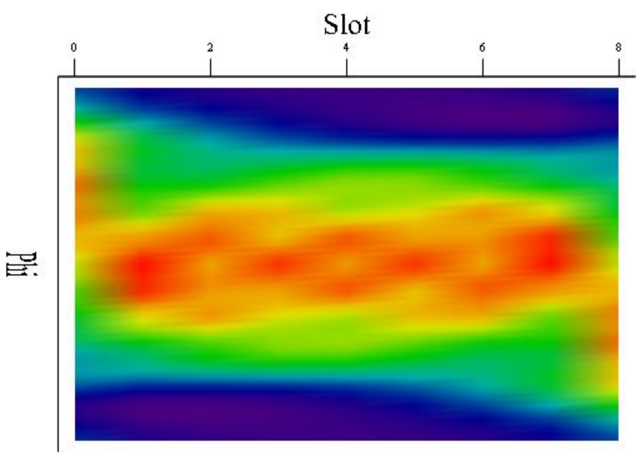


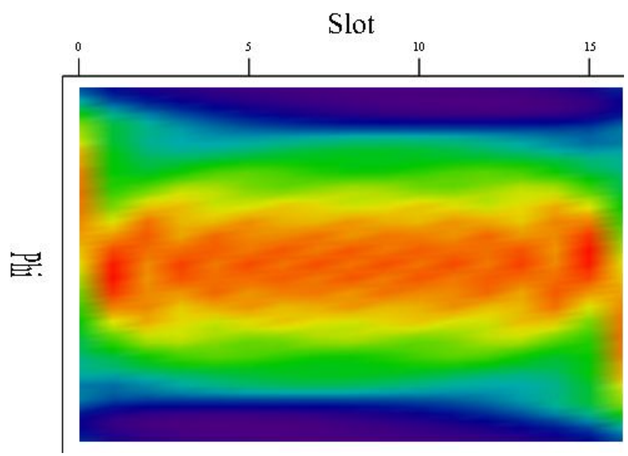
Simulated Array Pattern

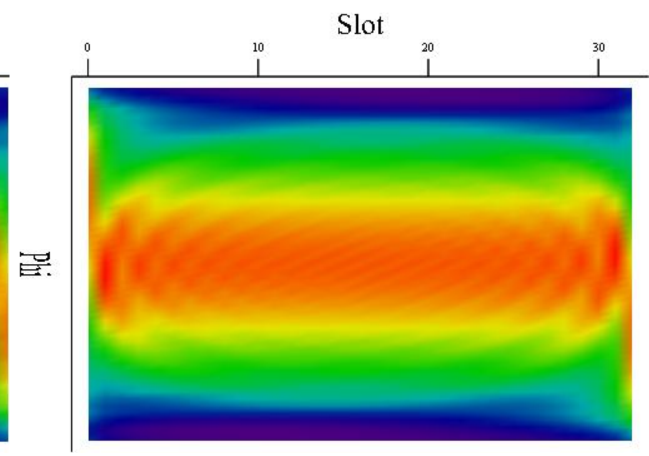




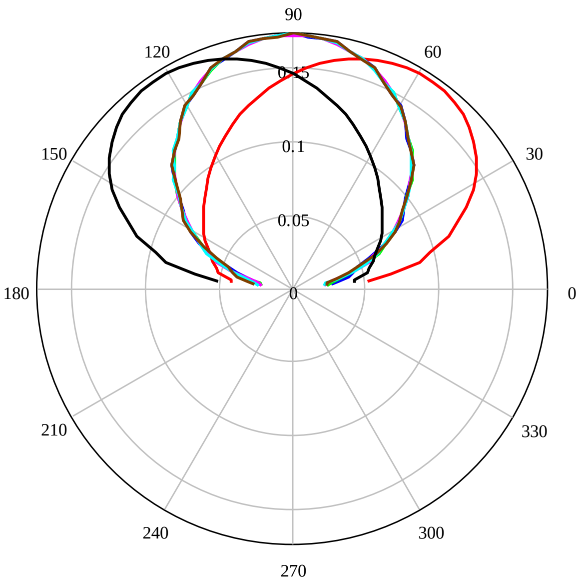


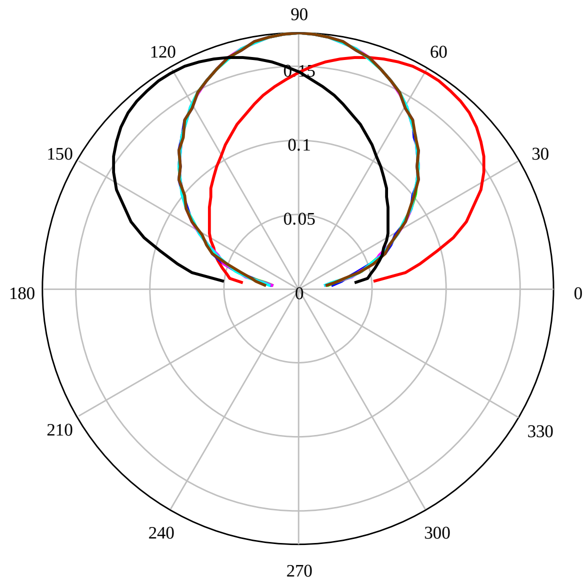


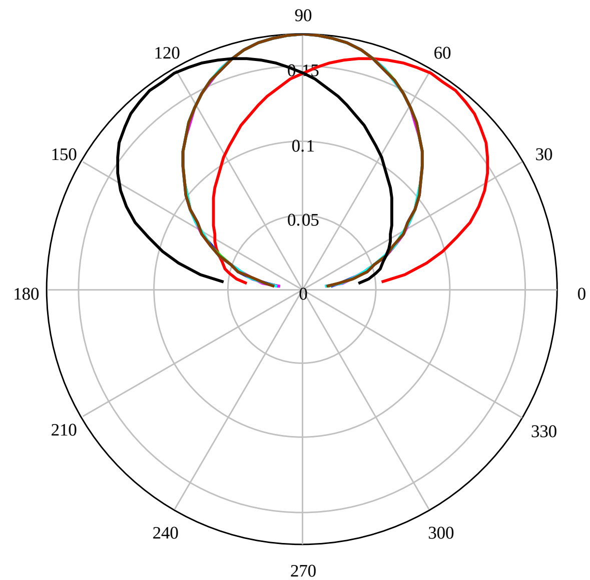


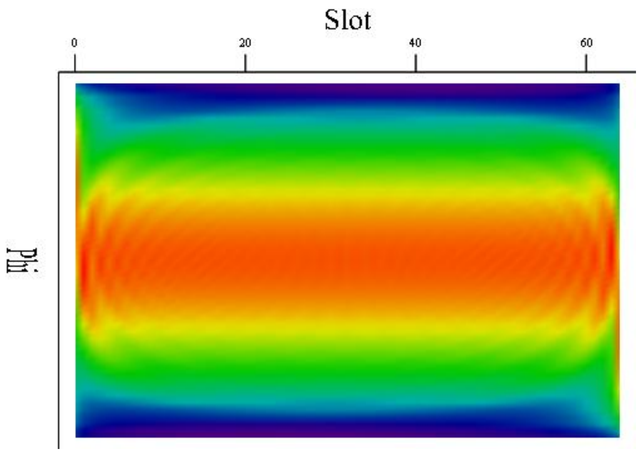


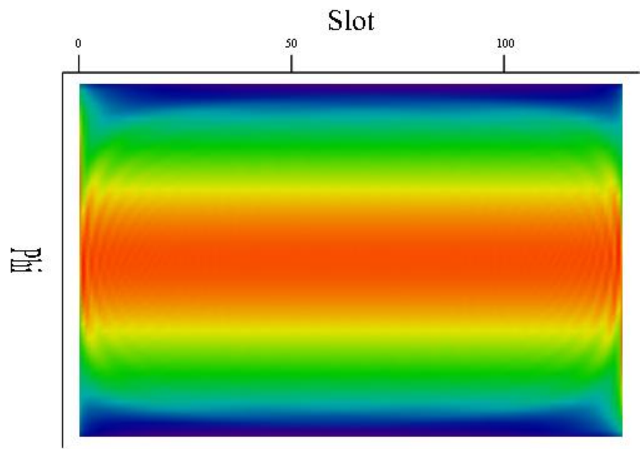
Simulated Array Pattern

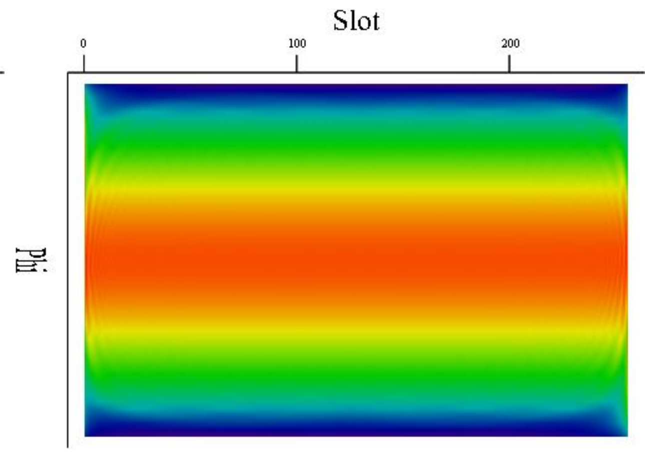












Future Work

- Moment Method simulations of slots
  - Add ground plane with dielectric to back side
  - Simulate x oriented slot
- Explore other slot designs
  - Square patch antenna
  - Folded dipole