Simulation of the MIDAS Antenna response

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IF - UFRJ

Microwave Detection of Air Showers Workshop, Chicago,
October 4-8, 2010

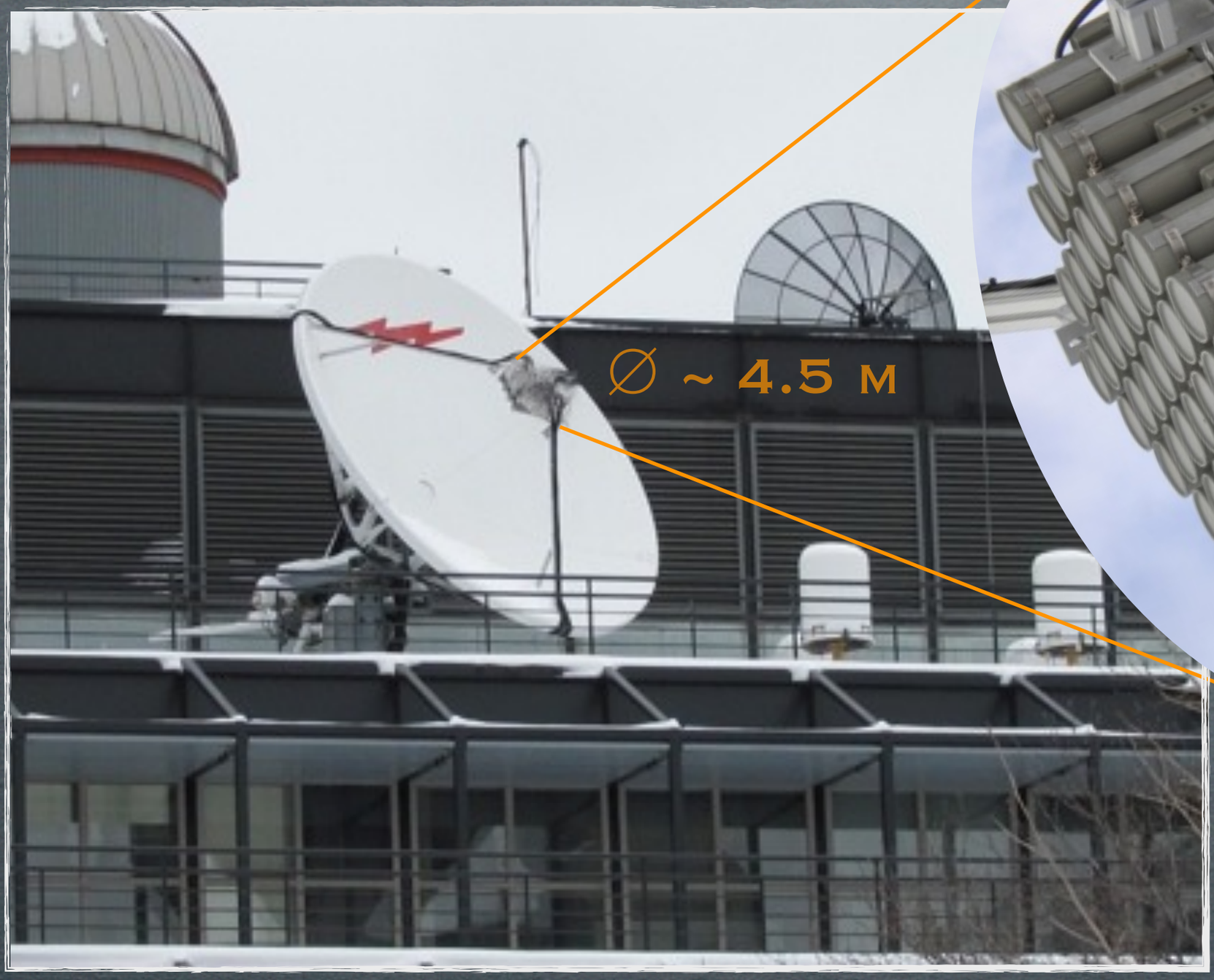
Layout

- Physics principles
- Wave guides
  - Aperture field
  - Power pattern
  - Transmission coefficient
- Parabolic dish
  - Aperture field
  - Power pattern
  - Polarization
- The feed camera
- Calibration with the sun

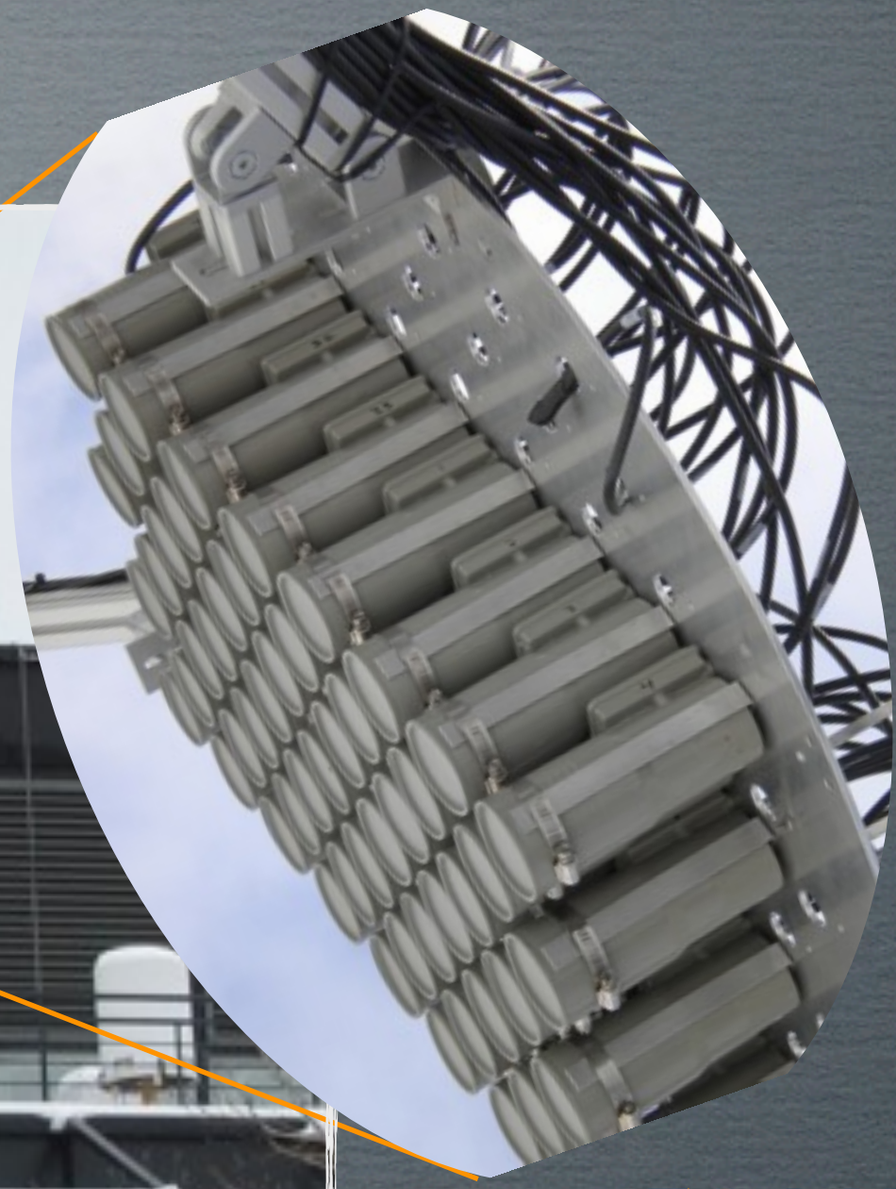
Goals

- Simulate the **response** of a microwave antenna as a function of the direction in the sky
- Do that from first principles: calculate and propagate electric fields entering and leaving the apparatus
- First step towards a complete simulation of the signals coming out from a setup like MIDAS
- Reproduce of the MIDAS Antenna Calibration

The Antenna @ Chicago



∅ ~ 4.5 m



53 LNBF
DMX241

Reciprocity Theorem

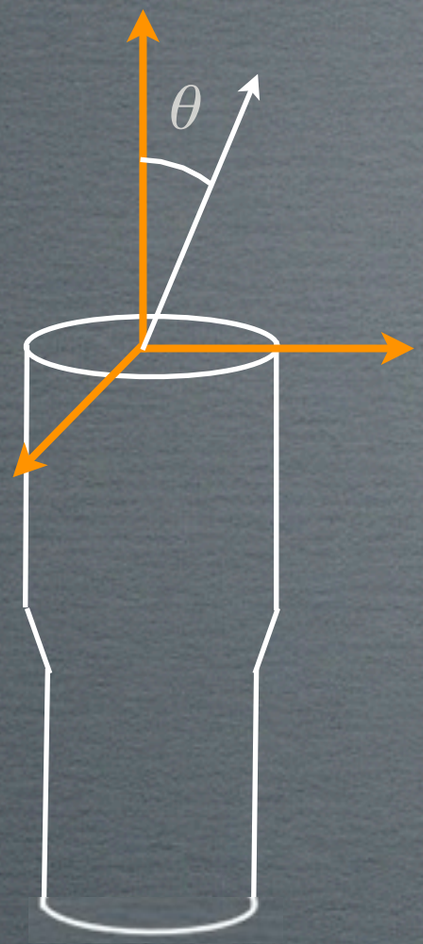
$$A_e(\theta,\phi) = \frac{\lambda^2\ G(\theta,\phi)}{4\pi}$$

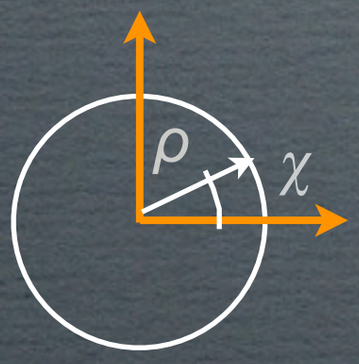
$A_e(\theta,\phi) =$ Effective area for power collection

$G(\theta,\phi) =$ Emitted power with respect to an isotropic antenna

$$G(\theta,\phi) = \frac{P(\theta,\phi)}{P_T/4\pi} \qquad P_T = \int_{4\pi} P(\theta,\phi)d\Omega$$

Feed Power Pattern



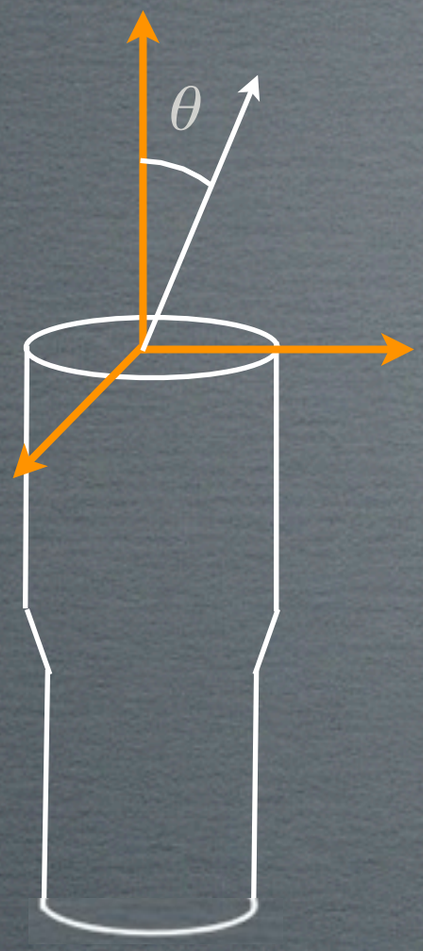


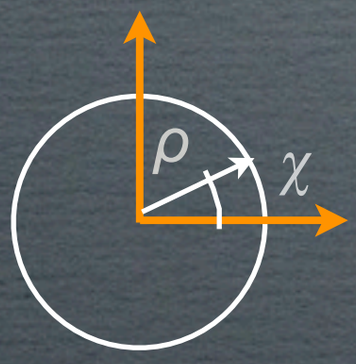
$$f(\theta,\phi) = \int_0^r d\rho \int_0^{2\pi} d\chi \; \vec{E}(\rho,\chi)\; \rho \; e^{i\vec{k}\cdot\vec{r'}}$$

$$\vec{r'} = \rho\,(\cos\chi\;\hat{\imath} + \sin\chi\;\hat{\jmath})$$

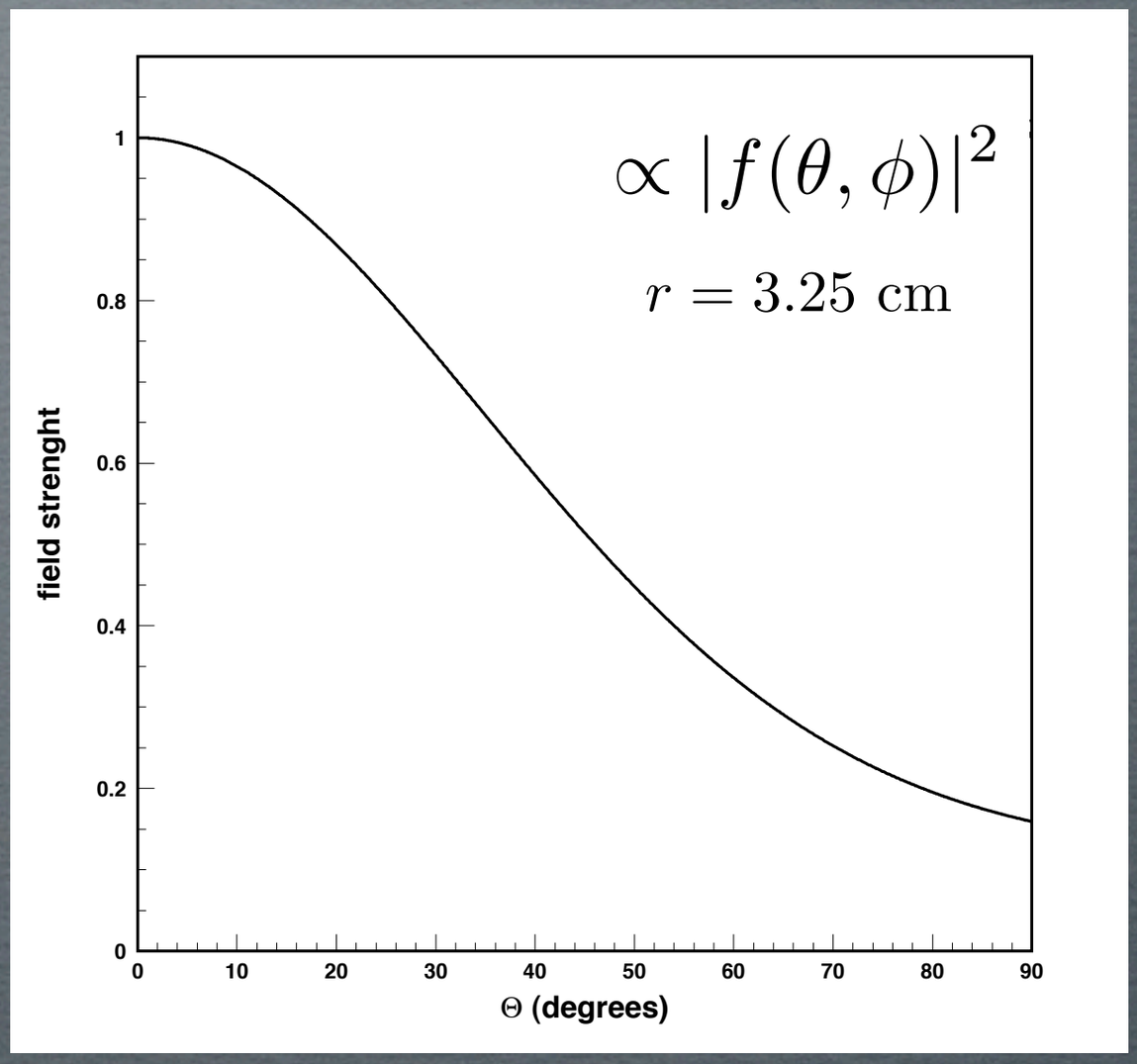
$$\vec{k} = \frac{2\pi}{\lambda}(\sin\theta\cos\phi\;\hat{\imath} + \sin\theta\sin\phi\;\hat{\jmath} + \cos\theta\;\hat{z})$$

Feed Power Pattern (uniform disk)





Disk diffraction field @ 4 GHz



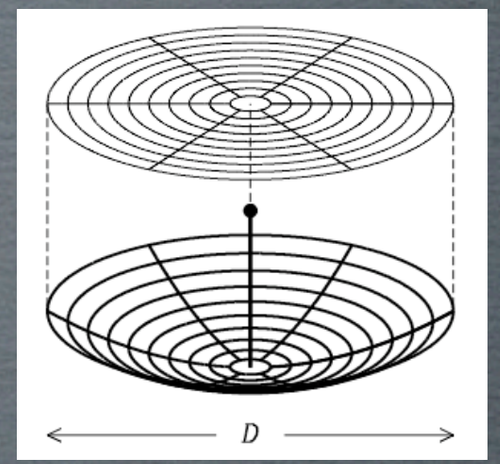
$$f(\theta,\phi) = \int_0^r d\rho \int_0^{2\pi} d\chi \; \vec{E}(\rho,\chi) \; \rho \; e^{i\vec{k}\cdot\vec{r'}}$$

Aperture Field Distribution

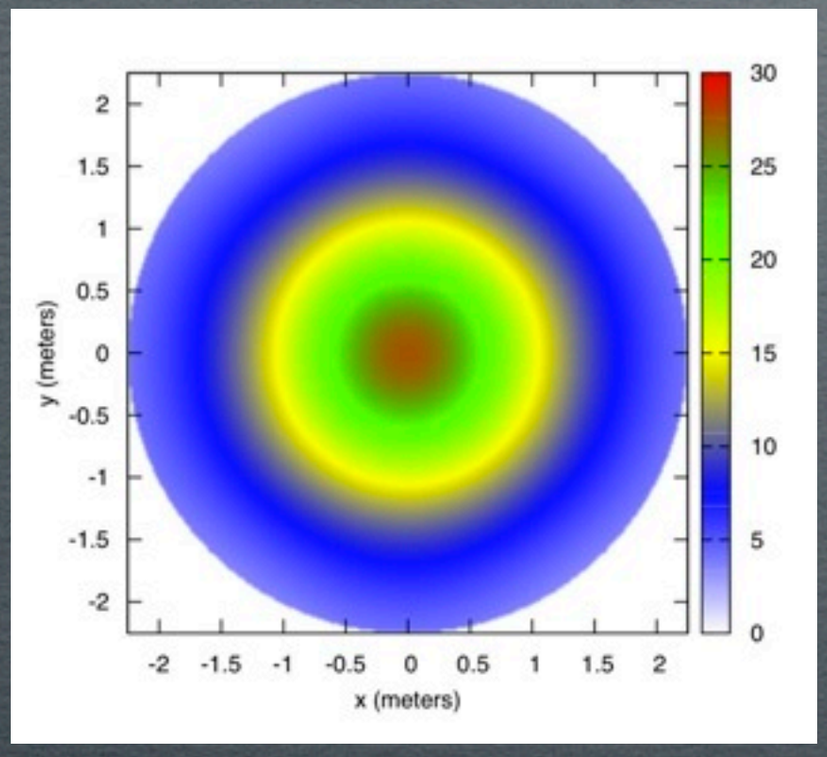
Parabolic dish

$$\vec{E}_r = -\vec{E}_i + 2\hat{n}(\hat{n} \cdot \hat{E}_i)$$

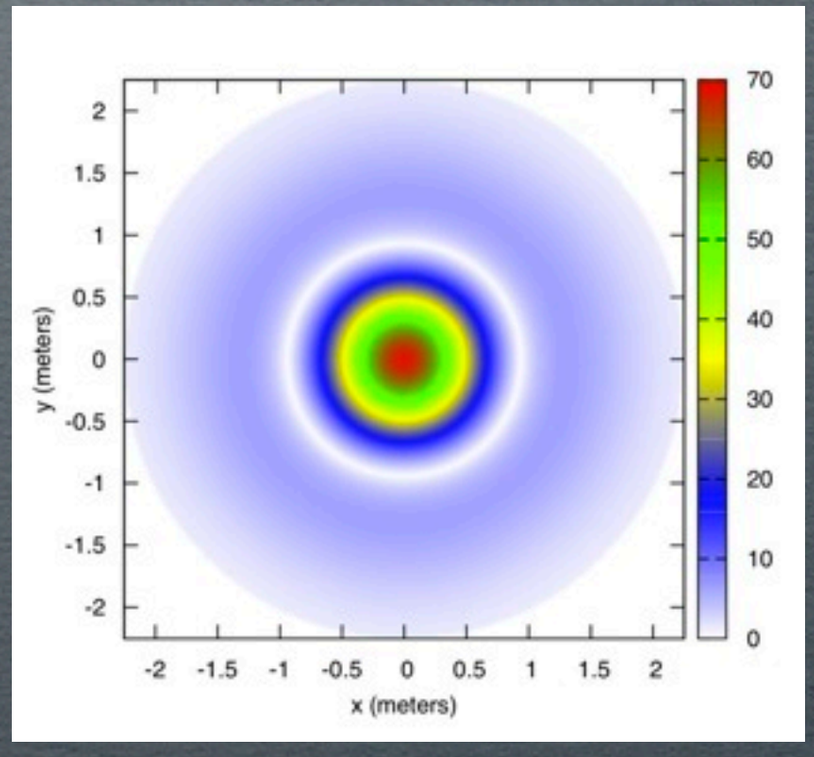
- Diameter: 4.5 m
- Aperture: projection of the dish
- **Uniformily illuminated Disk** located in the focus



4 GHz

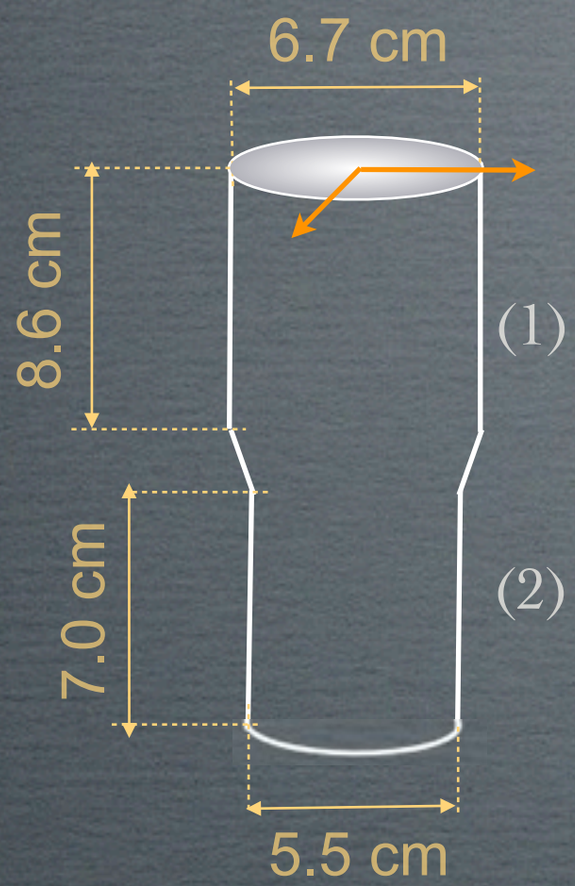


10 GHz



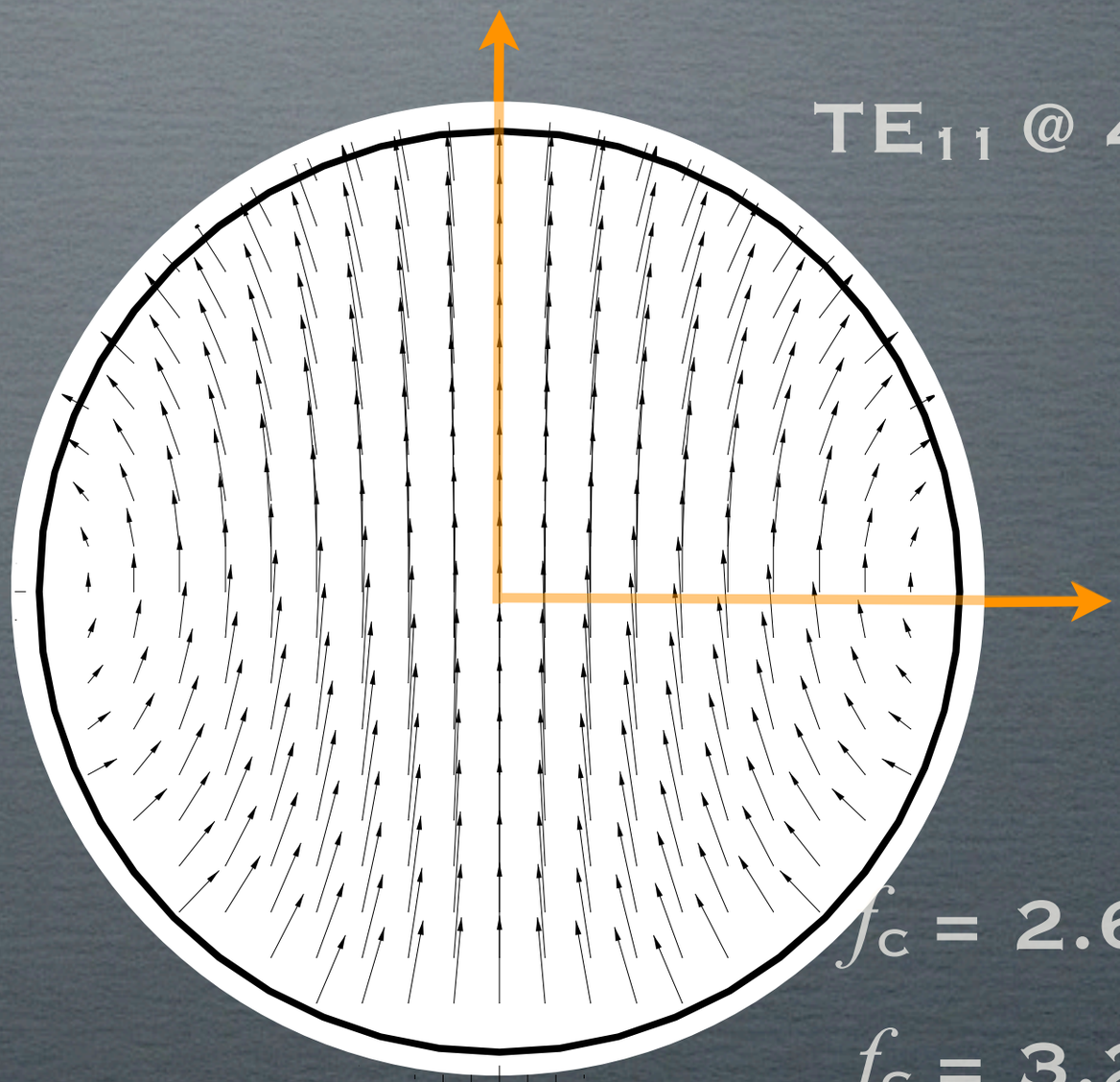
Feed Aperture Field

<u>Model:</u> Two different diameters taking into account the reflection



LNBF DMX241

Dual polarization
- Vertical
- Horizontal



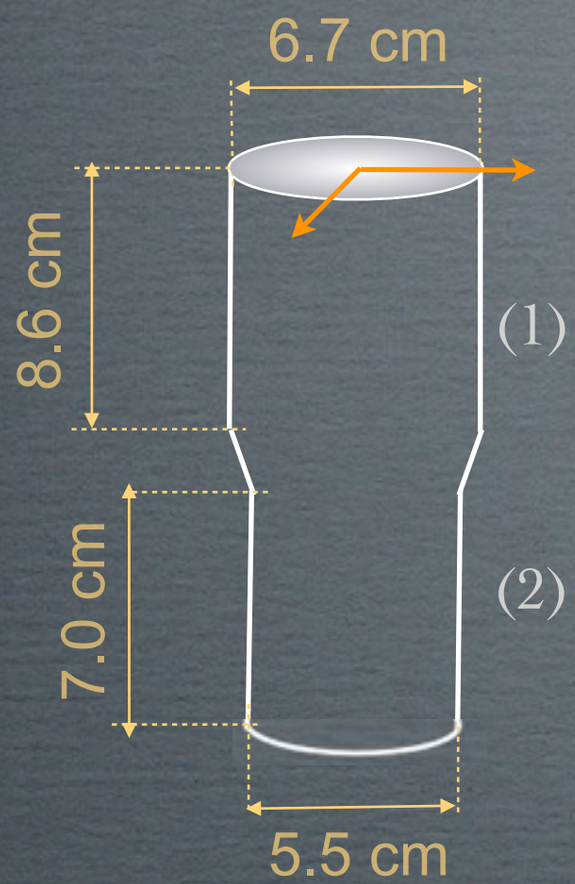
TE_{11} @ 4 GHz

f_c = 2.6 GHz (1)

f_c = 3.2 GHz (2)

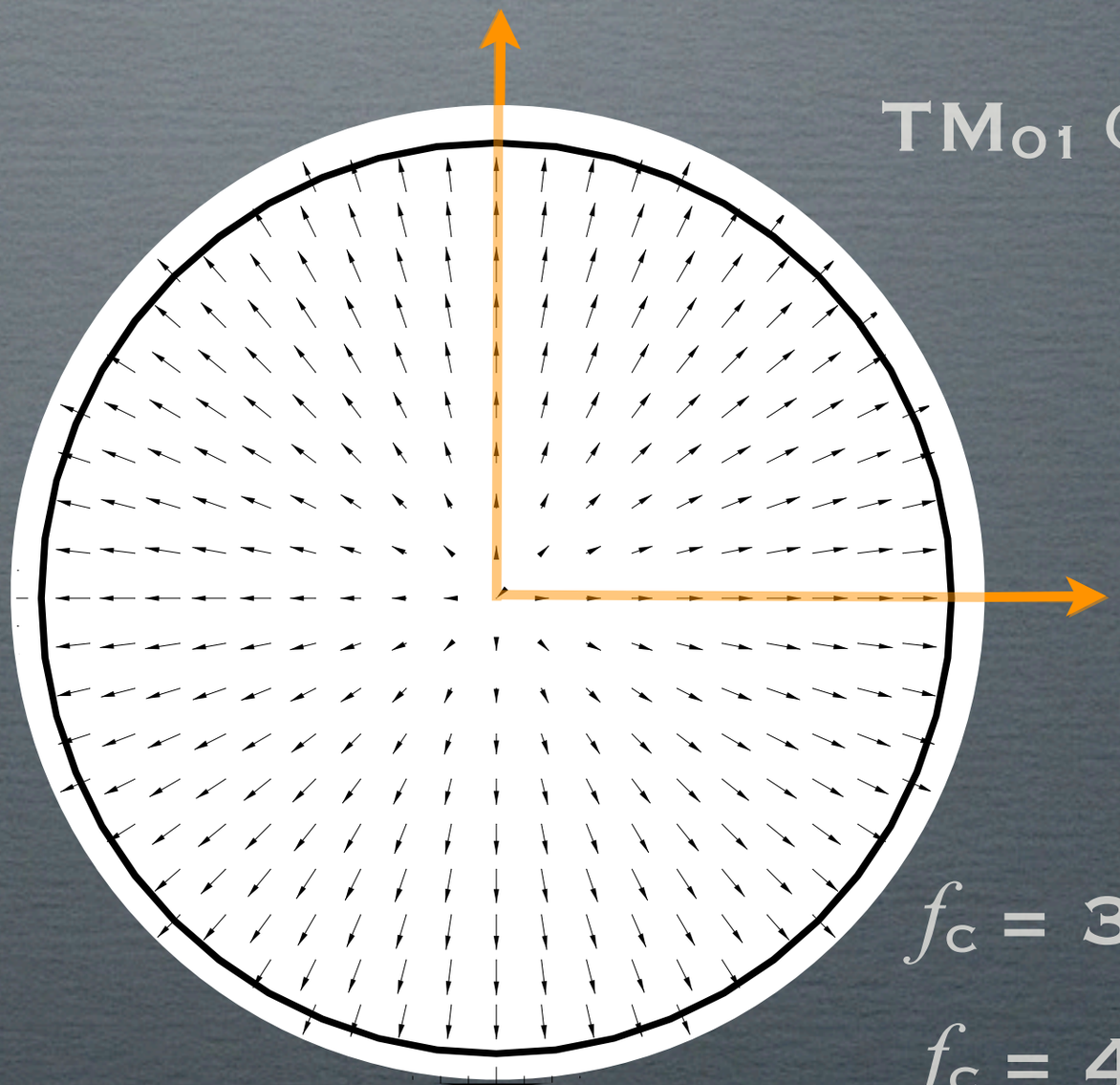
Feed Aperture Field

<u>Model:</u> Two different diameters taking into account the reflection



LNBF DMX241

Dual polarization
Vertical
Horizontal



TM_{01} @ 4 GHz

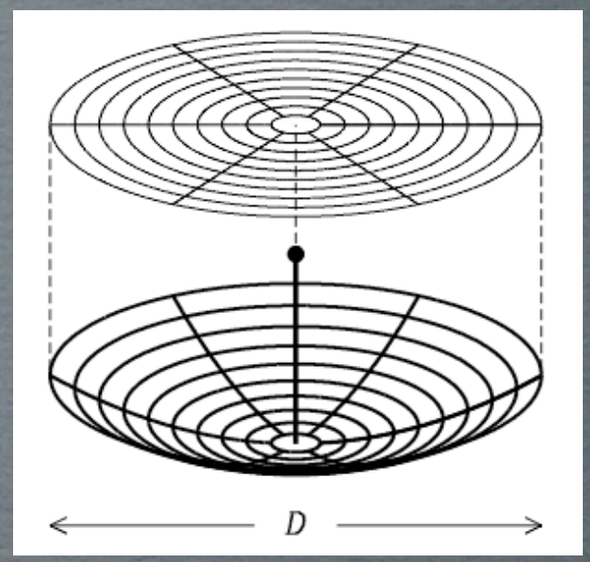
f_c = 3.4 GHz (1)

f_c = 4.2 GHz (2)

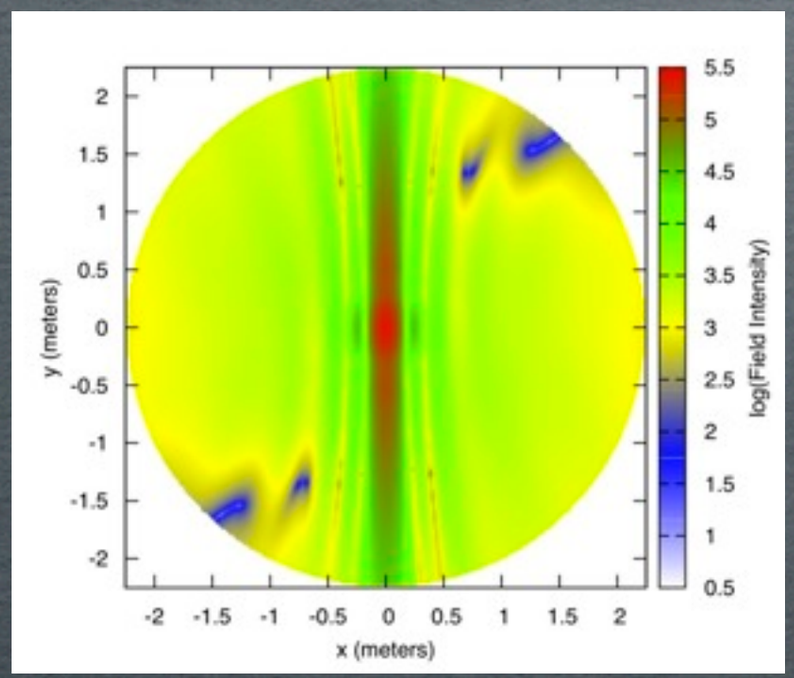
Aperture Field Distribution

Parabolic dish

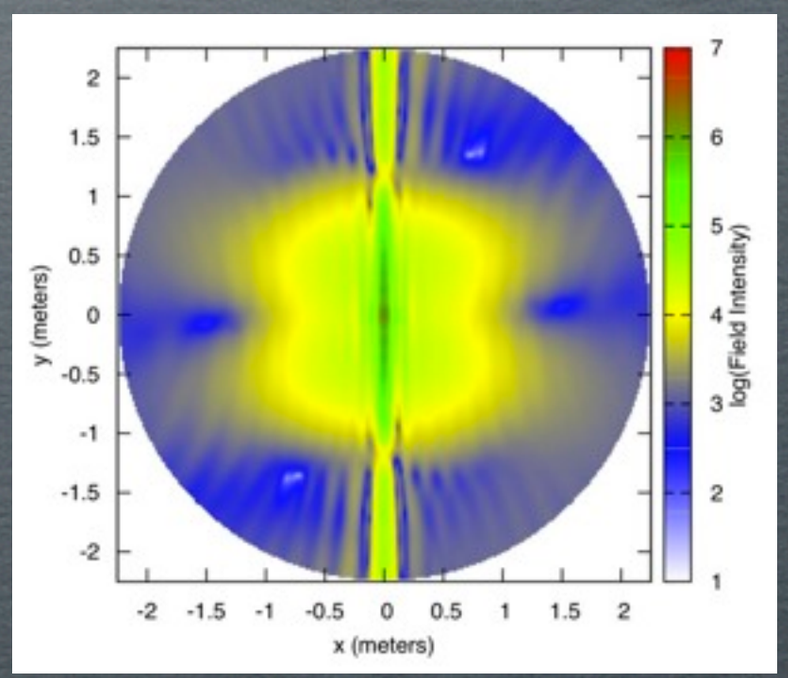
- Diameter: 4.5 m
- Aperture: projection of the dish
- **LNBF DMX241** located in the focus



4 GHz



10 GHz

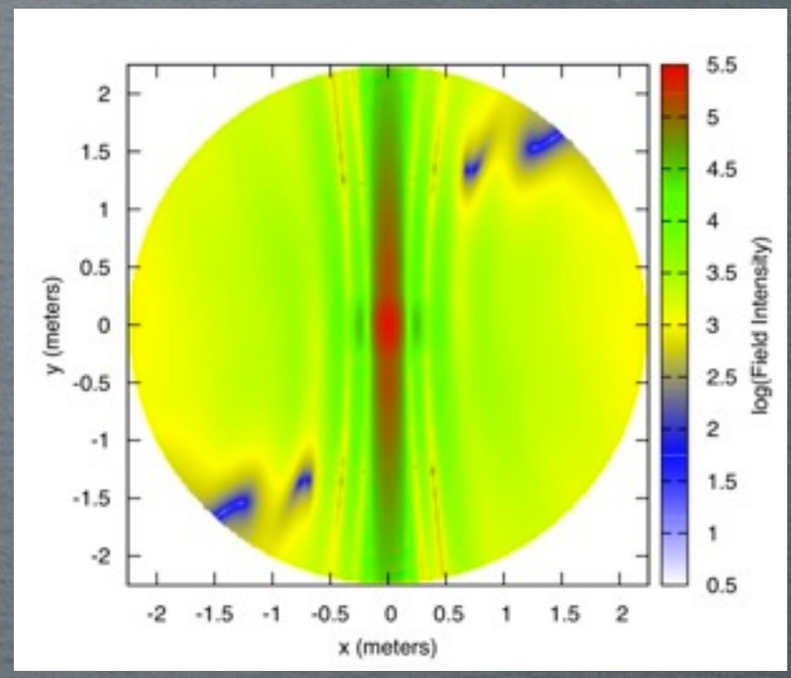


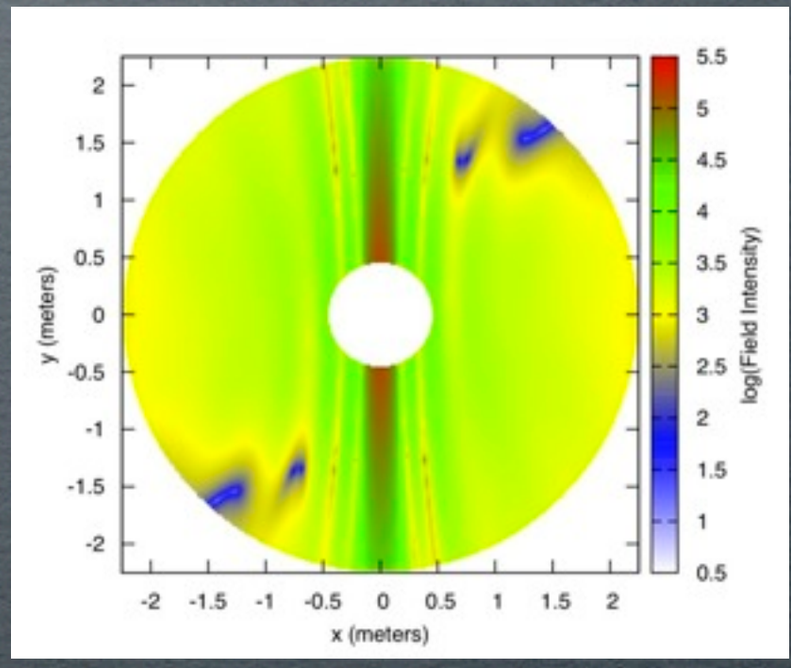
TE_{11}

Aperture Field Distribution

Camera makes a shadow on the aperture

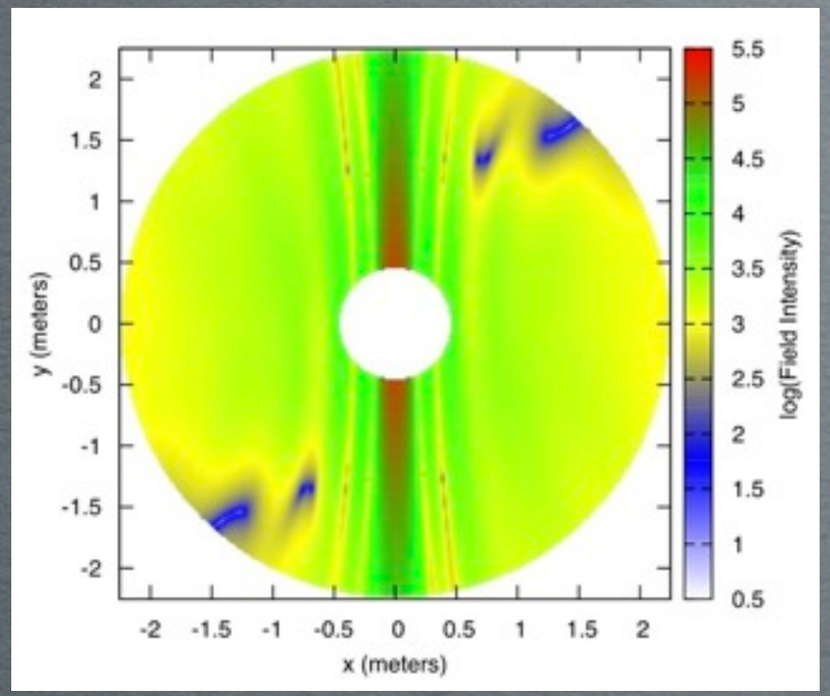
TE_{11} @ 4 GHz



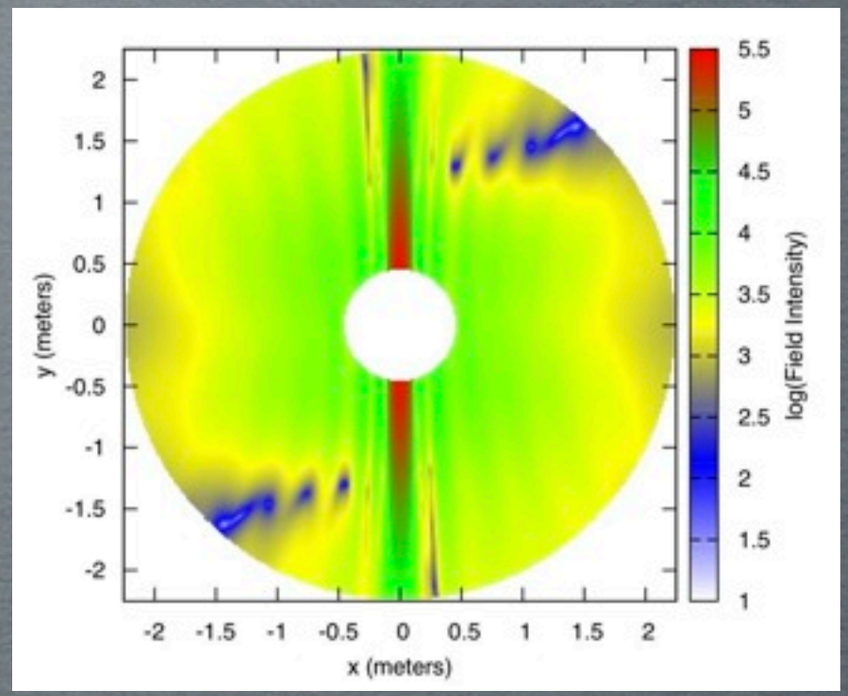


Aperture Field Distribution

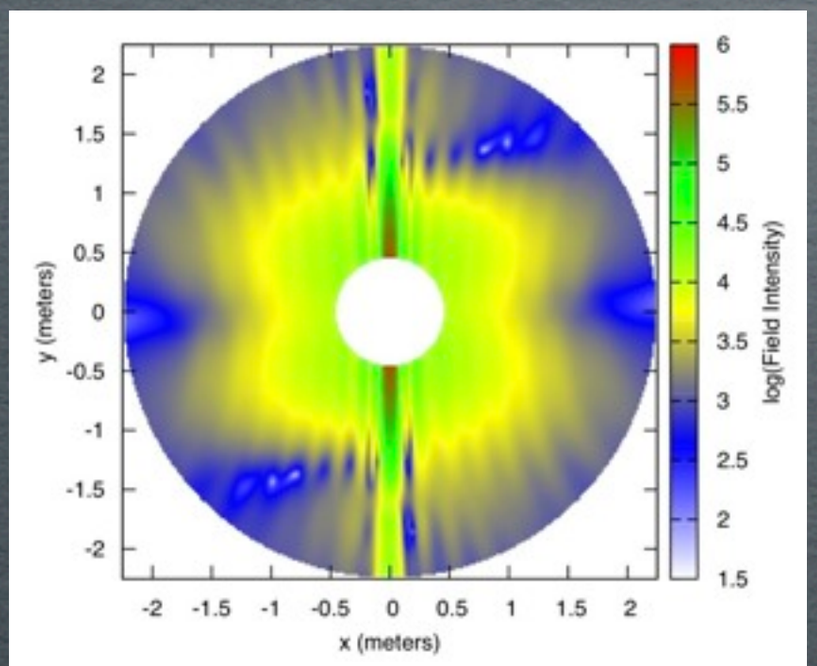
4 GHz



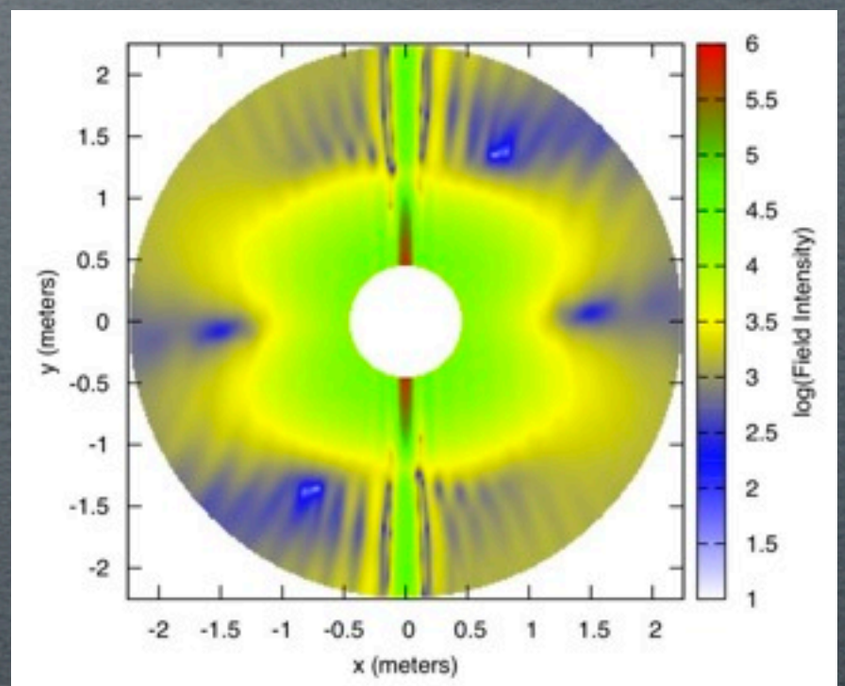
6 GHz



8 GHz

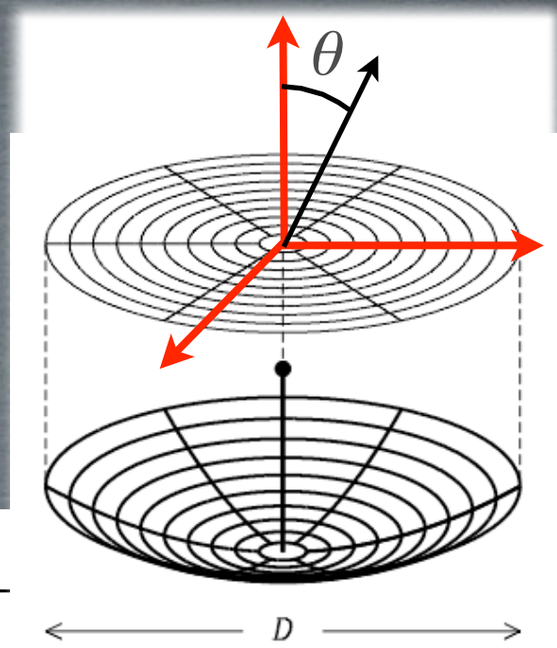


10 GHz

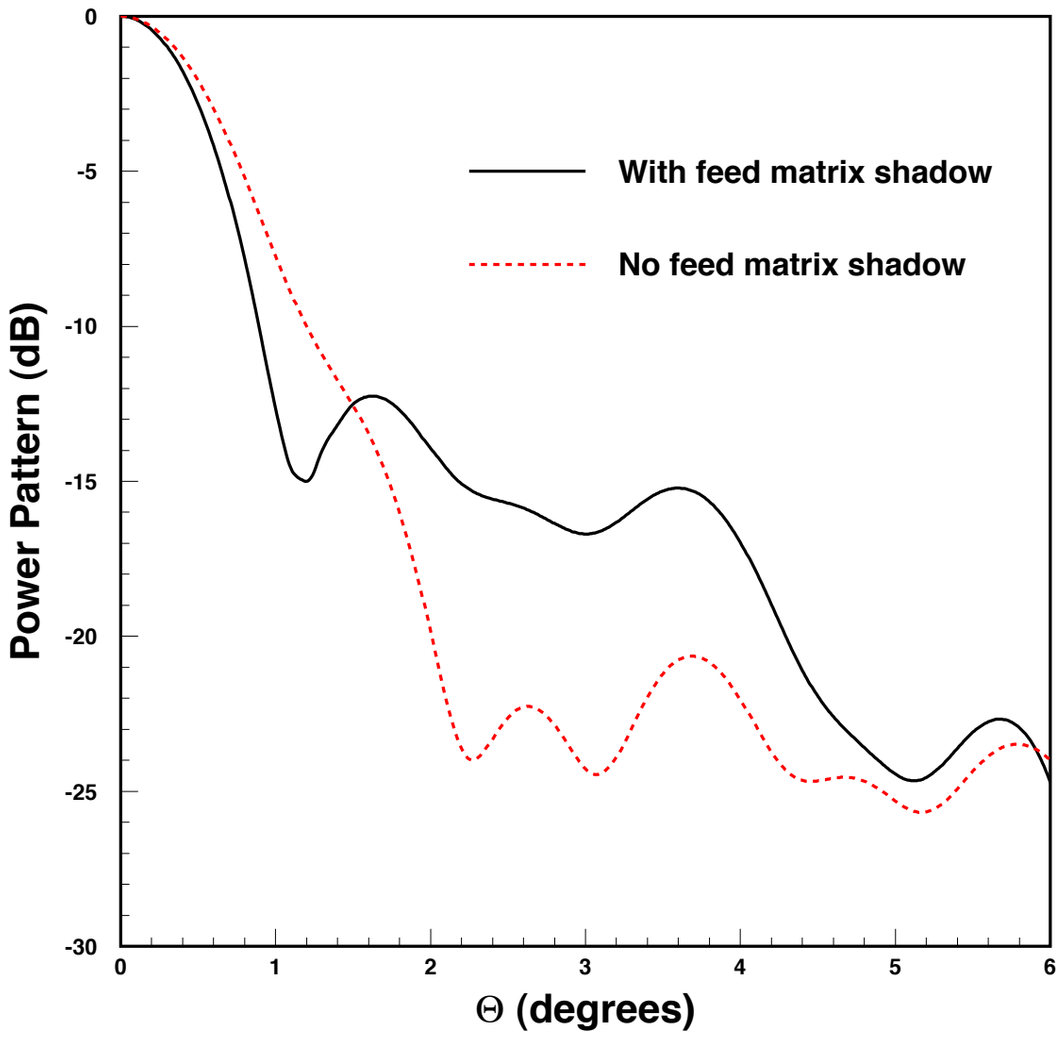


TE_{11}

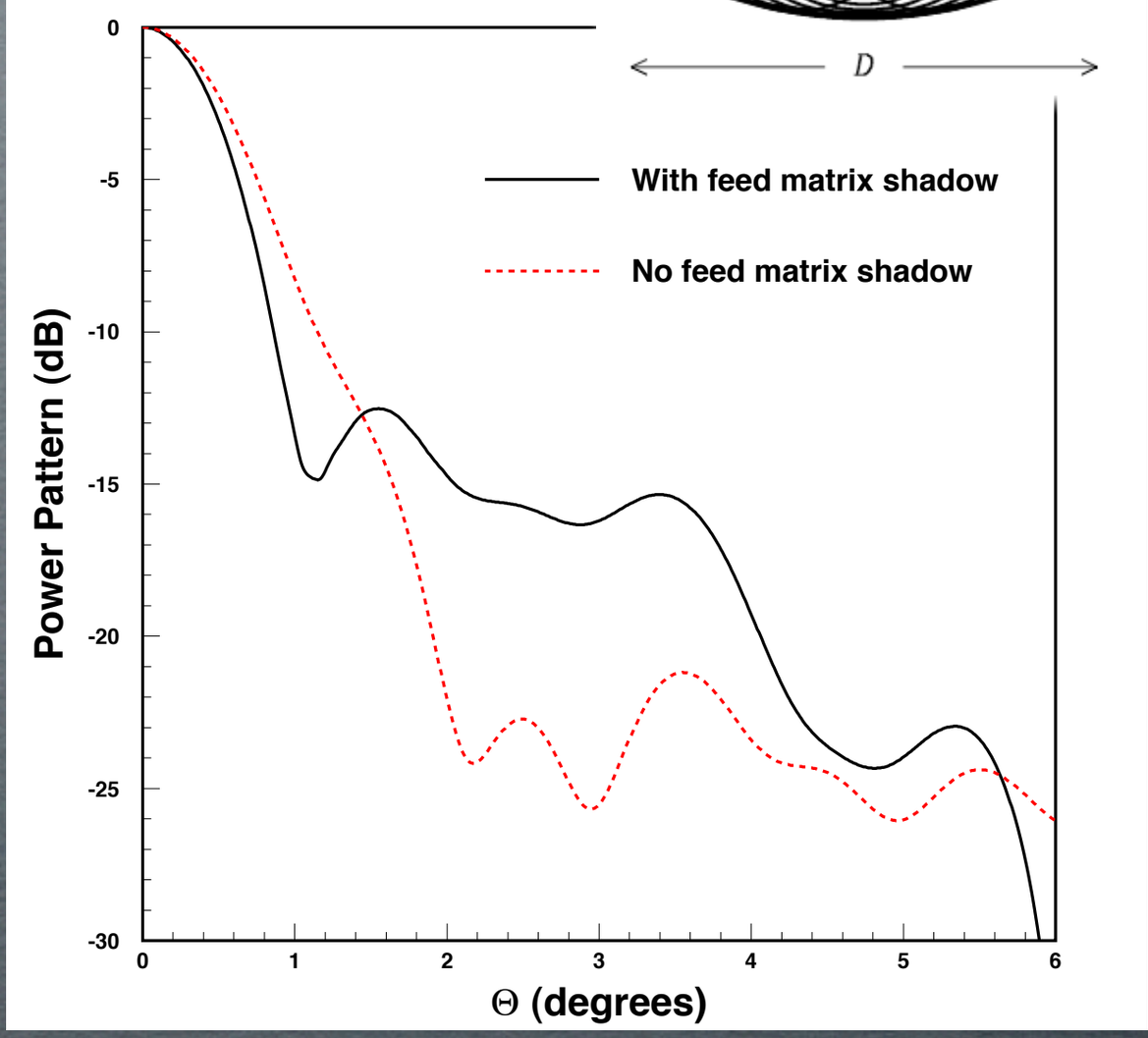
Shadow effect



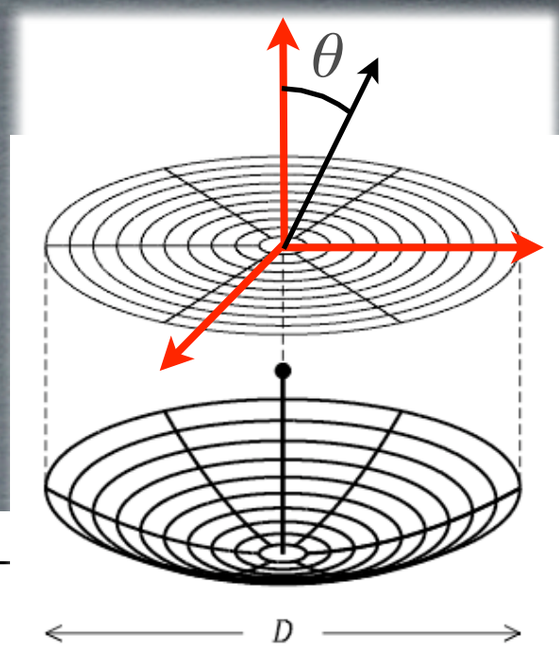
3.6 GHz



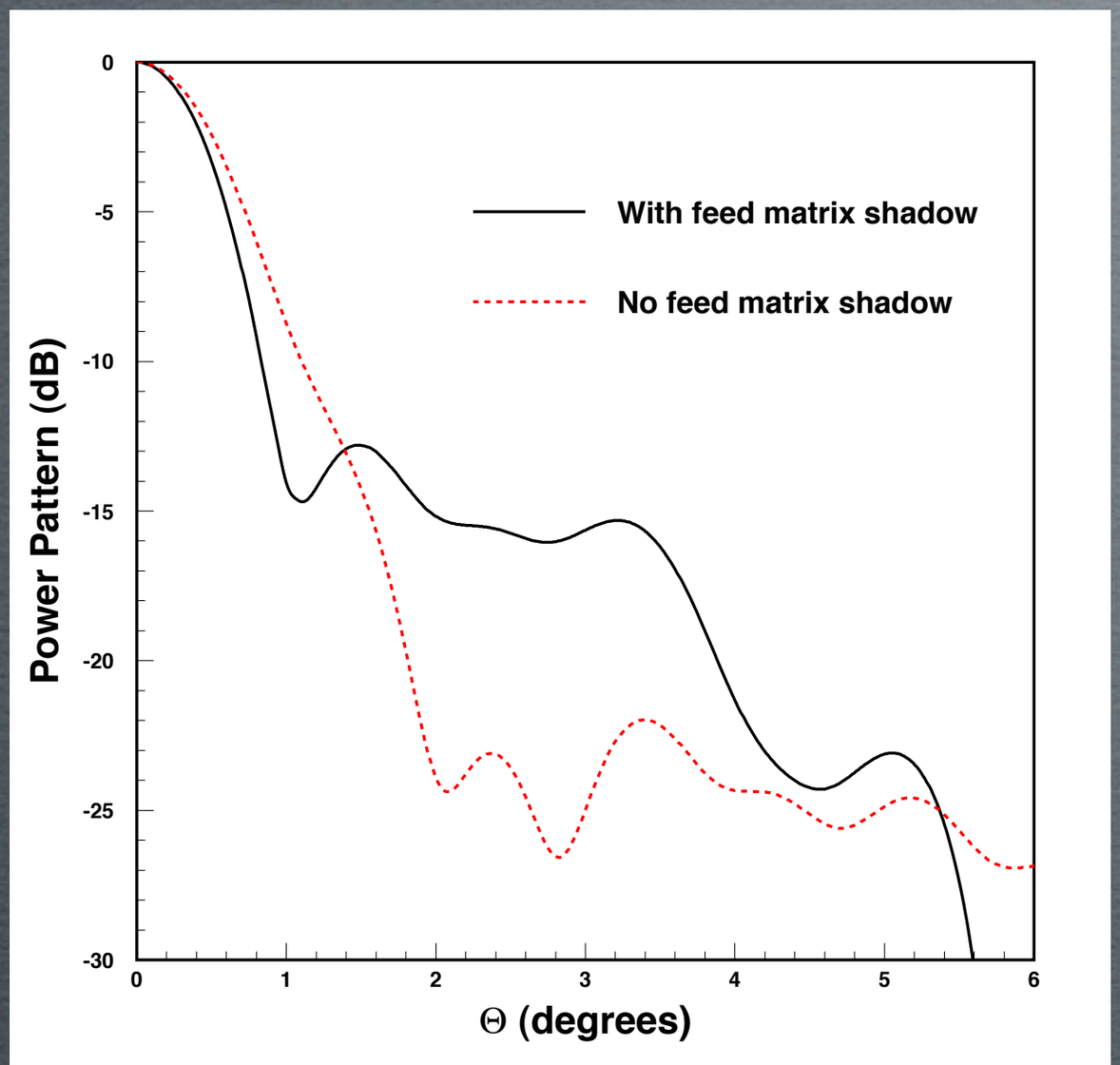
3.8 GHz



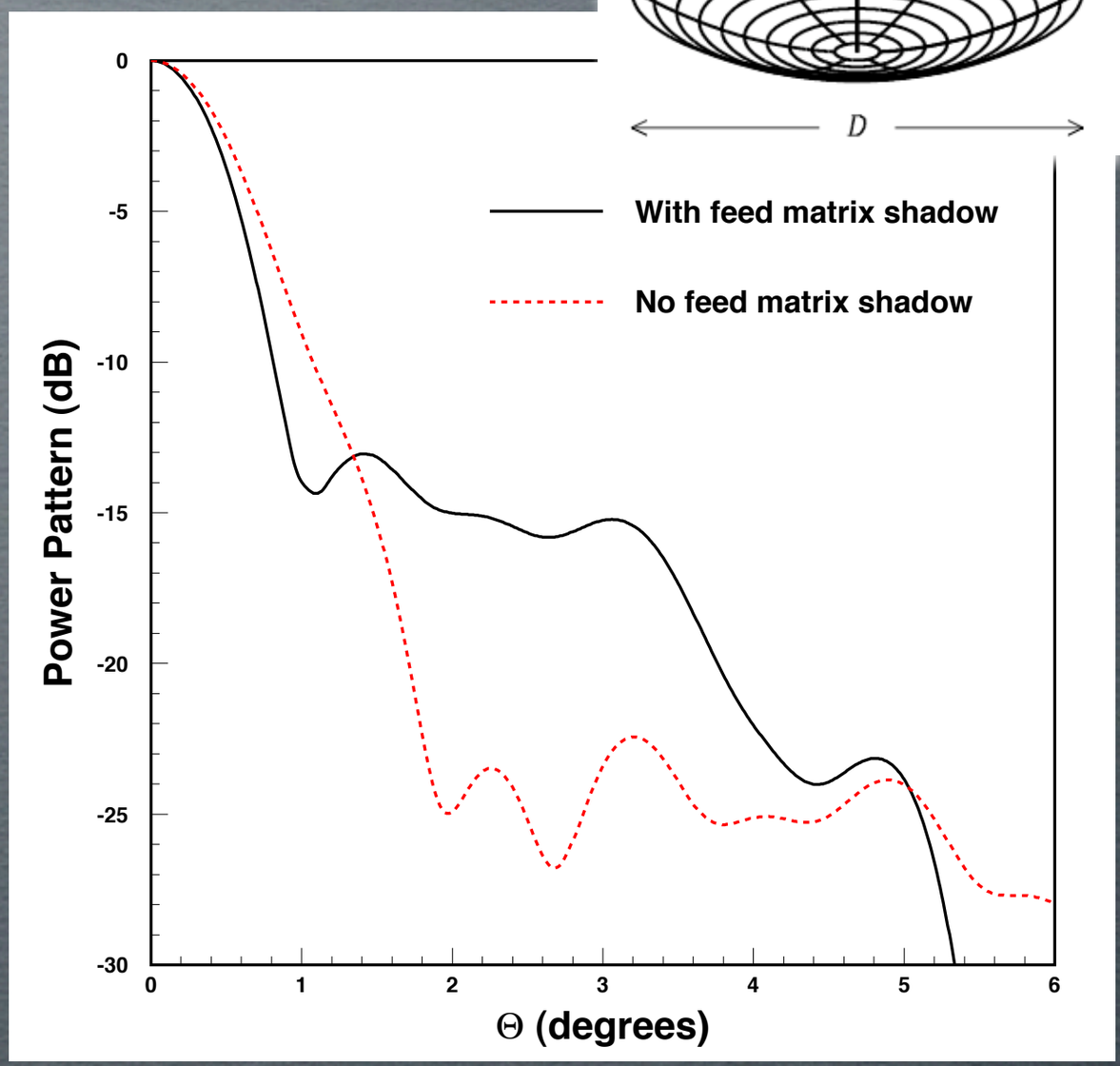
Shadow effect



4 GHz

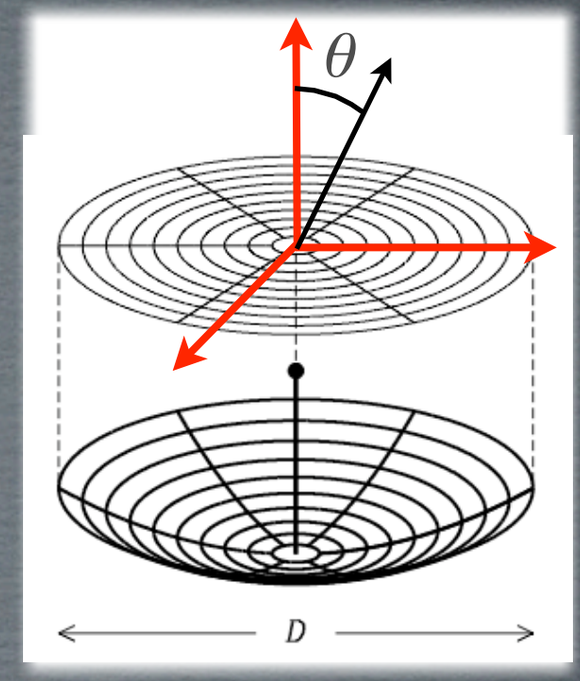


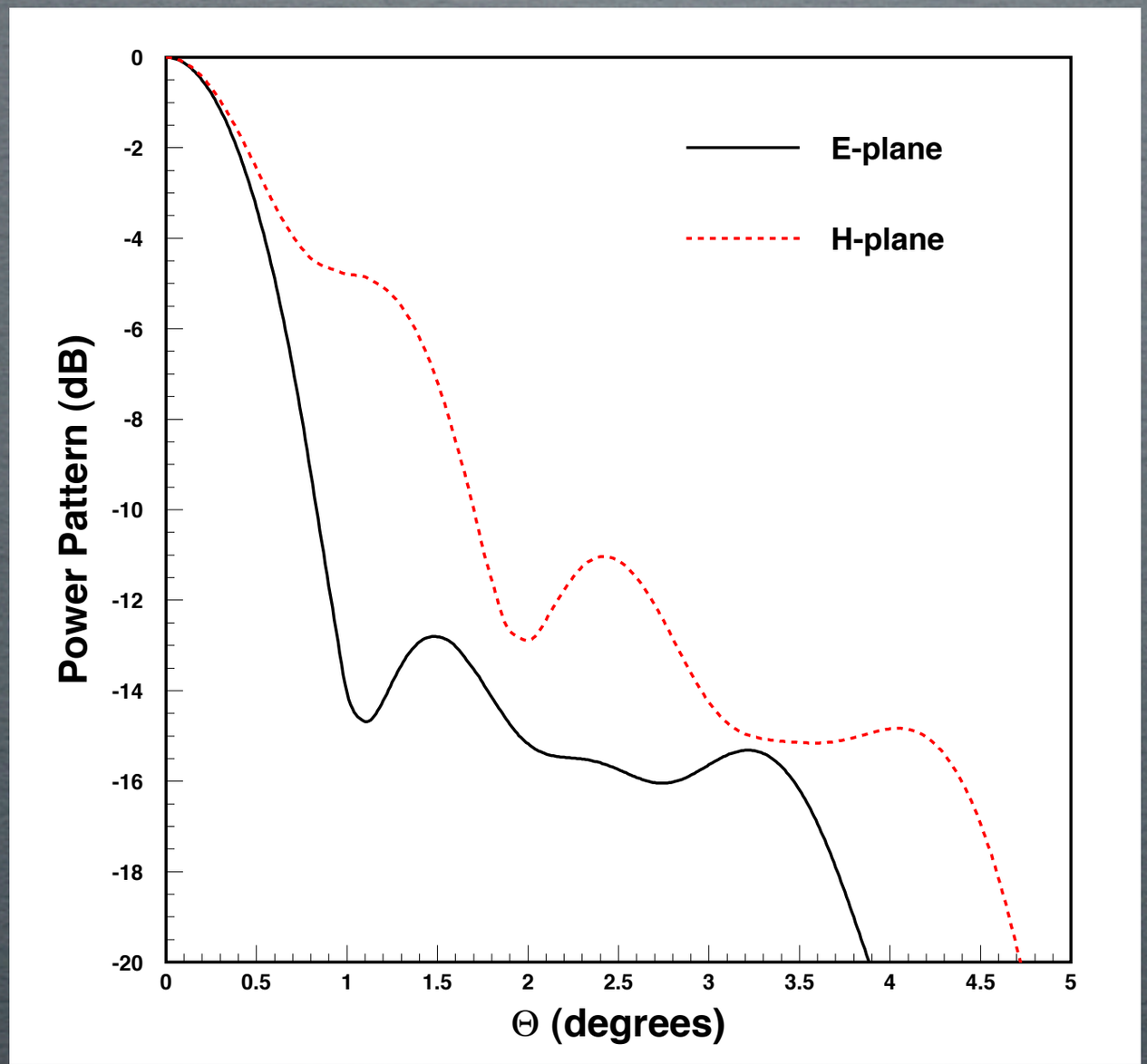
4.2 GHz



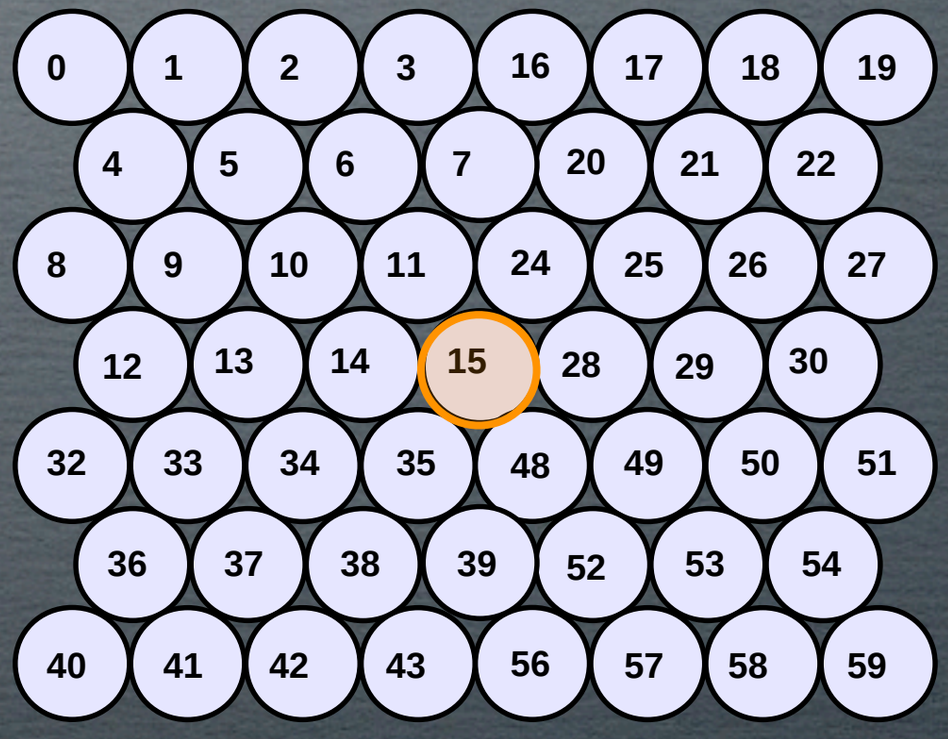
Power Pattern

Antenna in emission mode @ 4 GHz



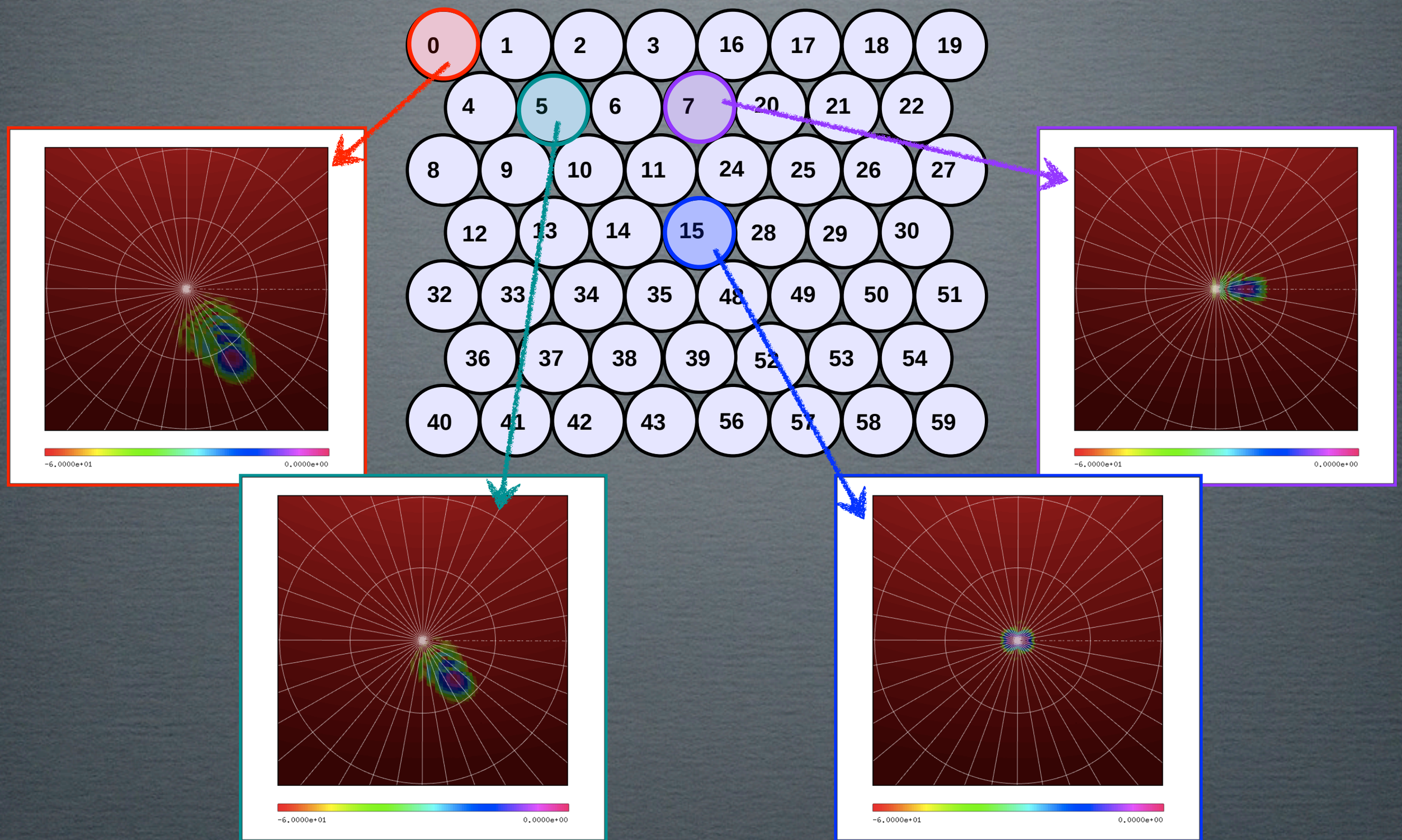


The camera



Central pixel (focus)

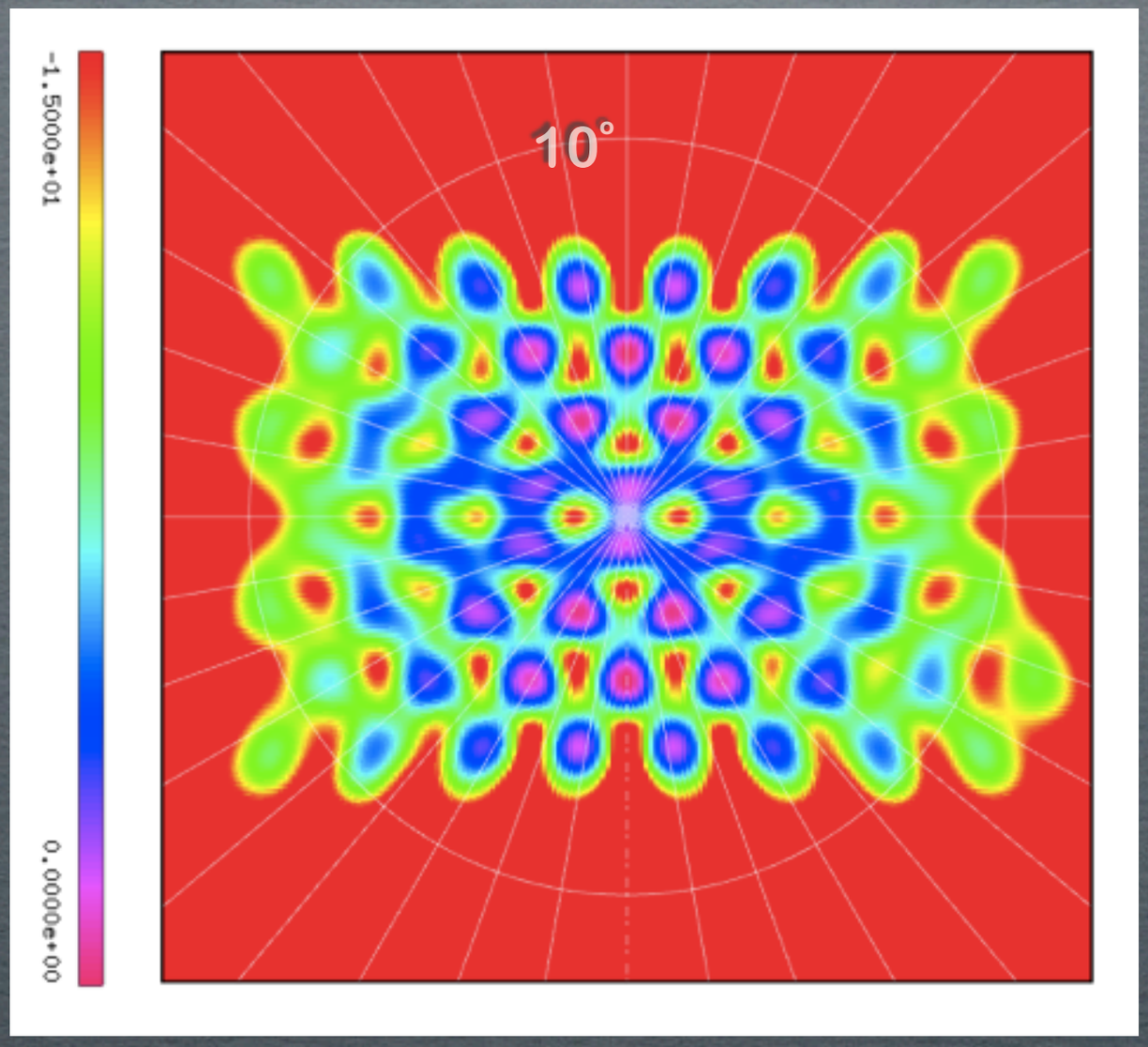
Feed Matrix 2D Patterns



2D Power Patterns

Normalized to the central feed (channel 15)

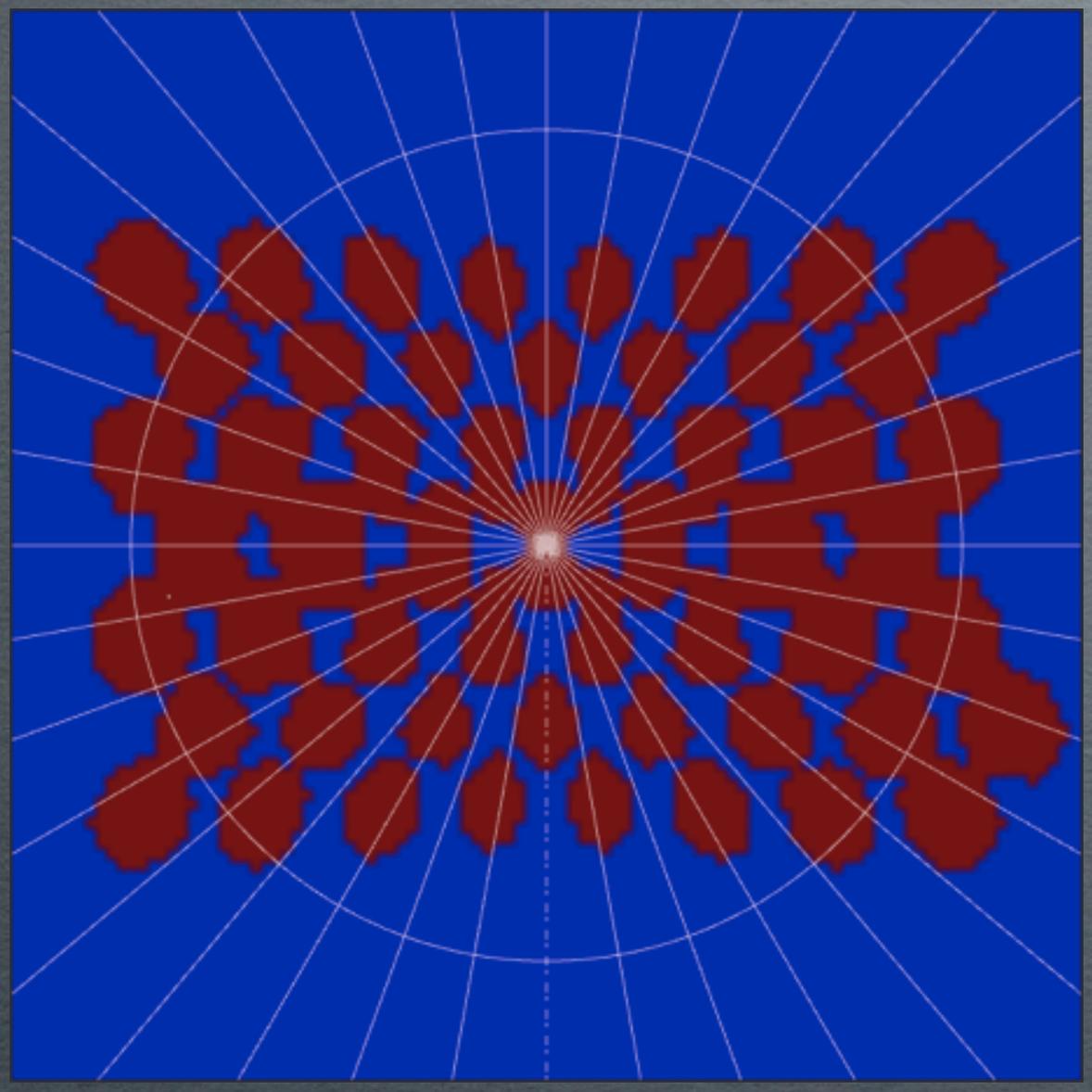
cut -15 dB



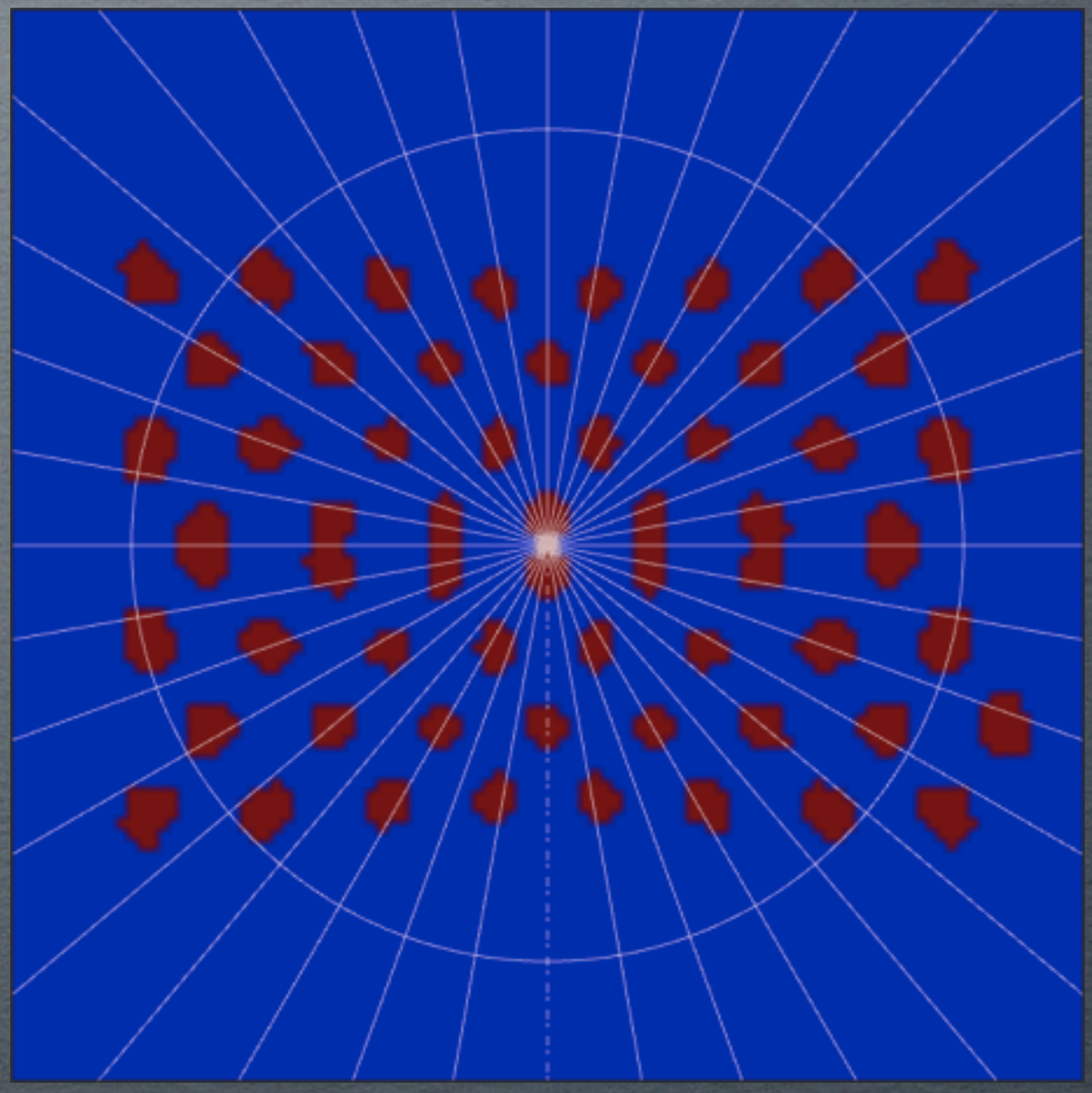
2D Power Patterns

Normalized to each pixel

cut -15 dB

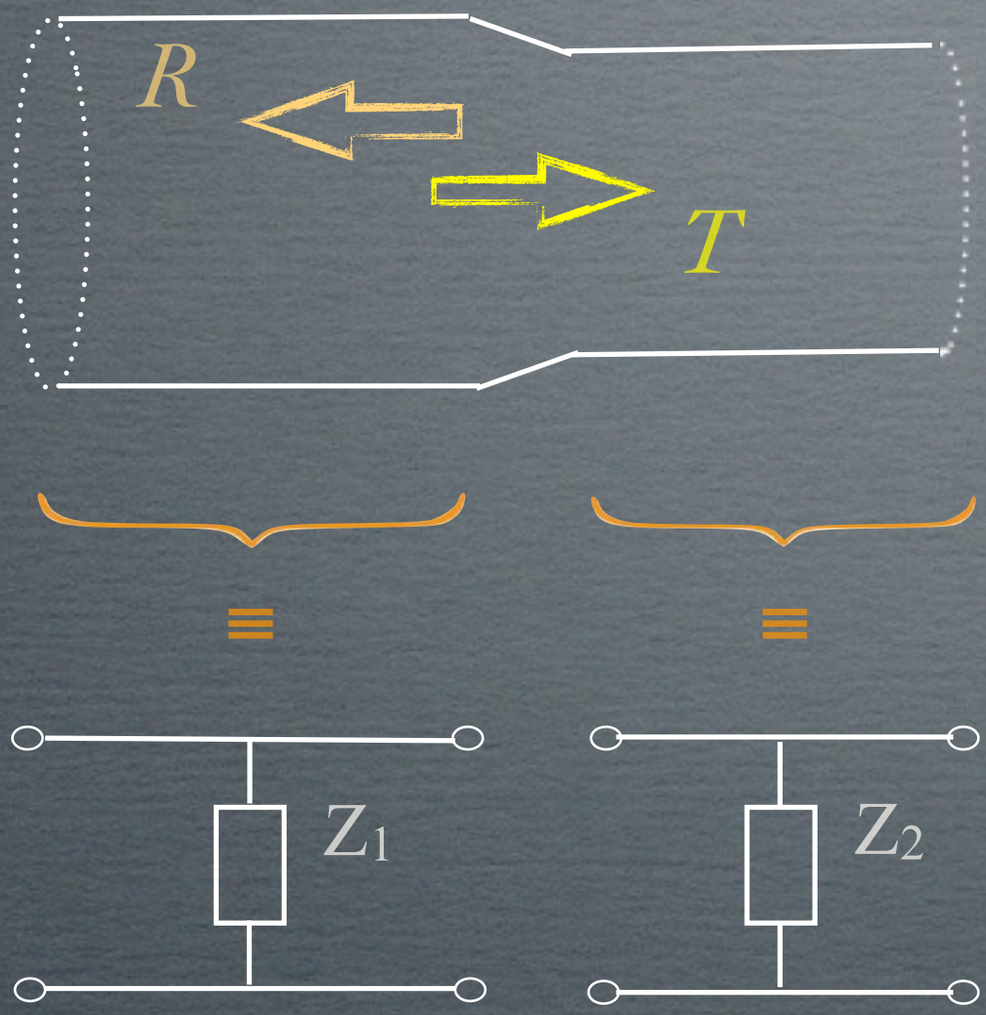


cut -3 dB



Transmission along the Feed

Reflexion in the feed



$$R \propto 1 - |\Gamma|^2 \qquad \Gamma = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

TE–mode $$Z_{mn} = \frac{j\omega\mu}{\gamma_{mn}}$$

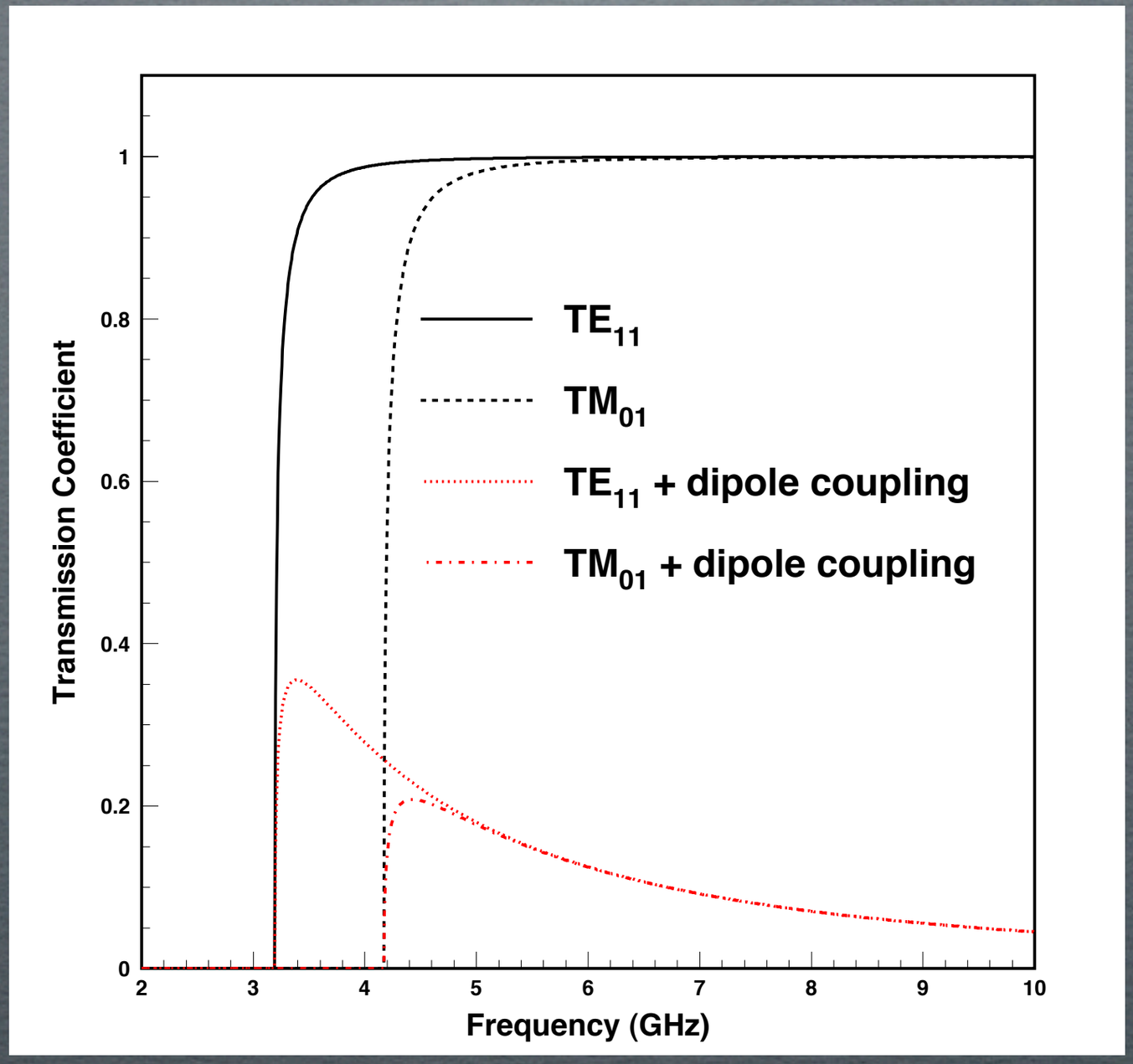
TM–mode $$Z_{mn} = \frac{\gamma_{mn}}{j\omega\epsilon}$$

$$\gamma_{mn} = (\kappa_{mn}^2 - k^2)^{1/2}$$

TE–mode $$J(\kappa_{mn}\, r) = 0$$

TM–mode $$J'(\kappa_{mn}\, r) = 0$$

Feed Transmission Coefficient

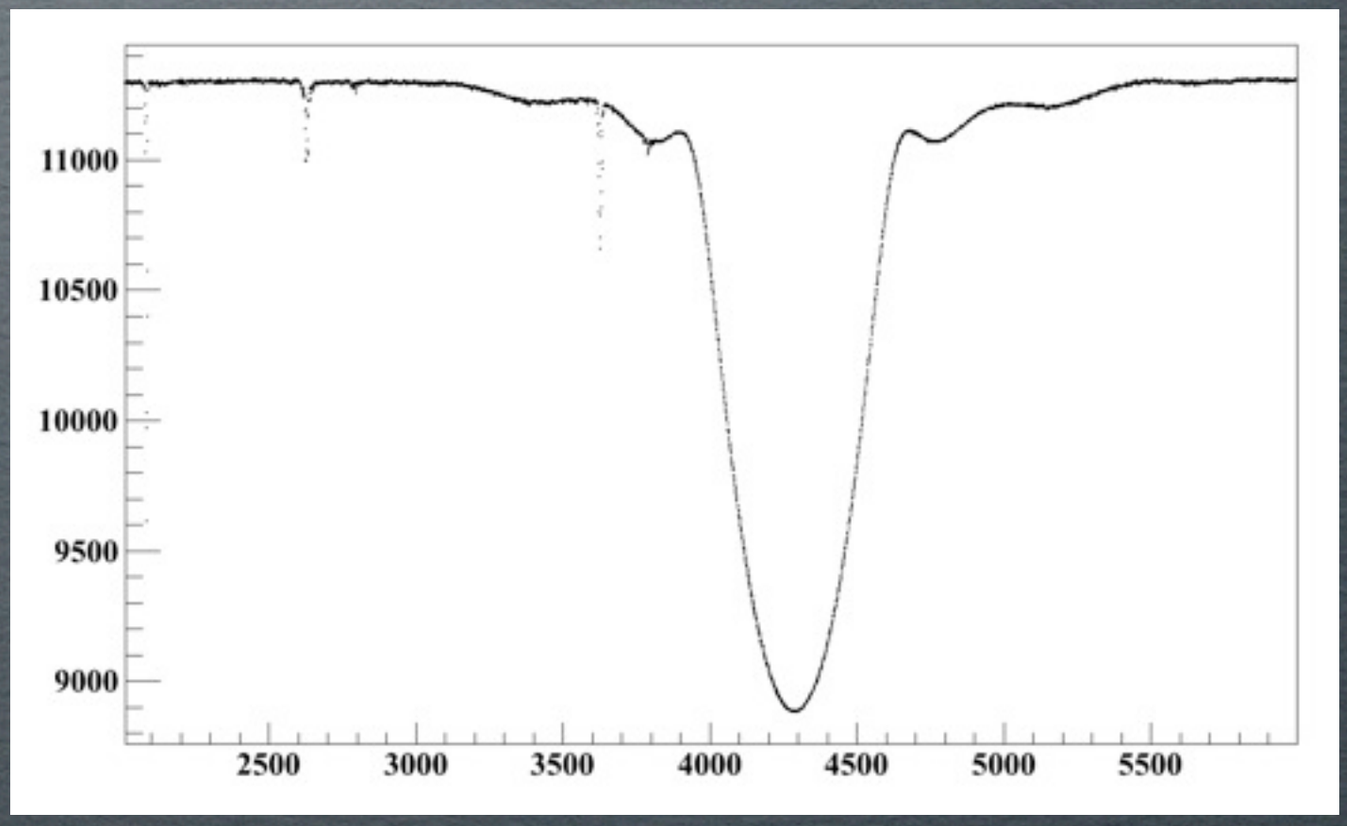


Additional effects simulated

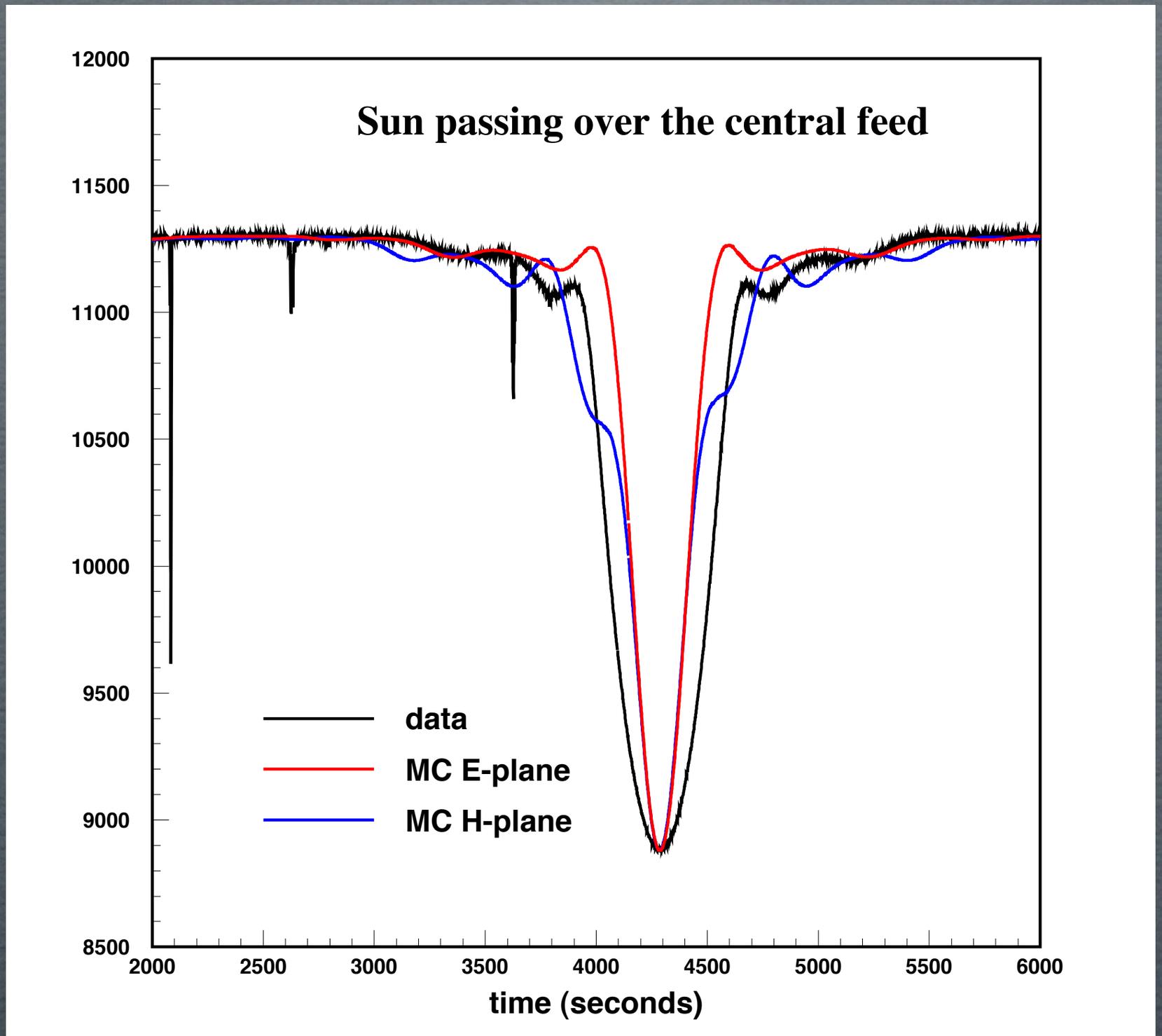
- Down-converter
  - frequency inversion (F_R = 5.15 GHz)
- Signal propagation in the coaxial cables
  - length: 33 m
  - dissipation losses in both ohmic conductor and dielectric

Calibration with the Sun

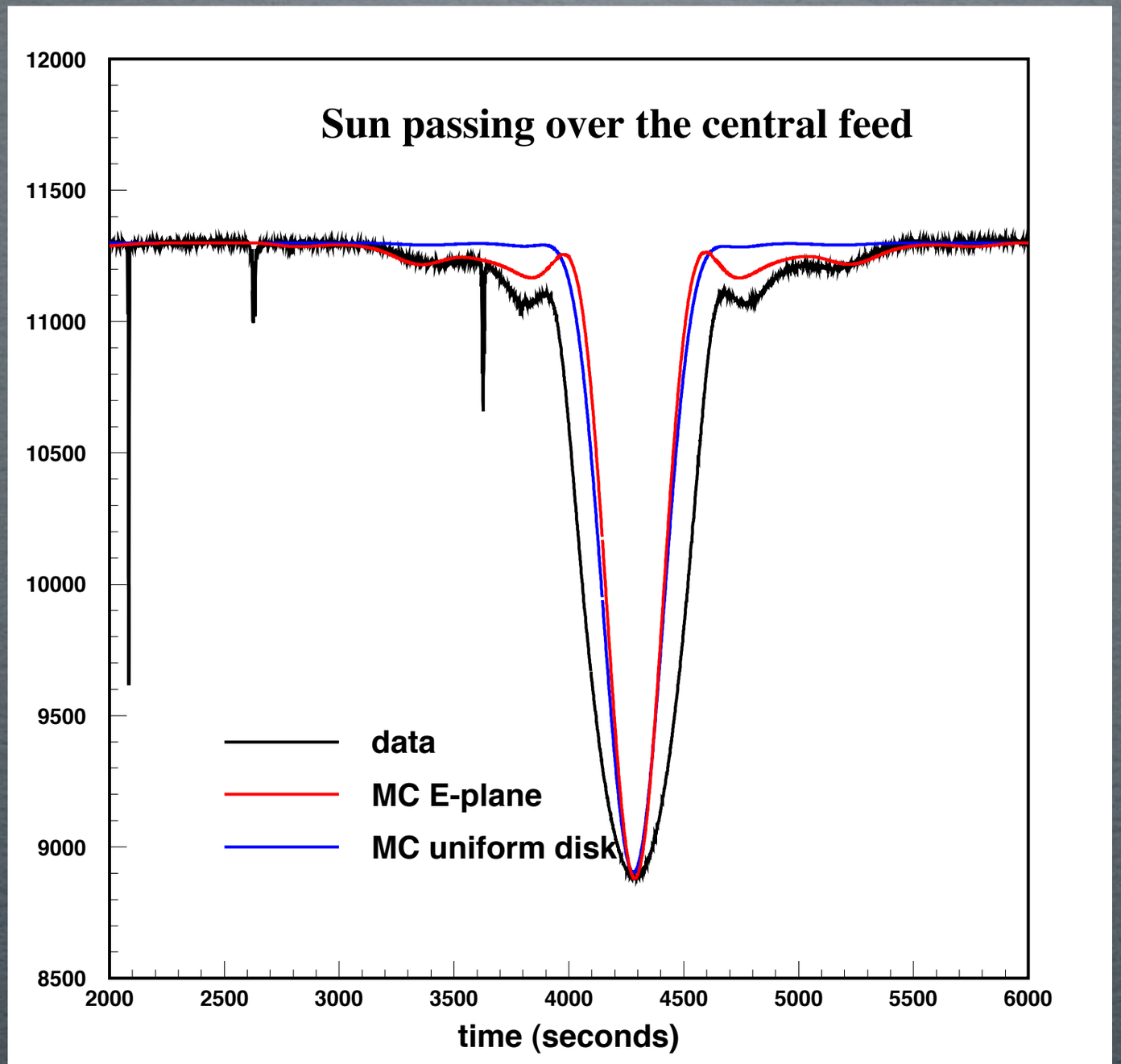
- Pointing direction:
  Azimuth: 154.72 ; Elevation: 61.93
- Run: Midas_2010_05_03_10h48m48s_bkg.txt
- Baseline 11300. Peak 8880.
- Nobeyama RP : 80 sfu
- With k =173 ADC/db
- F_sys = 3.3 10-22 W/m2/Hz
- Tsys = 120 K



Calibration with the Sun

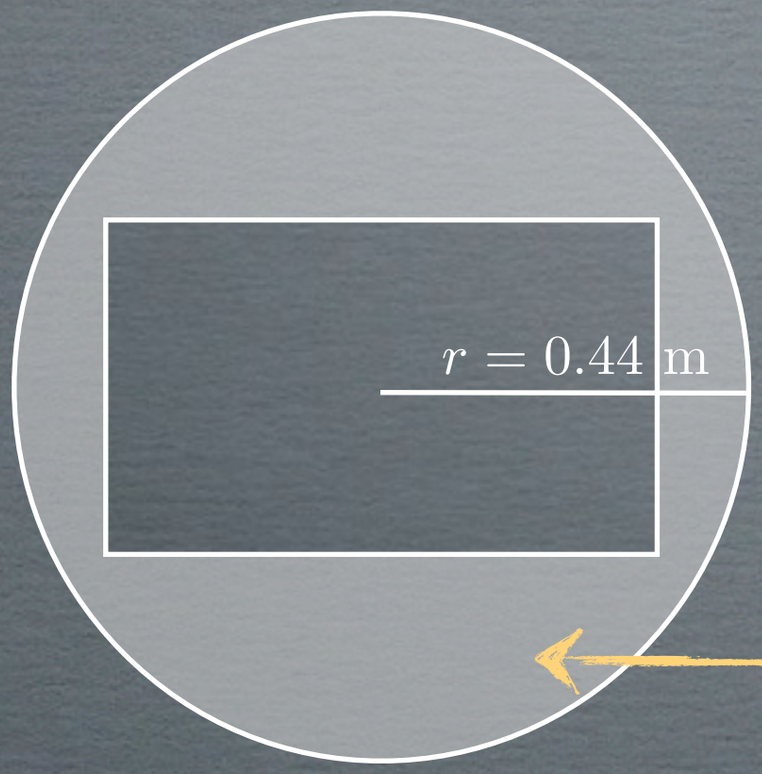


Calibration with the Sun



Calibration with the Sun

- Possible effect not taken into account:



- Another possibility is reflexions in the building walls: comparison with the Moon or Crab

Next Steps

- Effects of re-scattered field from feeds
- Illumination of the borders of metallic feed matrix support
- A better simulation of signal frequency downconverter: (its band pass and amplifier)
- phase errors due to reflector imperfections