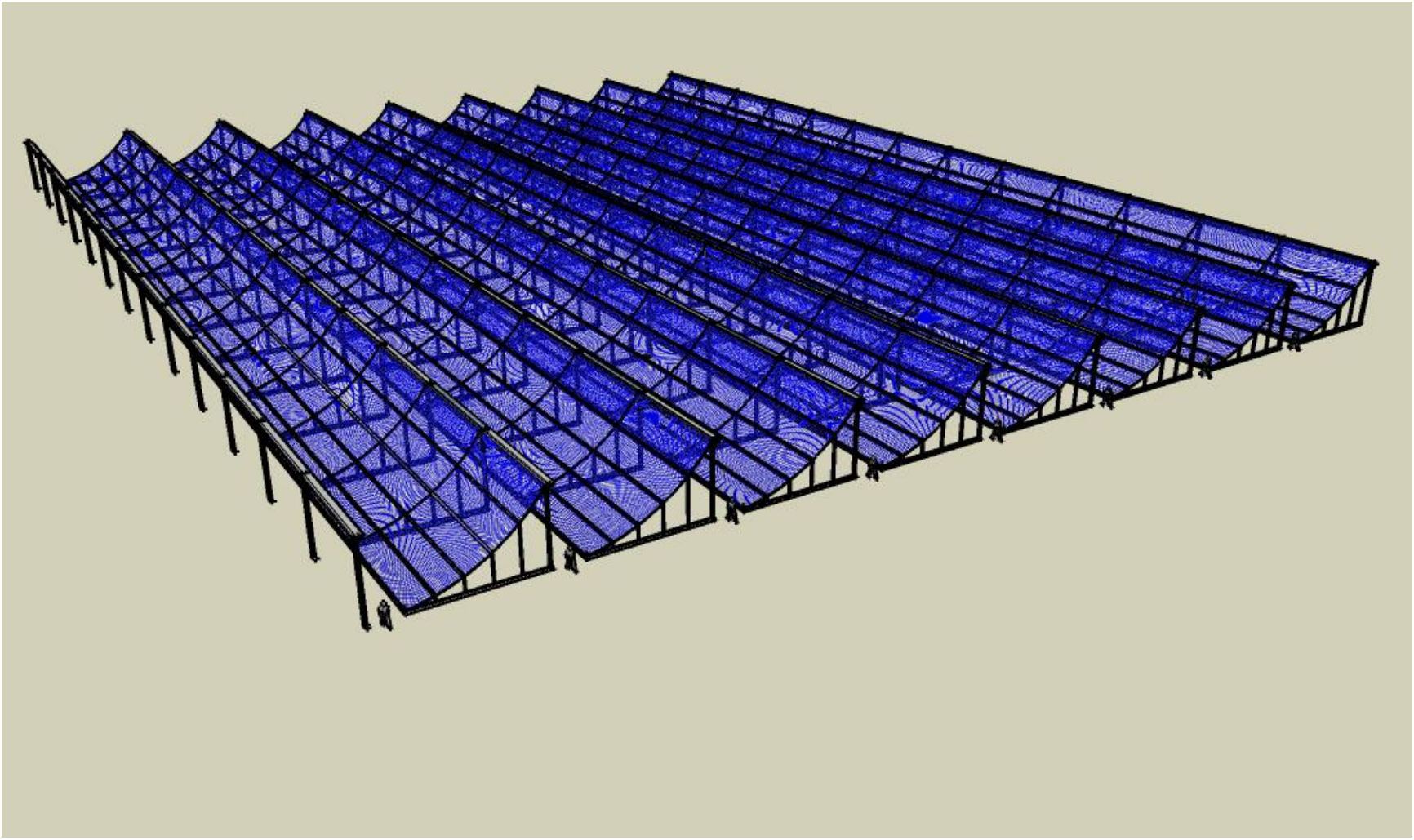
Parabolic Cylinder Analysis

Dave McGinnis
Fermilab
October 3, 2008

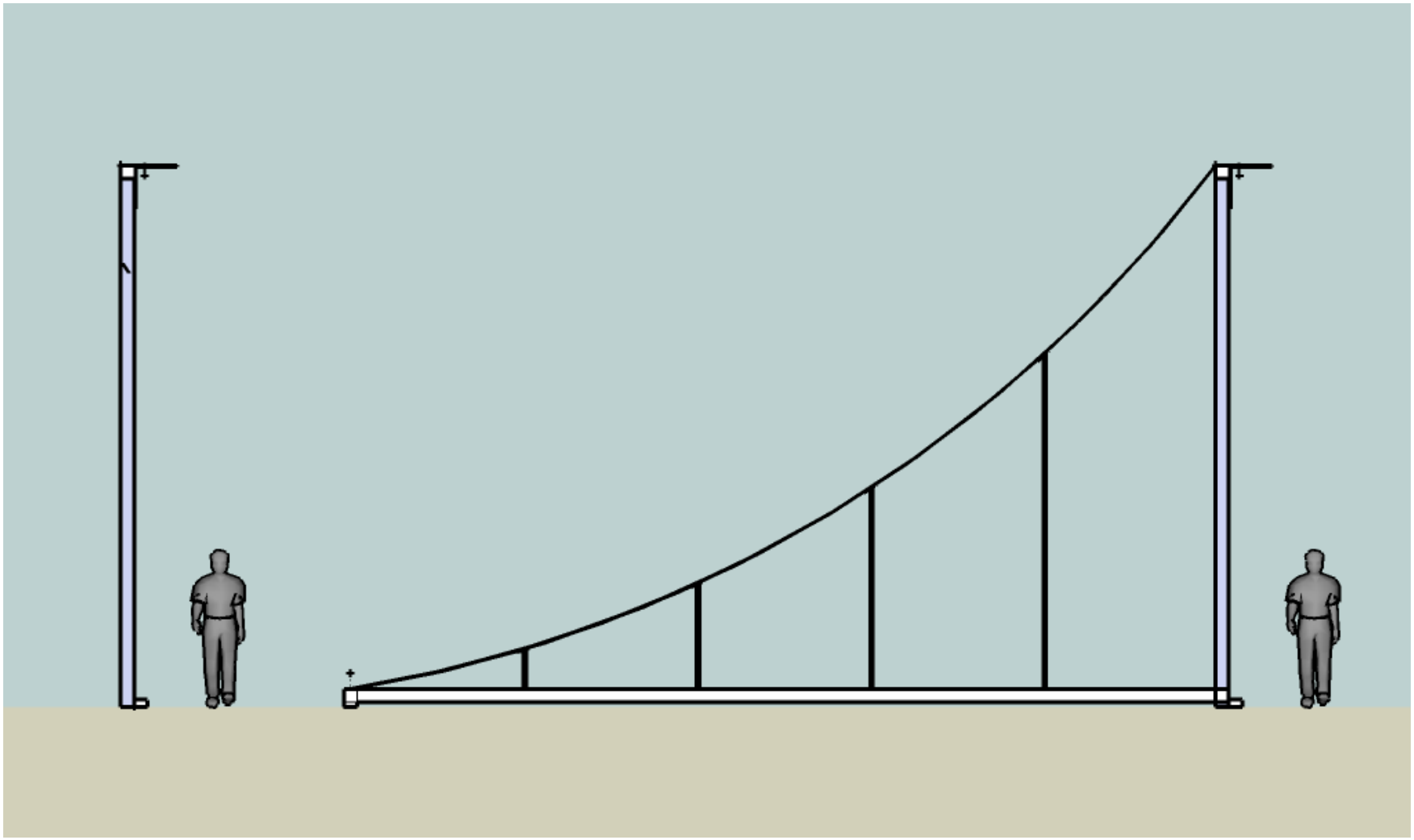
Design Parameters

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

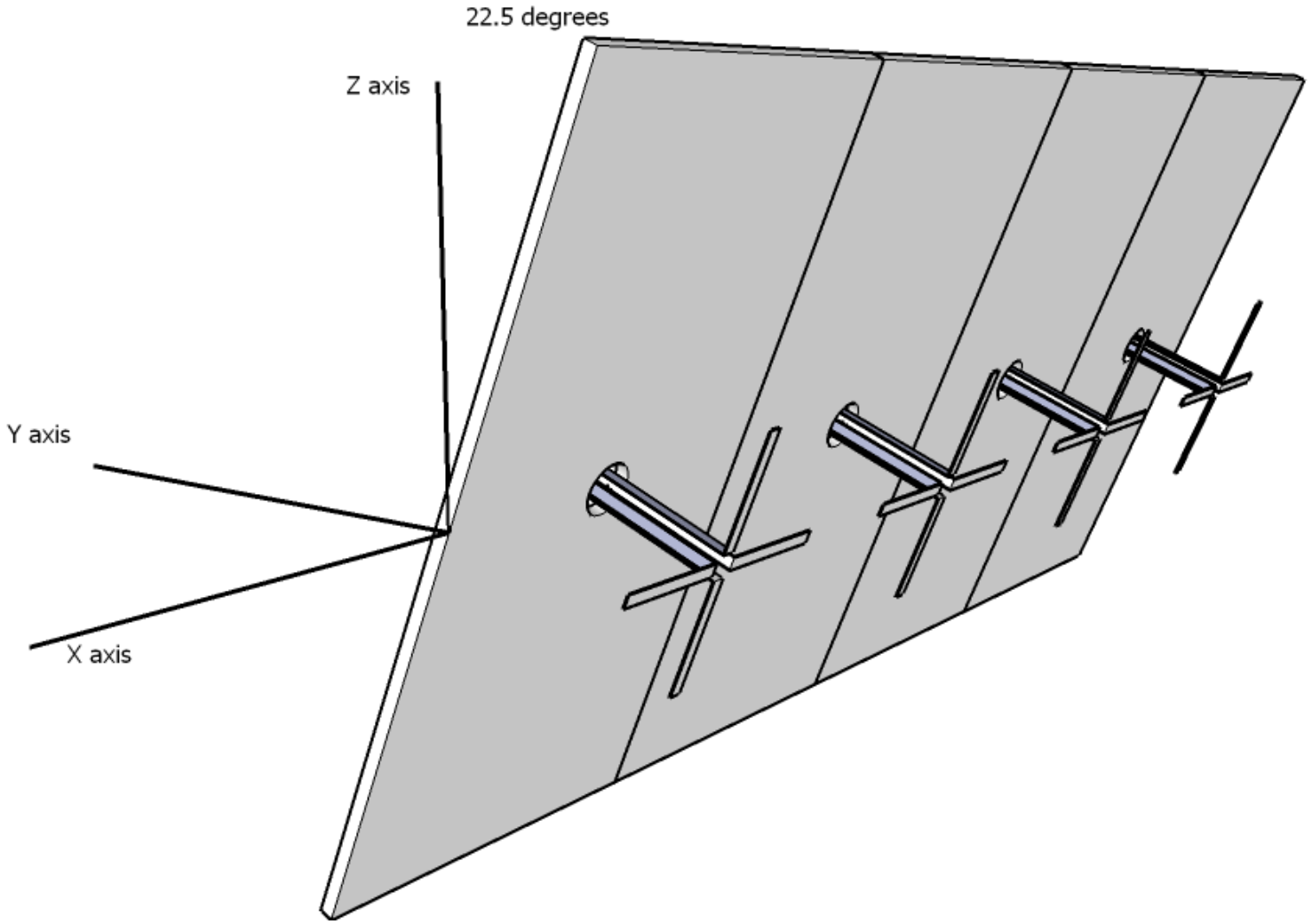
Telescope Layout



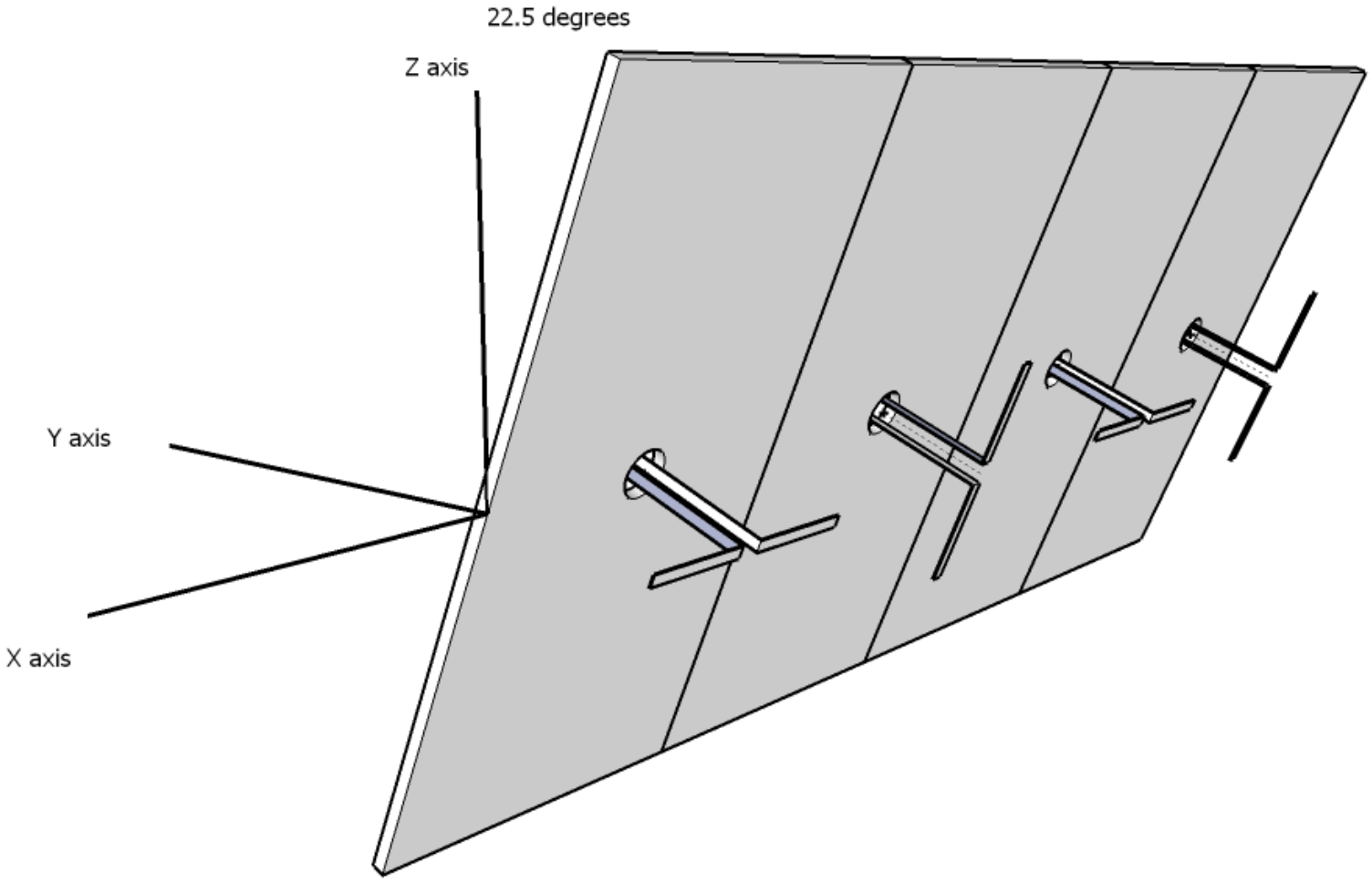
Cylinder Cross-Section



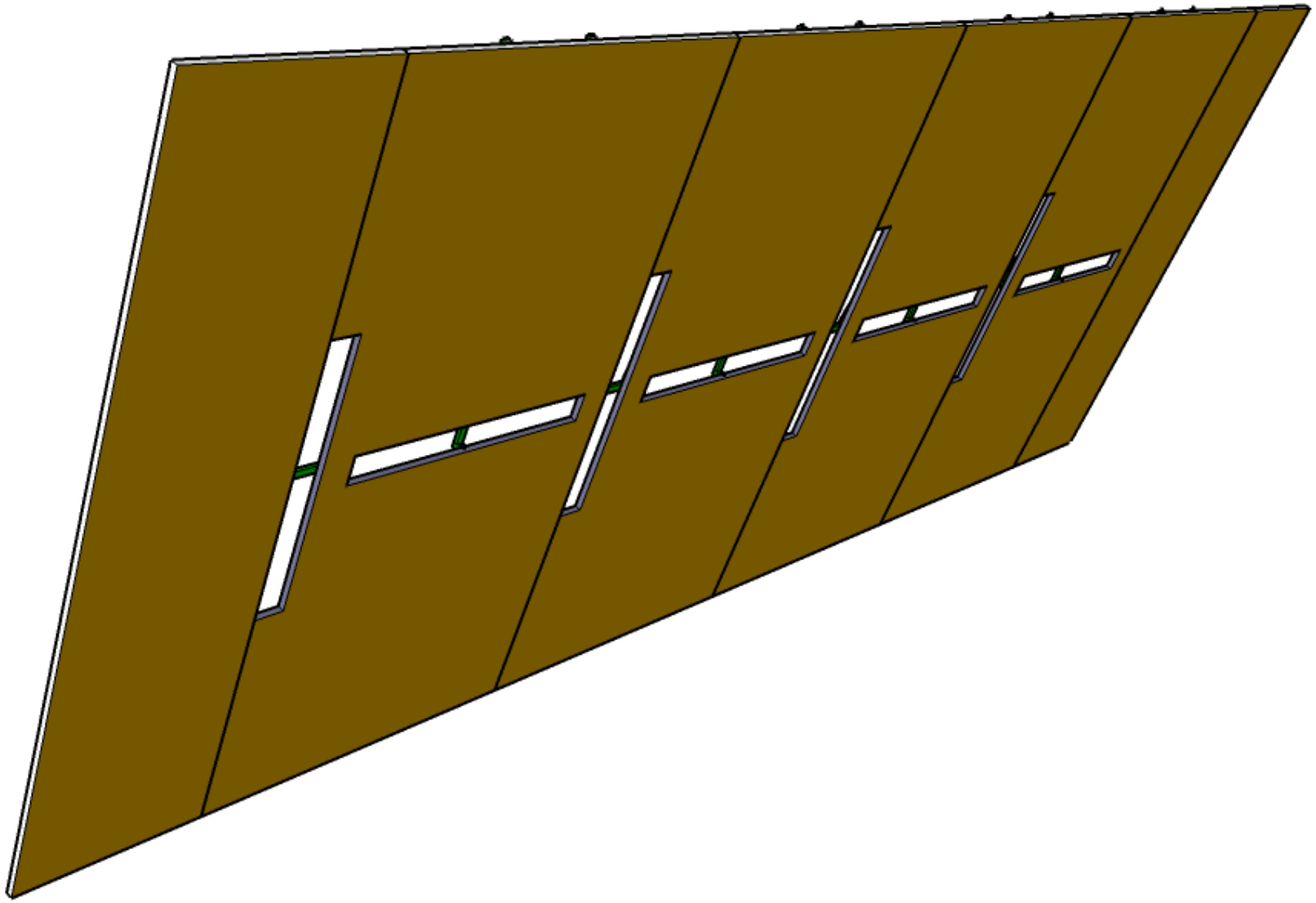
Simple Telescope Feed (first attempt)



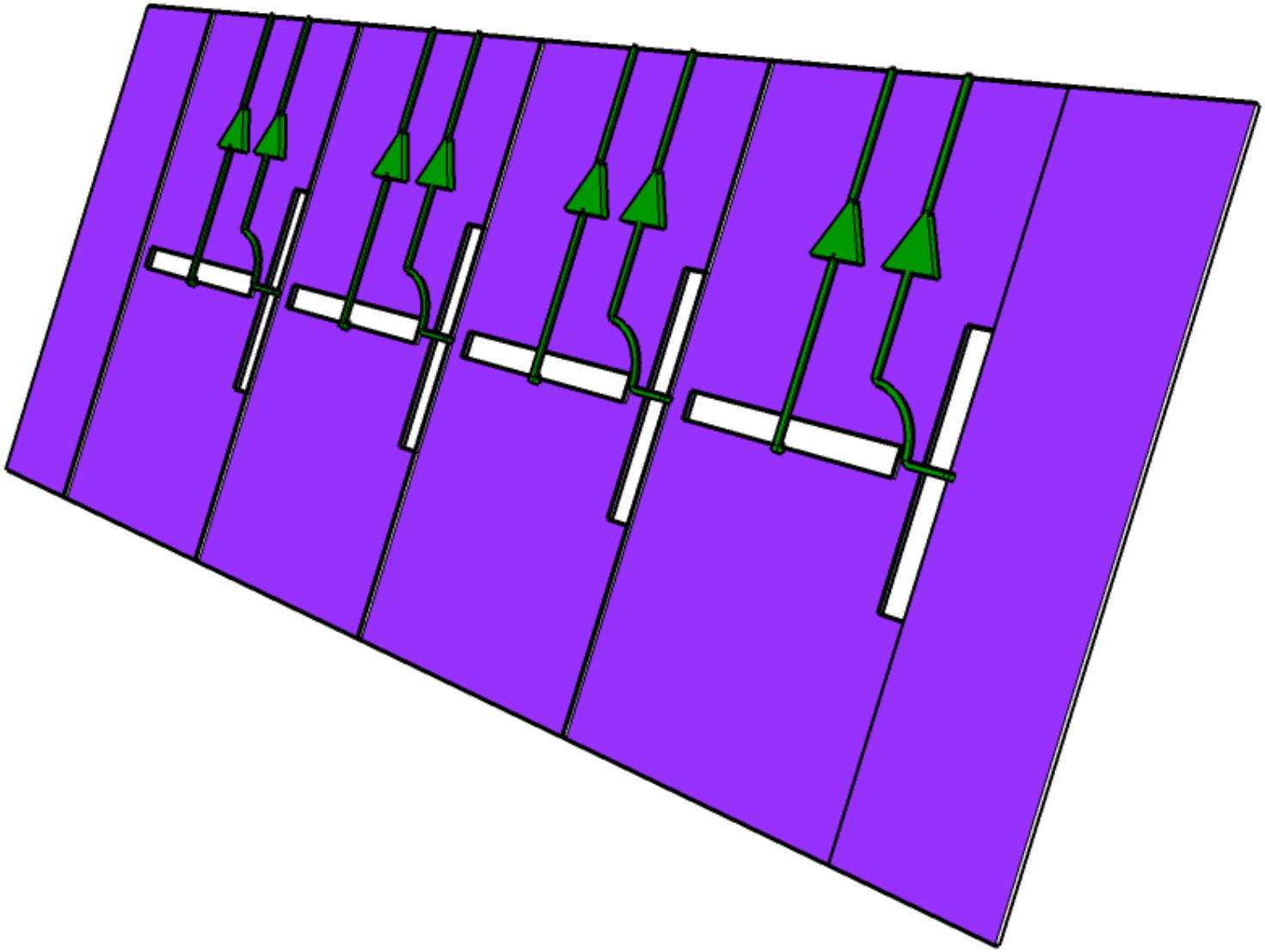
Alternating Telescope Feed



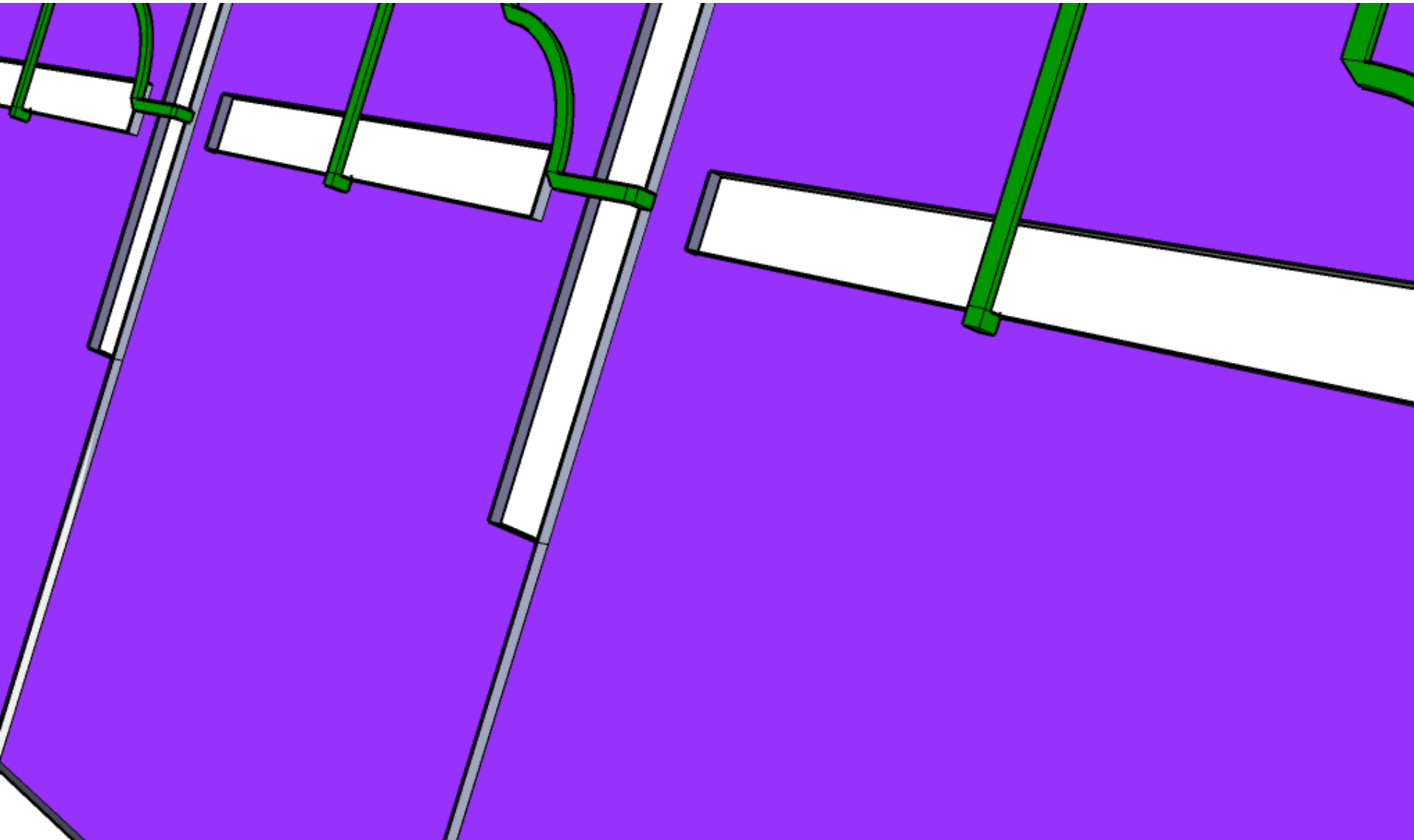
Slot Feeds



Slot Feeds



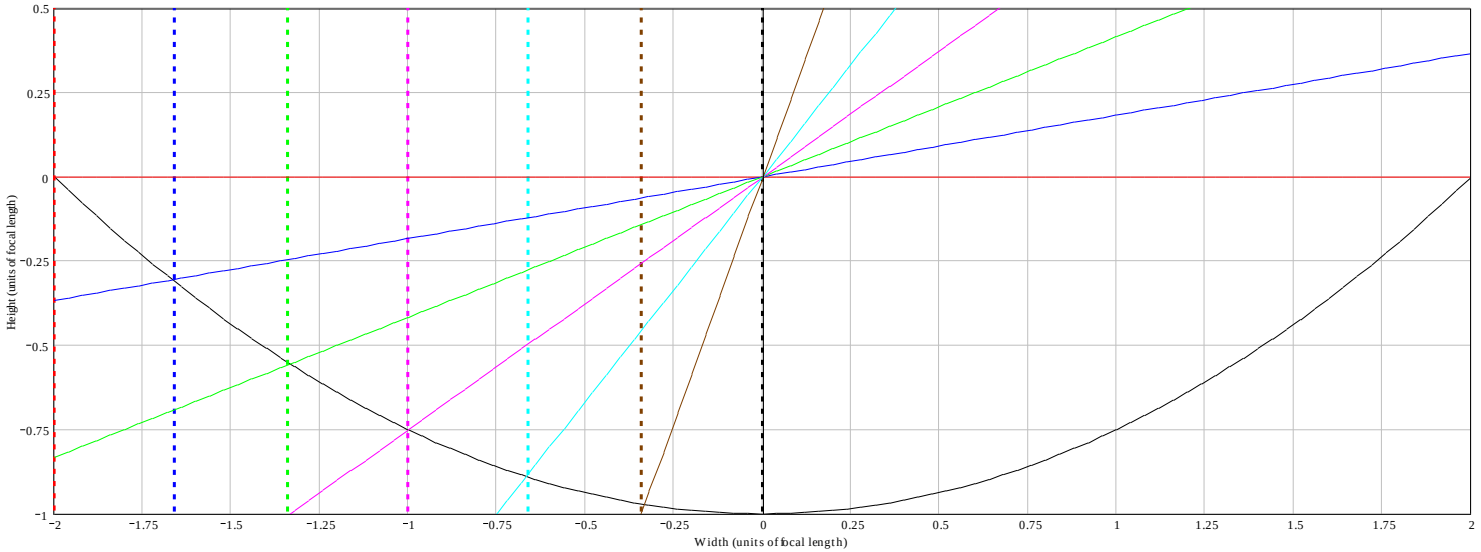
Slot Feeds

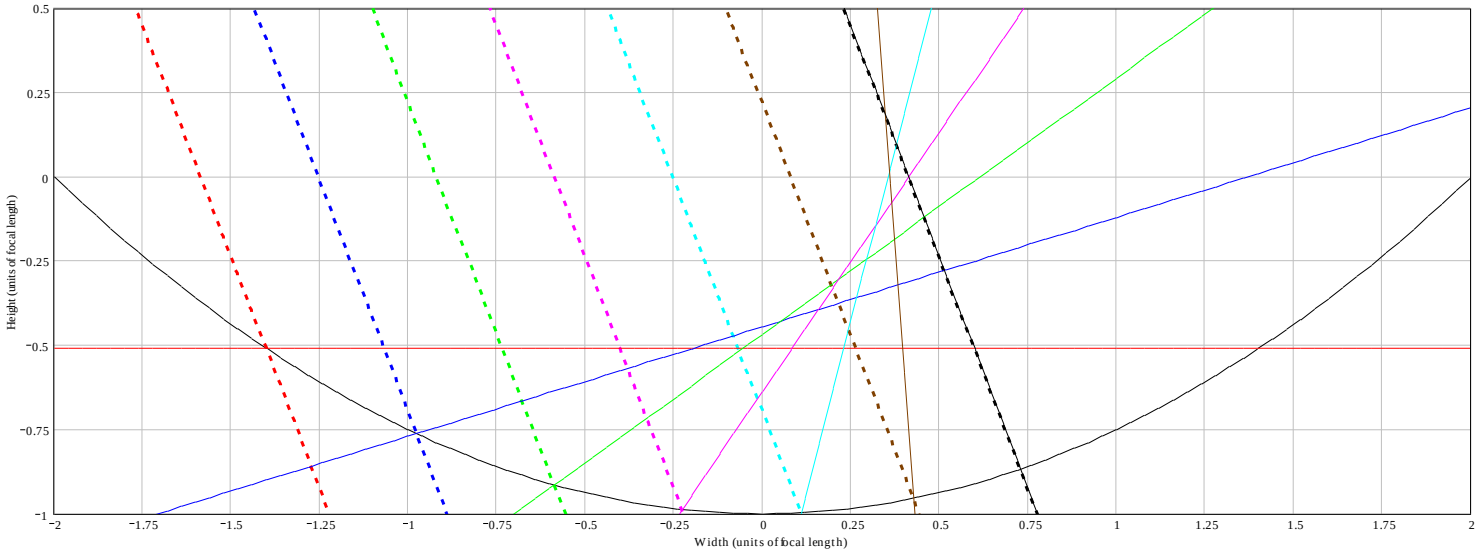


Offset-Fed Telescope

- 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

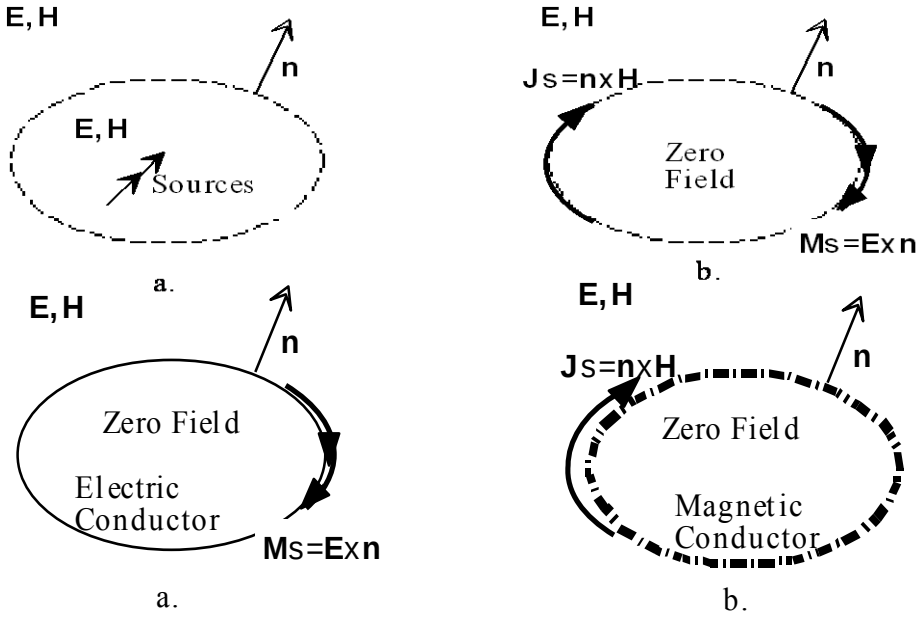


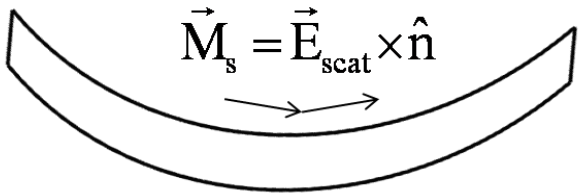


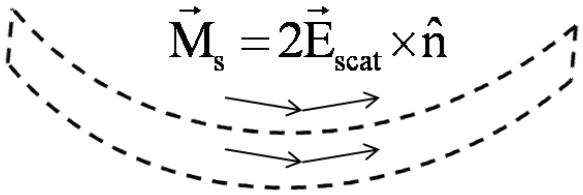
Cylinder Simulations

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

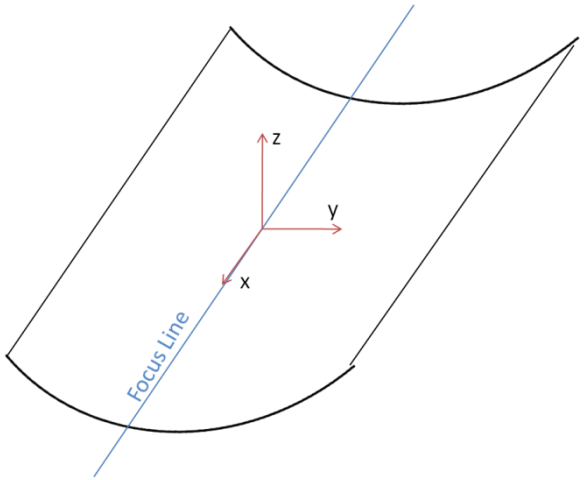
Physical Optics Approximation





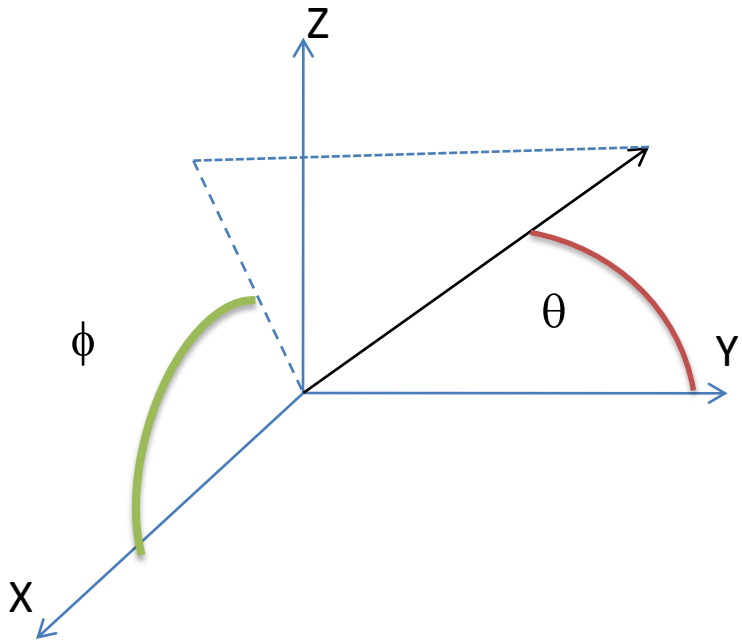


Telescope Coordinate System

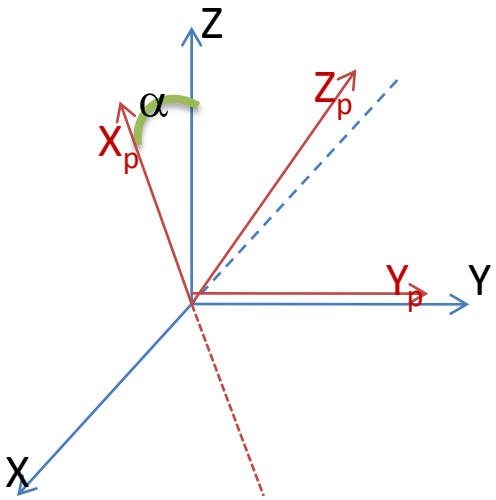


$$D(\phi,\theta) = \frac{U(\phi,\theta)}{\frac{1}{4\pi}\iint U(\phi,\theta)\sin(\theta)\,d\theta\,d\phi}$$

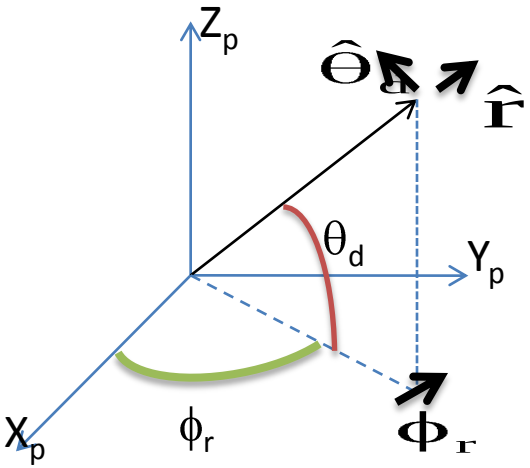
$$U(\phi,\theta) = \frac{1}{2}\,\mathrm{Re}\left\{\vec{E}\times\vec{H}^{*}\right\}\cdot\hat{r}R^{2}$$



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_r

$$\widehat{\theta_d} = \begin{matrix} -\left(\sin(\alpha)\sin(\theta_d)\cos(\phi_r) + \cos(\alpha)\cos(\theta_d)\right)\hat{x} \\ +\left(\sin(\theta_d)\sin(\phi_r)\right)\hat{y} \\ +\left(-\cos(\alpha)\sin(\theta_d)\cos(\phi_r) + \sin(\alpha)\cos(\theta_d)\right)\hat{z} \end{matrix}$$

$$\widehat{\phi_r} = \begin{matrix} -\left(\sin(\alpha)\sin(\phi_r)\right)\hat{x} \\ +\left(\cos(\phi_r)\right)\hat{y} \\ -\left(\cos(\alpha)\sin(\phi_r)\right)\hat{z} \end{matrix}$$

Directivity

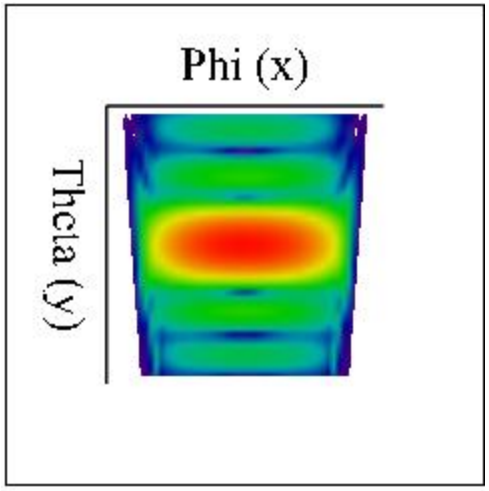
$$D(\phi,\theta) = \frac{U(\phi,\theta)}{\frac{1}{4\pi}\iint U(\phi,\theta)\sin(\theta)\,d\theta\,d\phi}$$

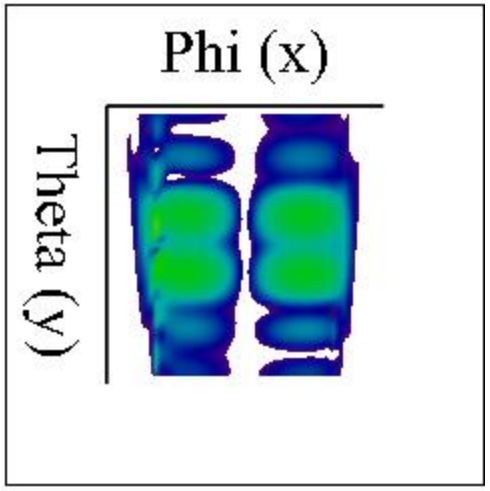
$$\Omega_A = \frac{4\pi}{D_{max}}$$

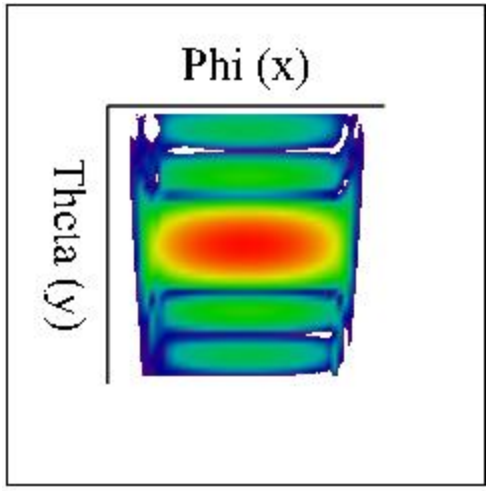
$$A_{em} = \frac{\lambda^2}{\Omega_A}$$

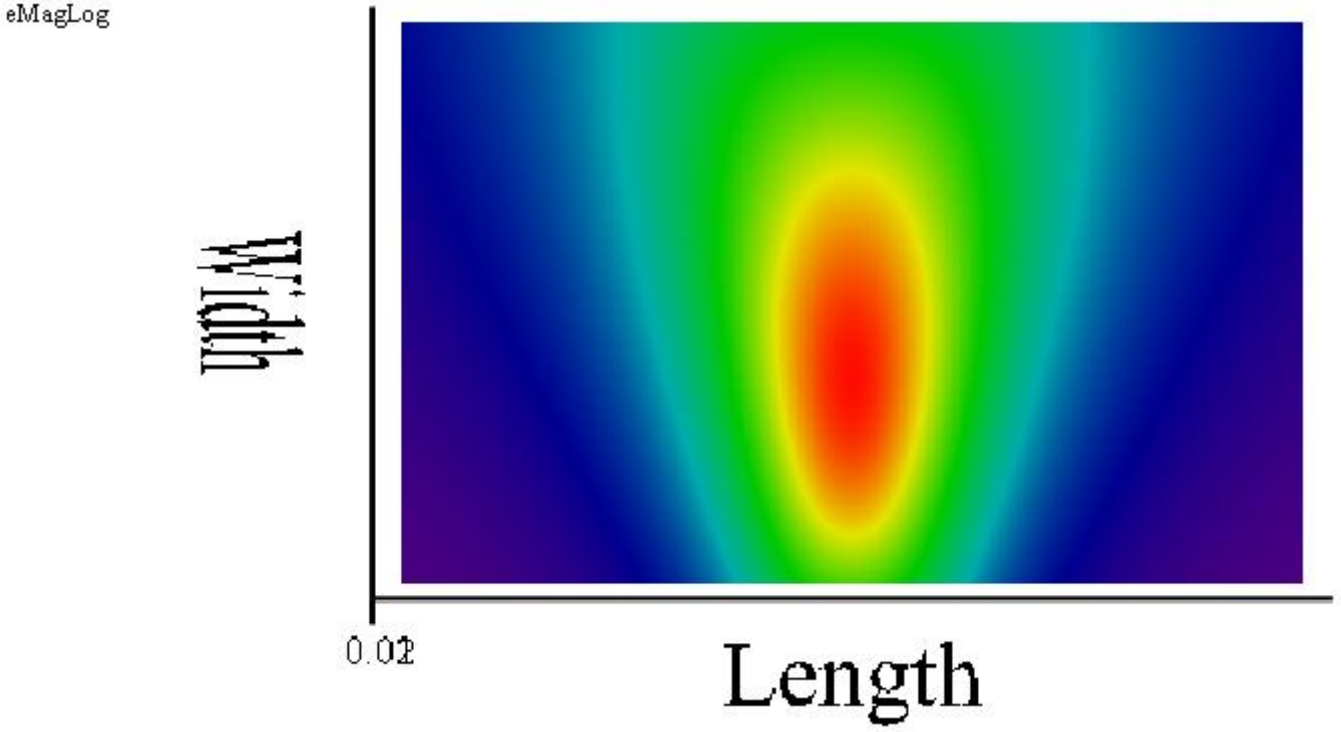
$$L_{em} = \frac{A_{em}}{W}$$

Y-Z Polarization Results

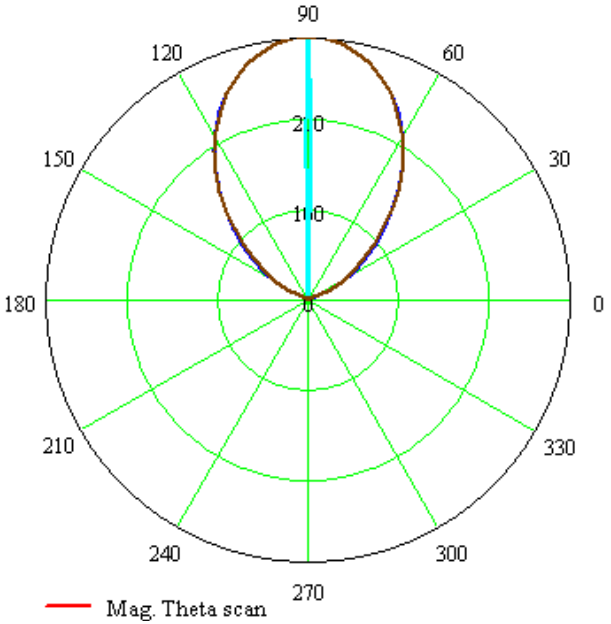




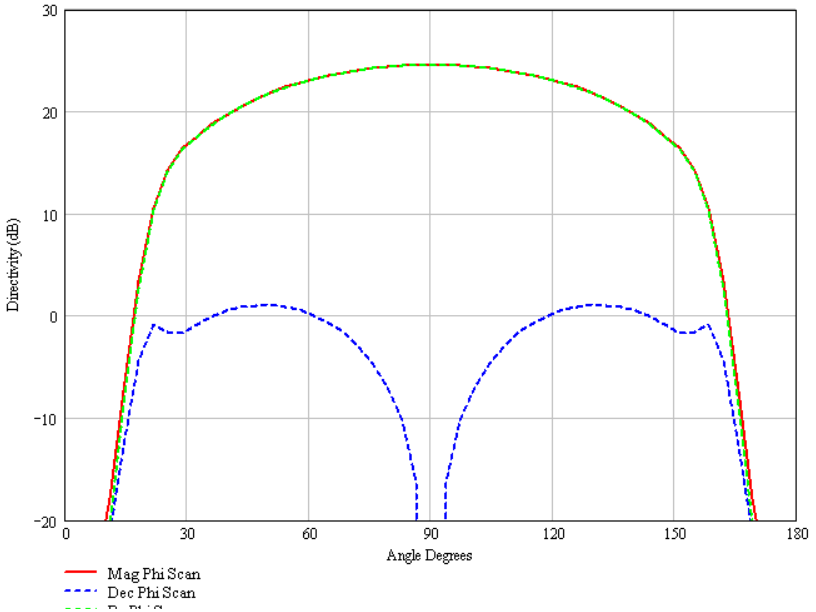


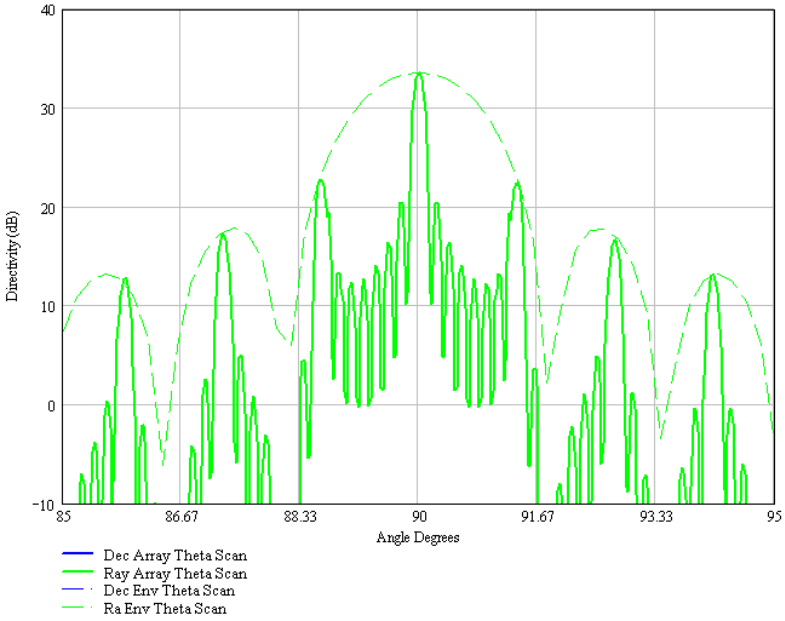


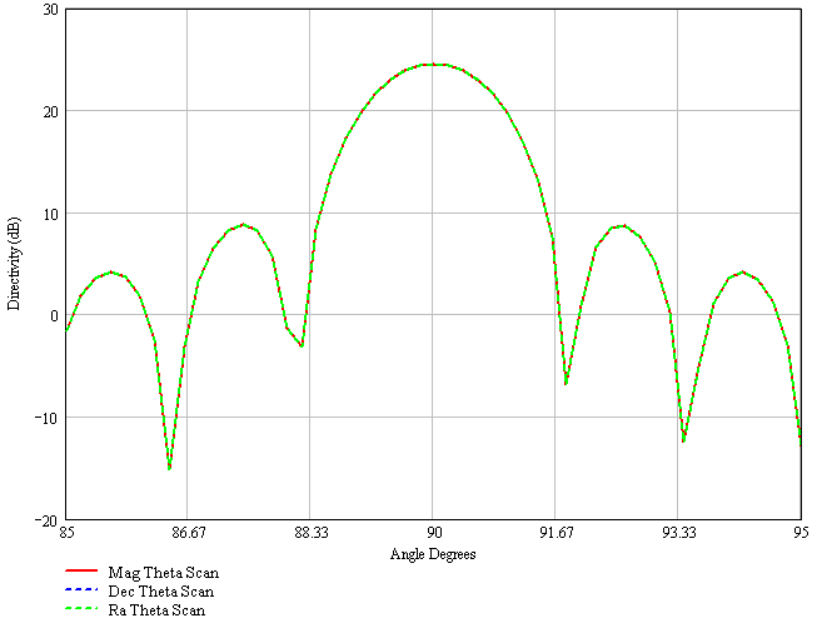
Y-Z Polarization Results



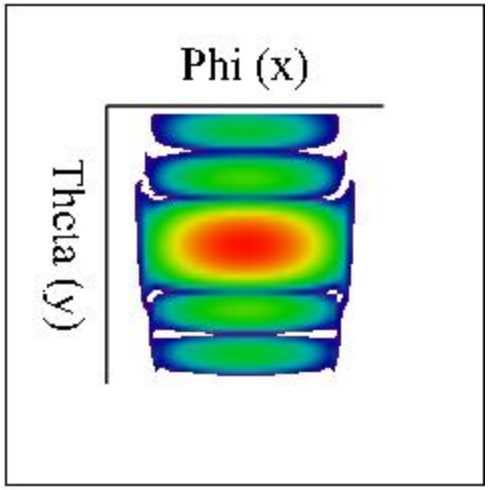
$$\frac{L_{em}}{\lambda} = 0.687$$



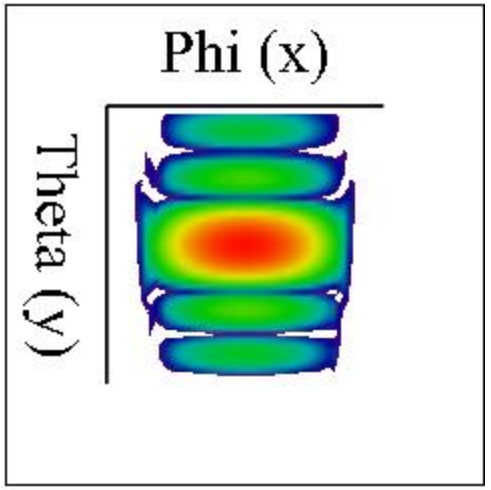




X-Polarization Results



eMagLog



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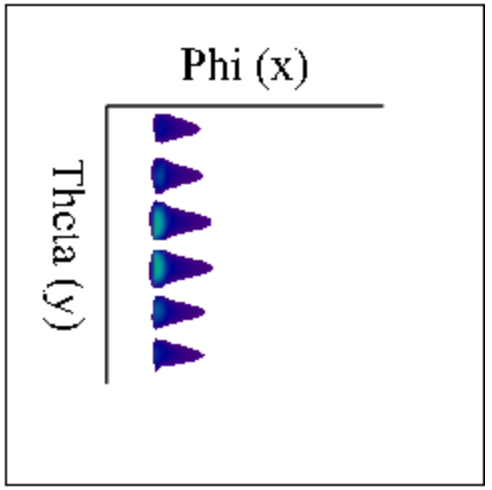

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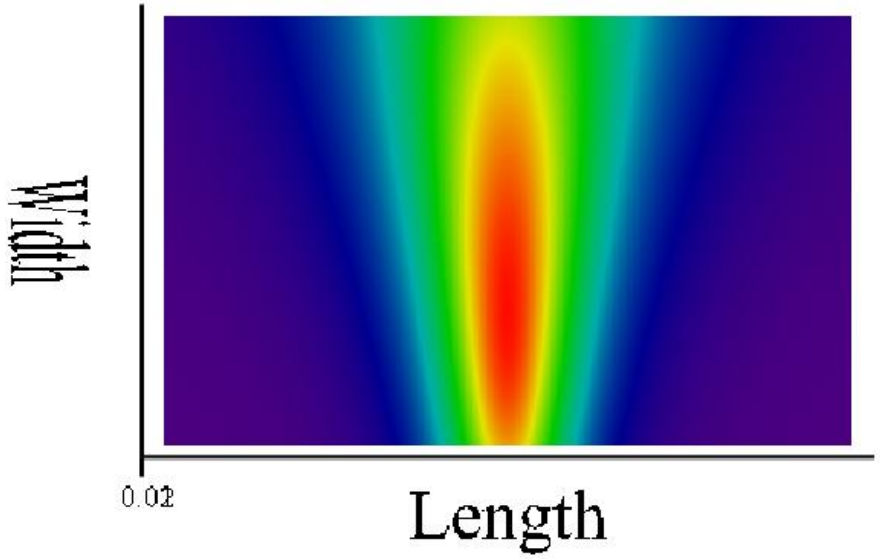
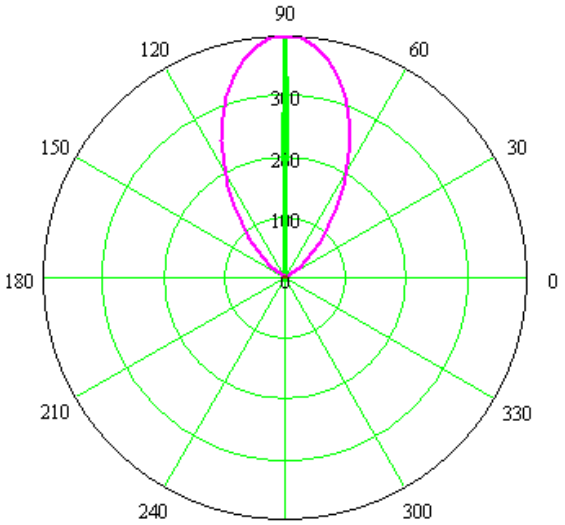
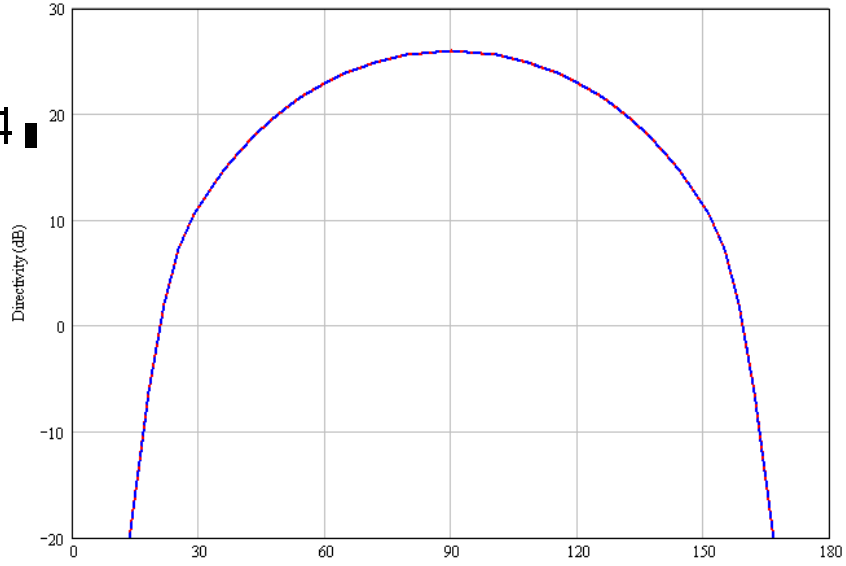
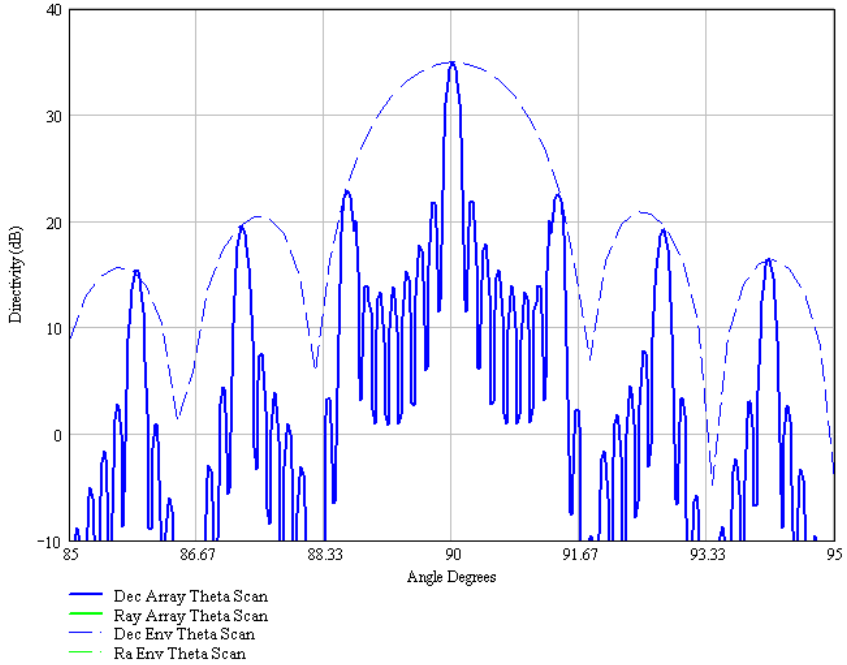


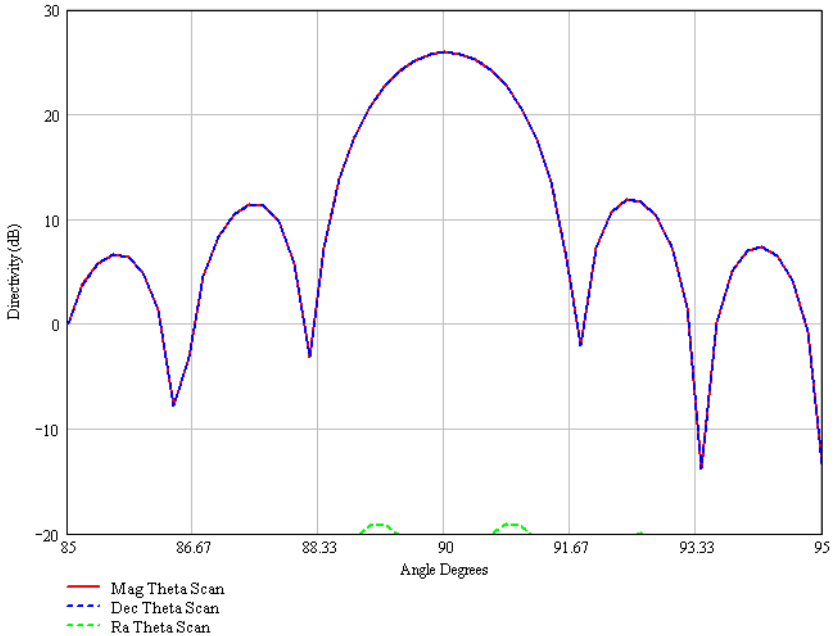
X-Polarization Results



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



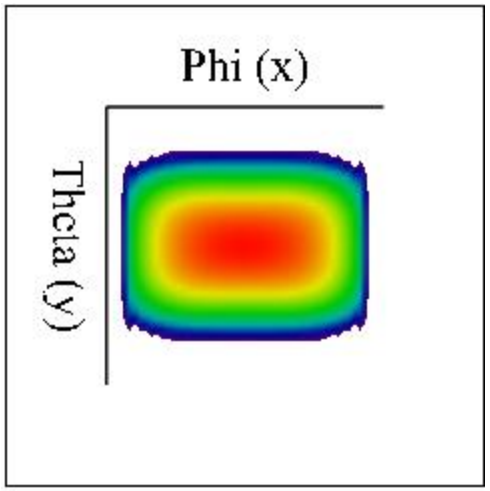




Future Work

- Explore other feed designs
  - Square patch antenna
  - Folded dipole
- Moment Method simulation of feed to understand coupling
- Explore larger f-ratio

Y Polarization (Full Width)



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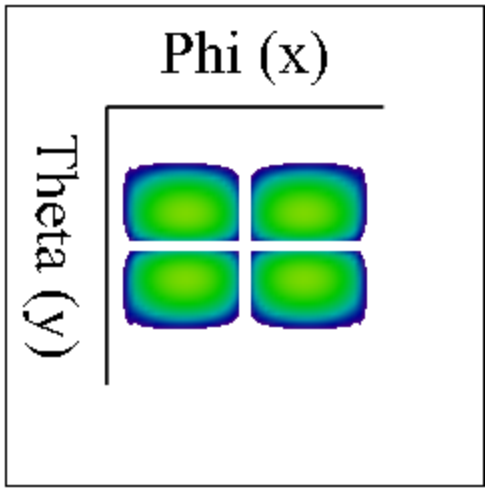

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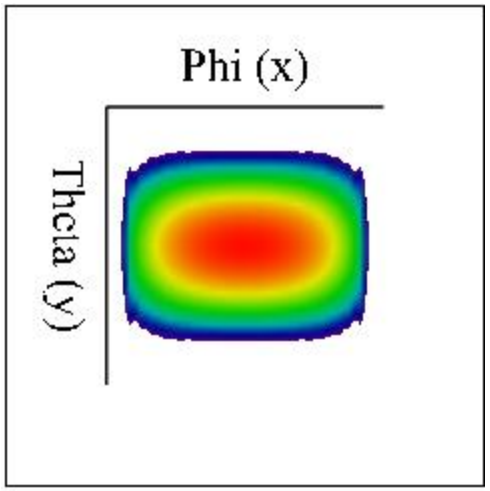

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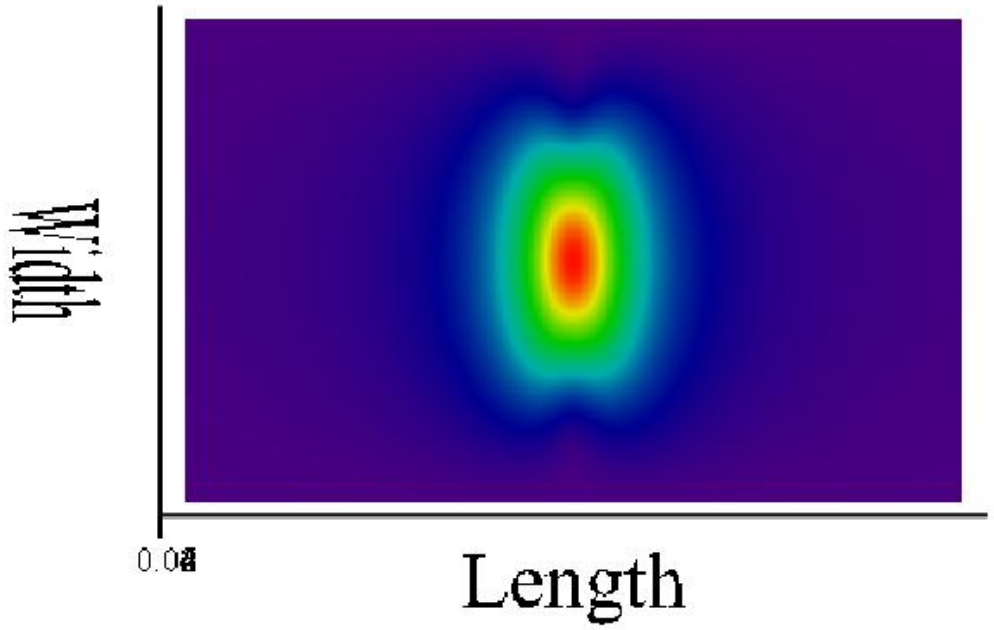
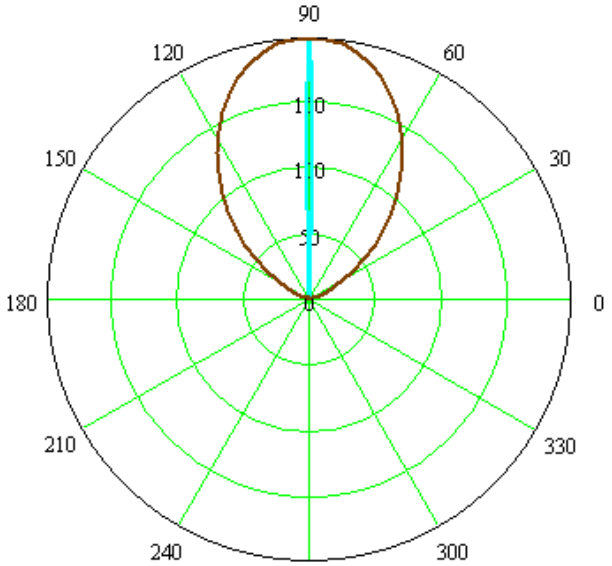
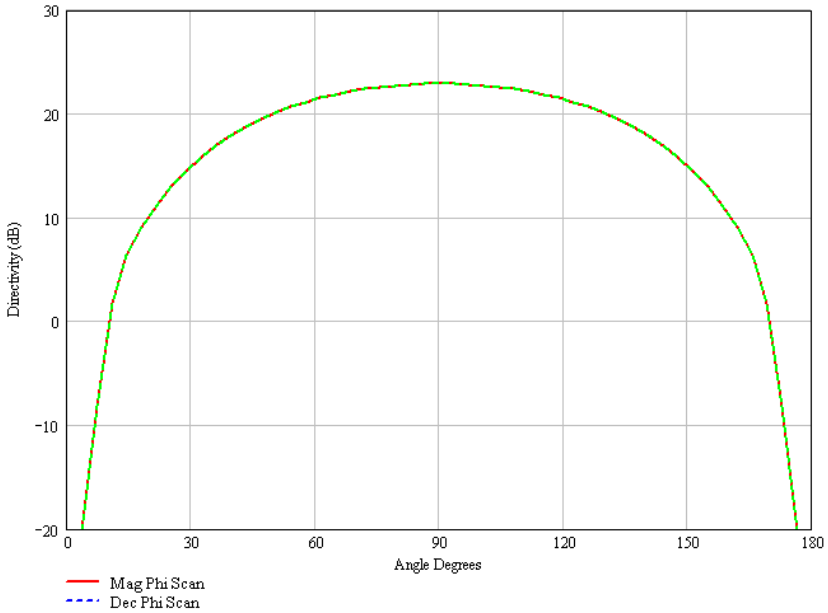
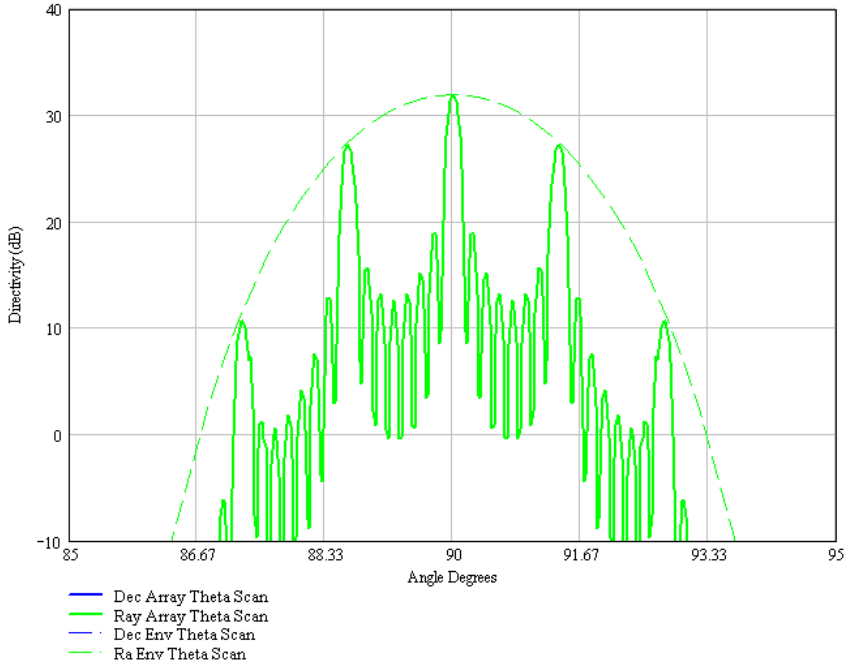


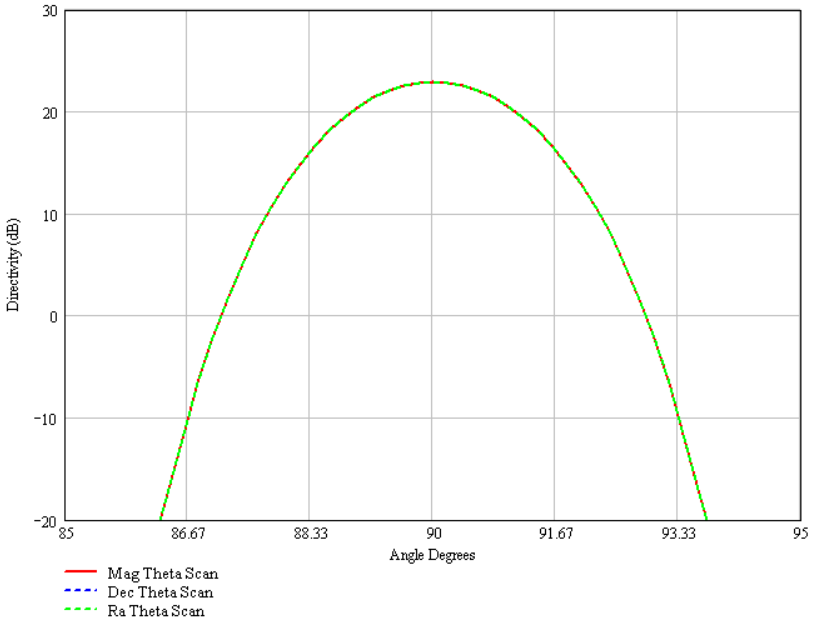
Y Polarization (Full Width)



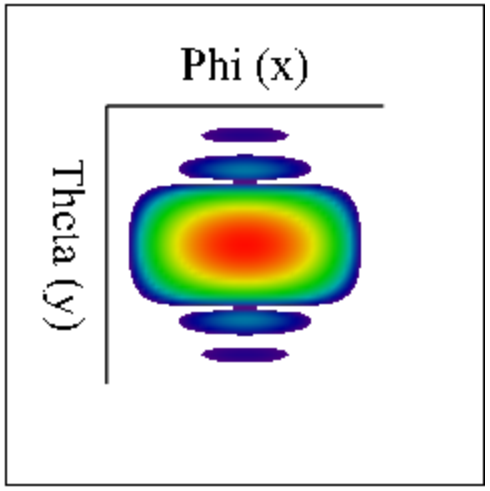
$$\frac{L_{em}}{\lambda} = 0.376$$







X Polarization (Full Width)



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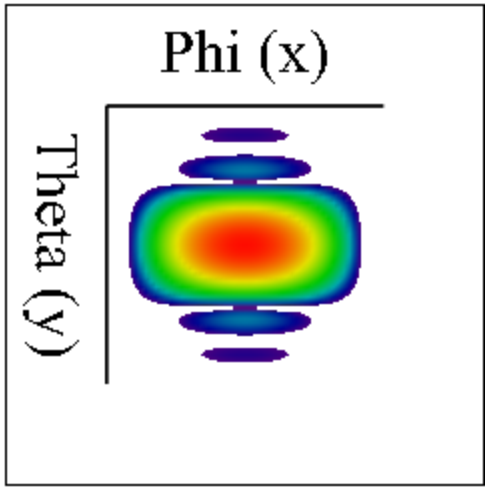

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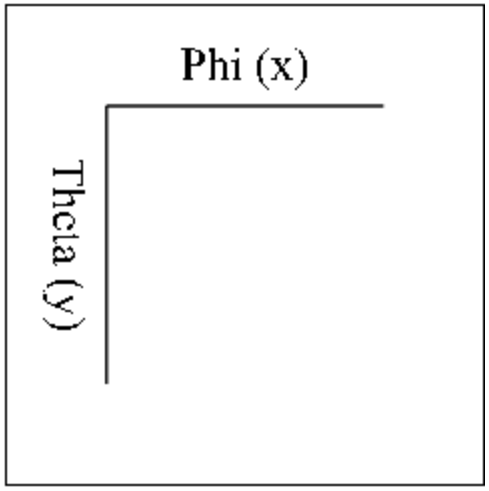
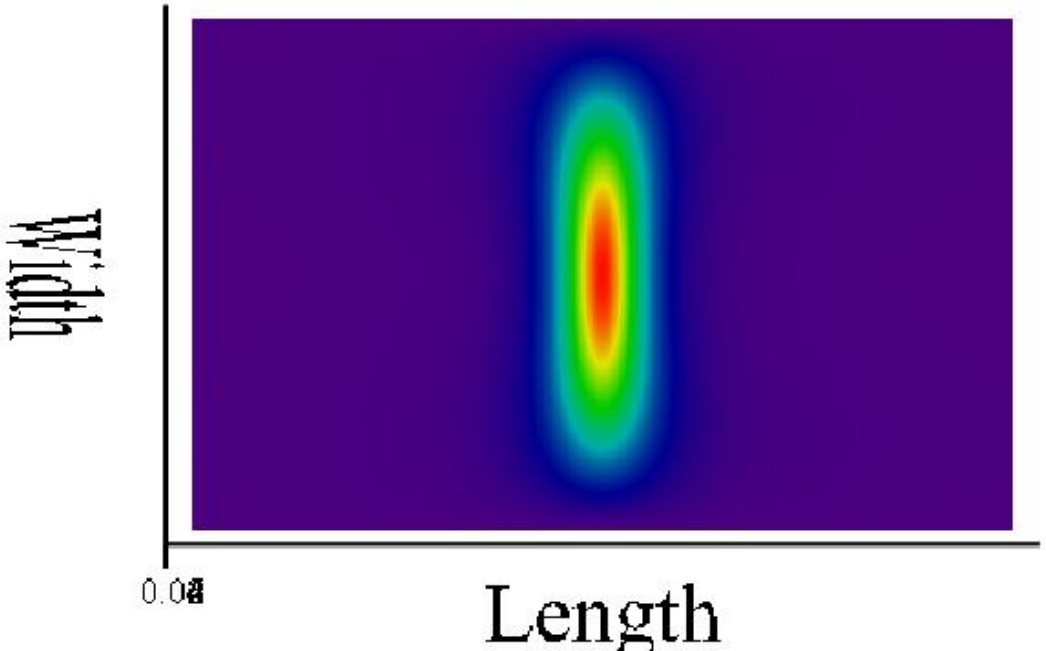
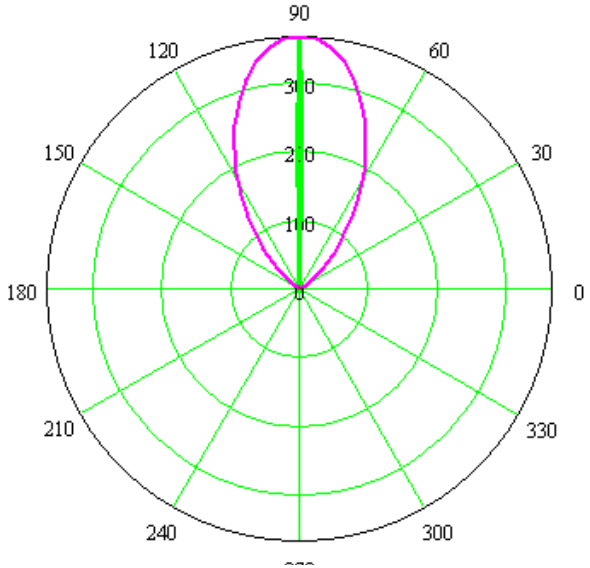


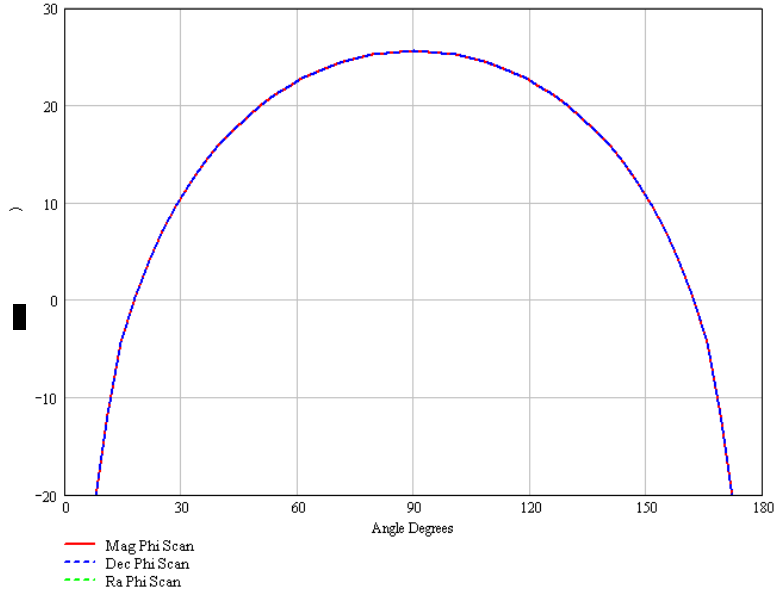
eRaLog

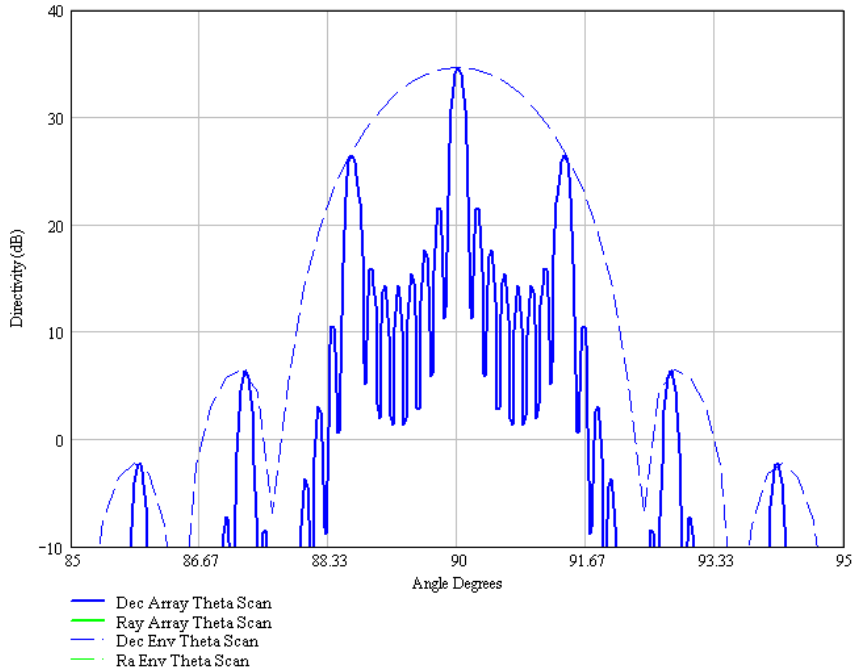


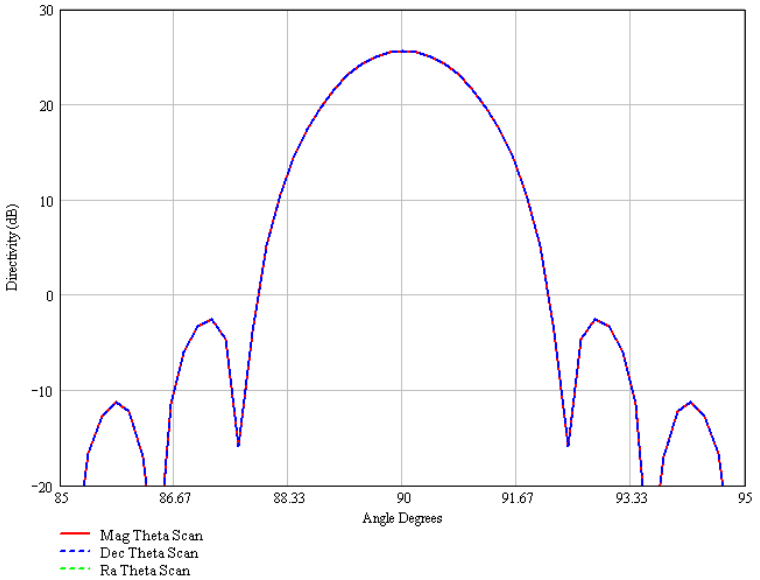
X Polarization (Full Width)



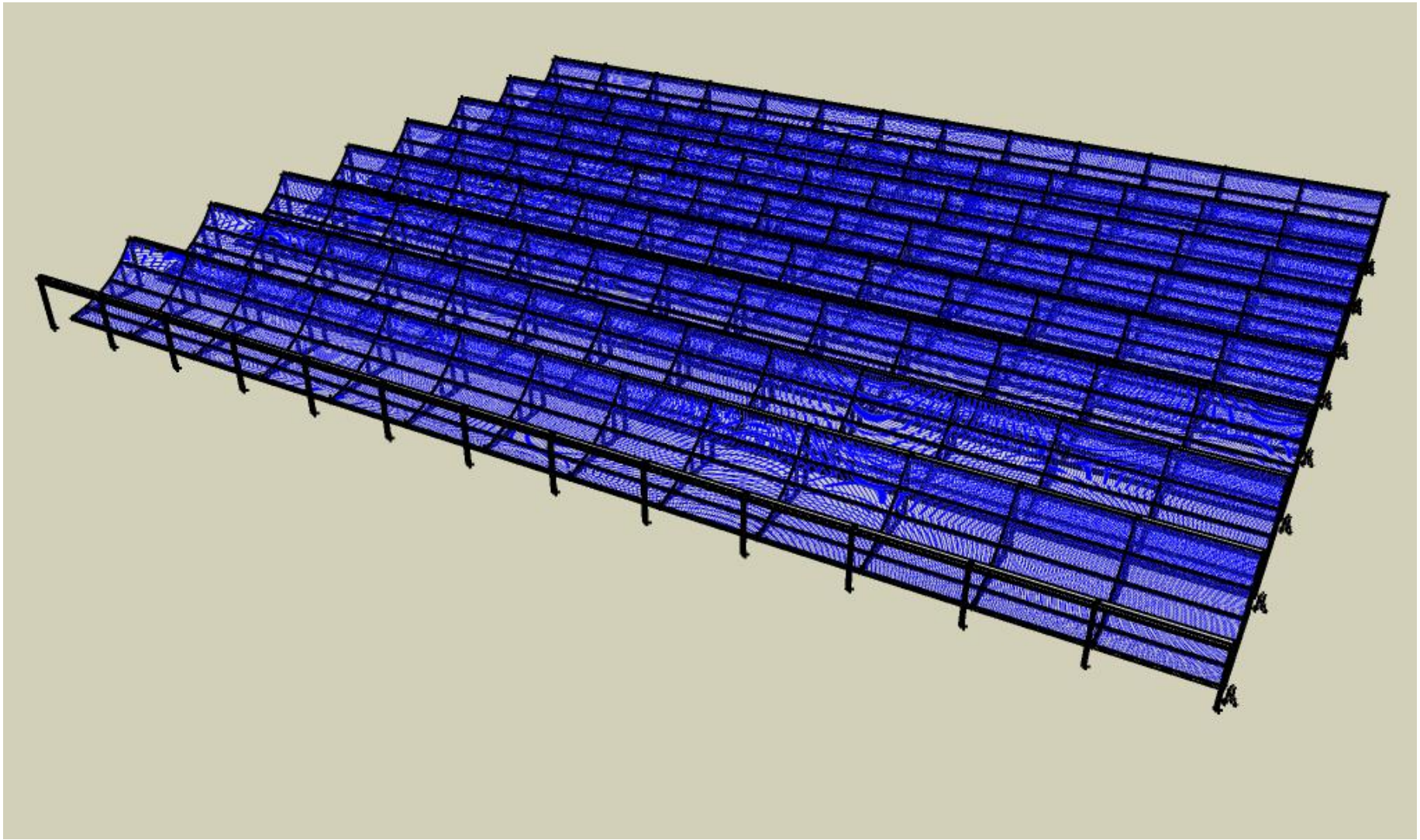
$$\frac{L_{em}}{\lambda} = 0.698$$







Telescope Layout



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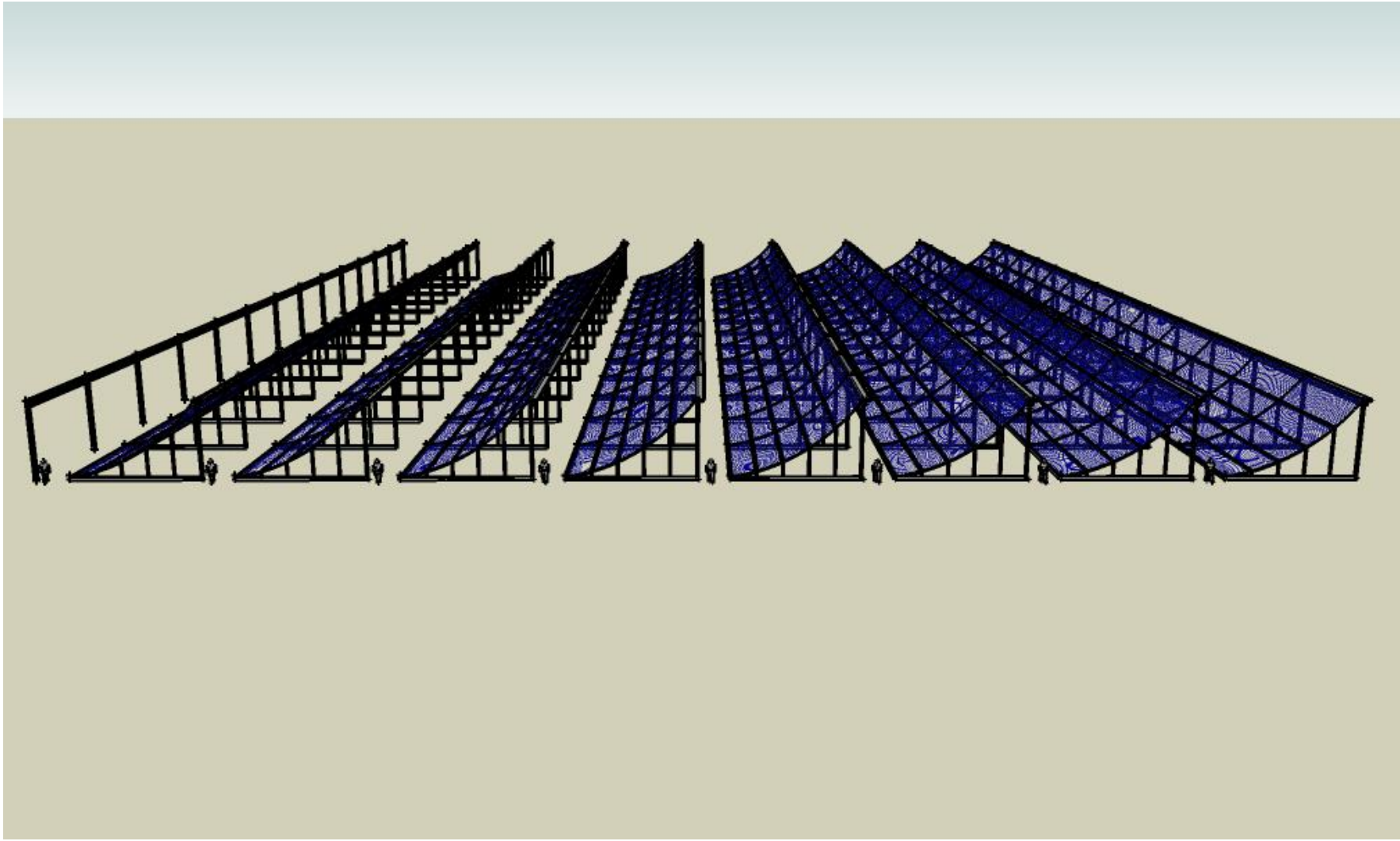

Iriki Dry Lake Site

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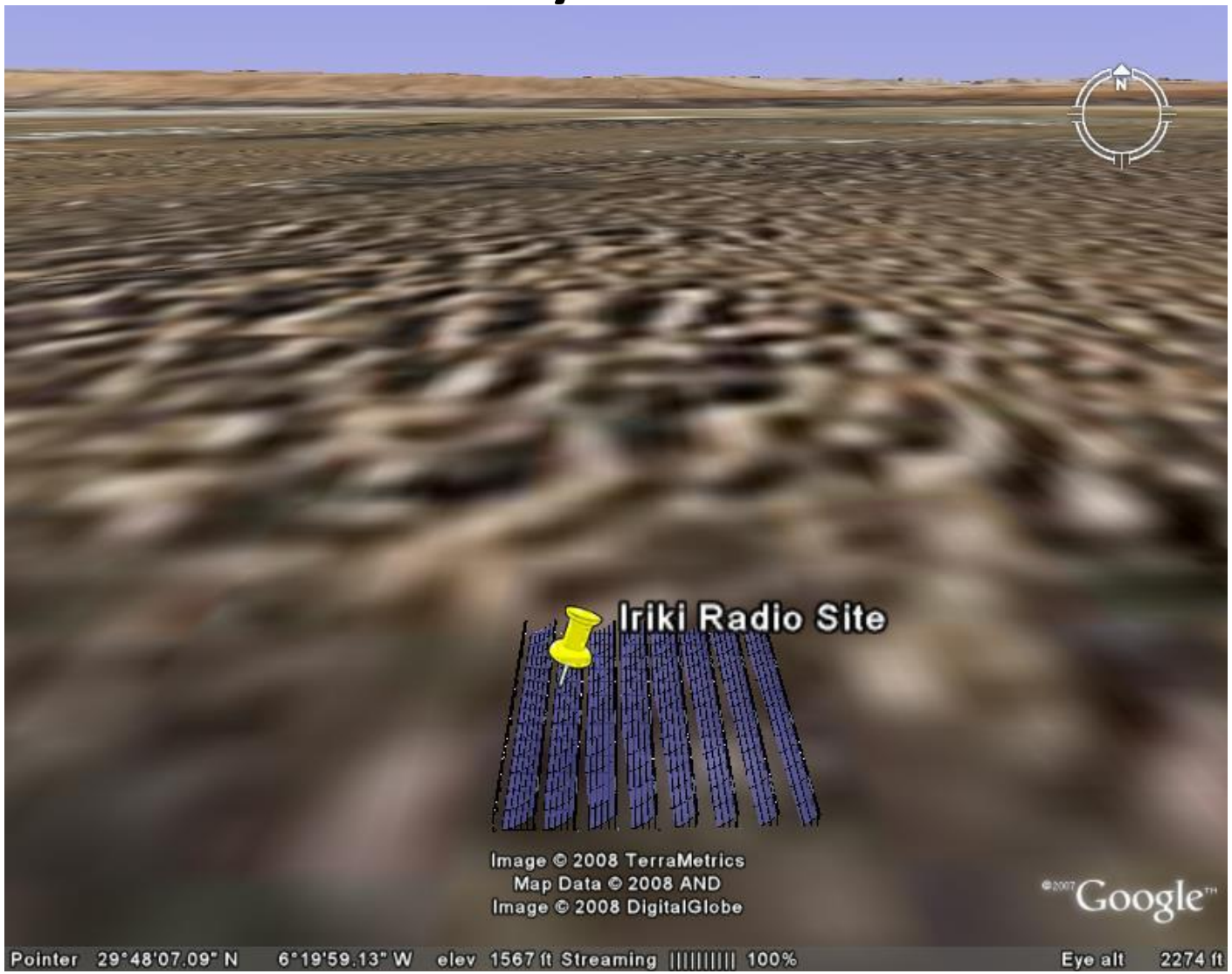

Iriki Dry Lake Site