# The antenna element

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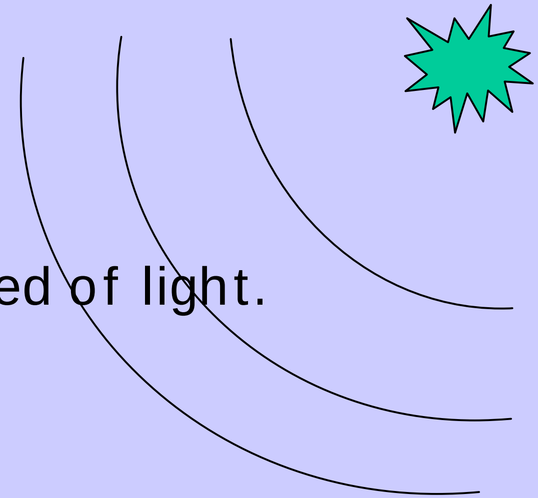
1. The role of the antenna in a Fourier synthesis radio telescope
2. The Compact array antenna.

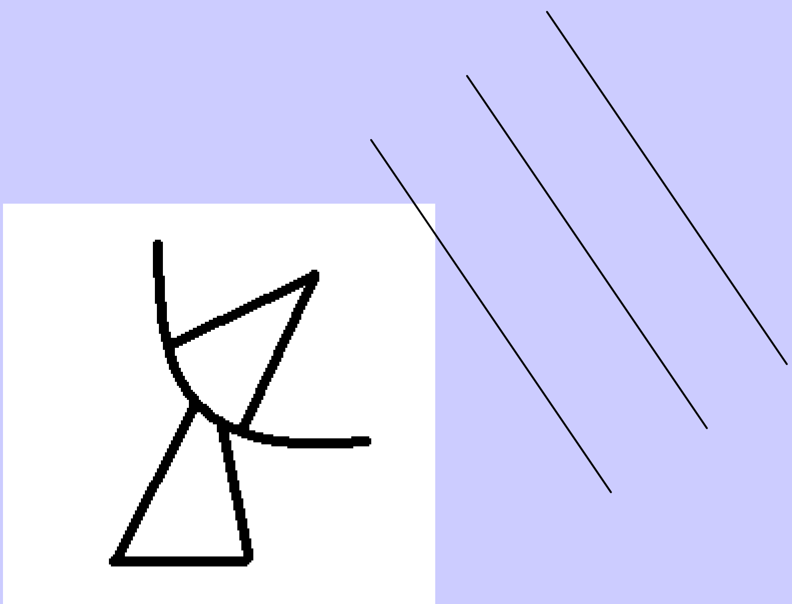
The radio sources in the sky

foreground, background, discrete, extended

-> Electromagnetic field on the ground

that rushes past us at the speed of light.





Sources on the sky cause an EM field on the ground.

Radio source

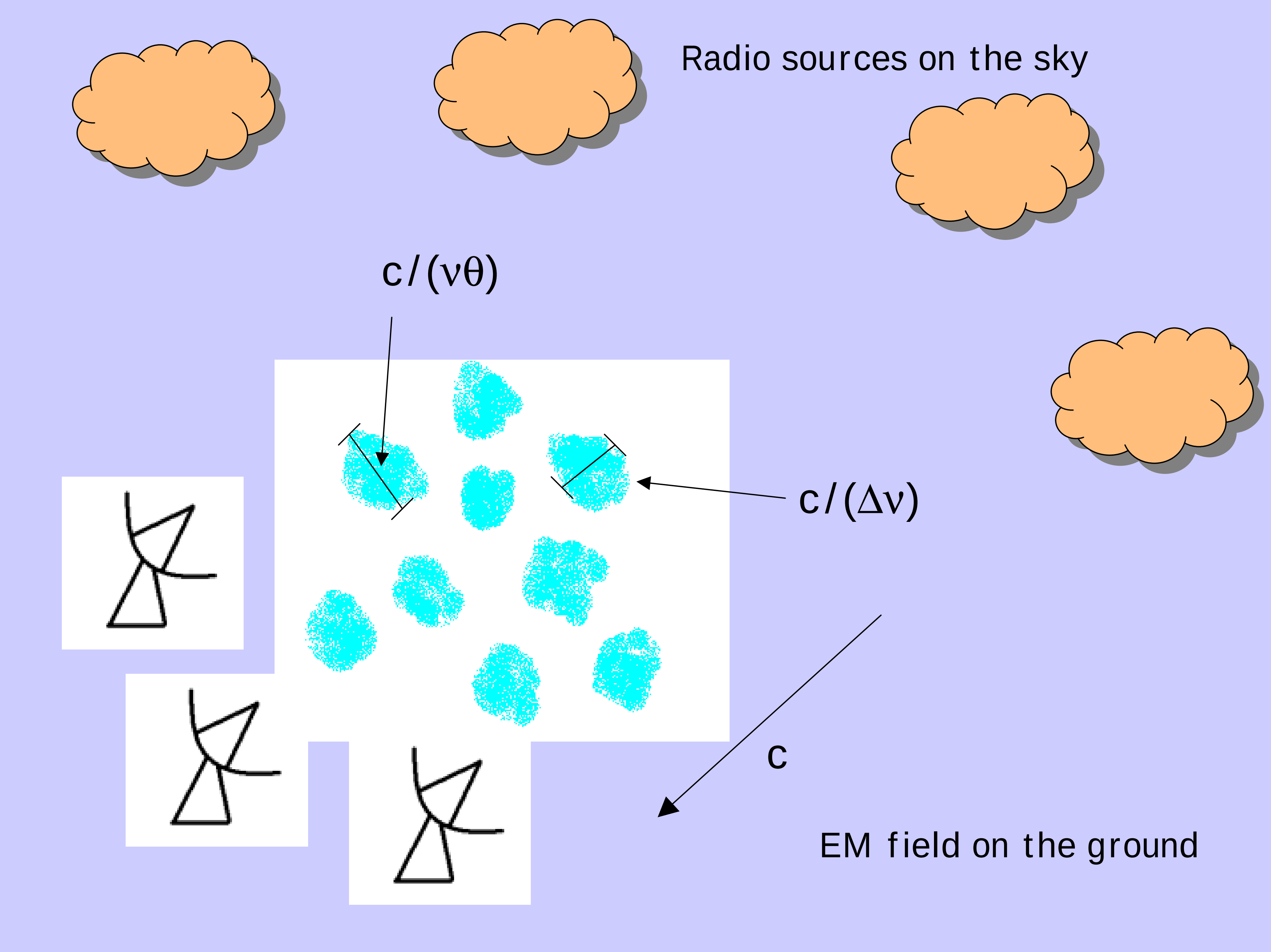
Sources appear to have different angular sizes θ

θ

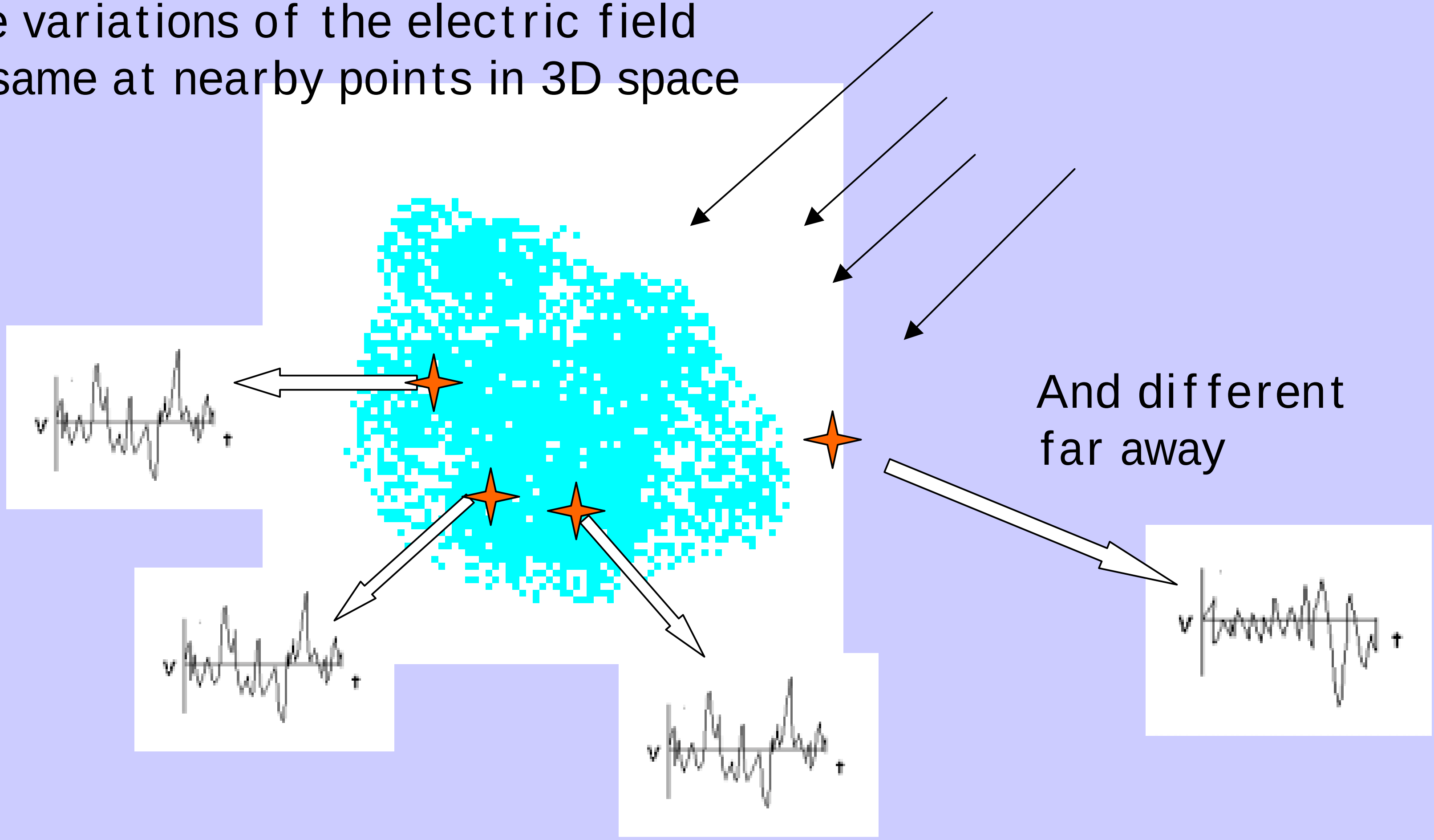
Different sources have different radio spectra:

continuum & line (Δν/ν)

EM field on the ground has 3D spatial "structure"


Radio sources on the sky
c/(νθ)
c/(Δν)
c
EM field on the ground

The time variations of the electric field are the same at nearby points in 3D space




And different far away

Examining the similarity (coherence) properties of the EM field on the ground tells us the structure and spectra of sources in the sky

How the telescope works:

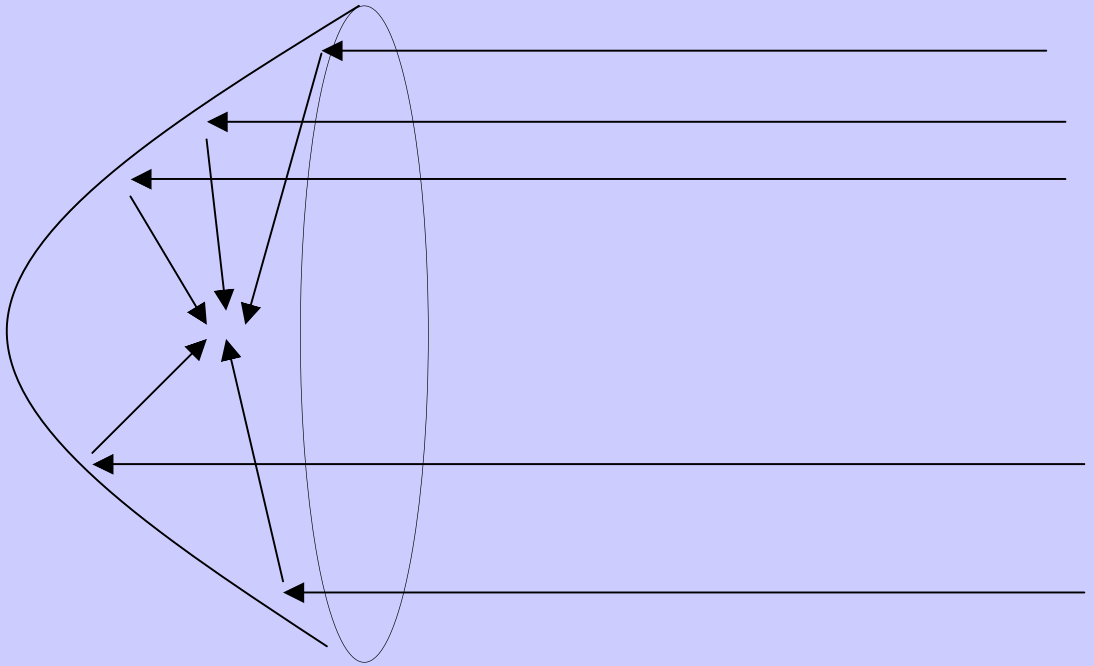
1. The antenna measures the EM field at its location on the ground and converts it into a voltage waveform in a cable.

2. The receivers magnify the voltage signal.

3. The correlator compares these field voltages
   at the different antenna locations and
   at different times
   and computes the degree of similarity => visibilities.

4. Miriad works out the radio
   brightness distribution &
   spectrum

Parabolic reflector:

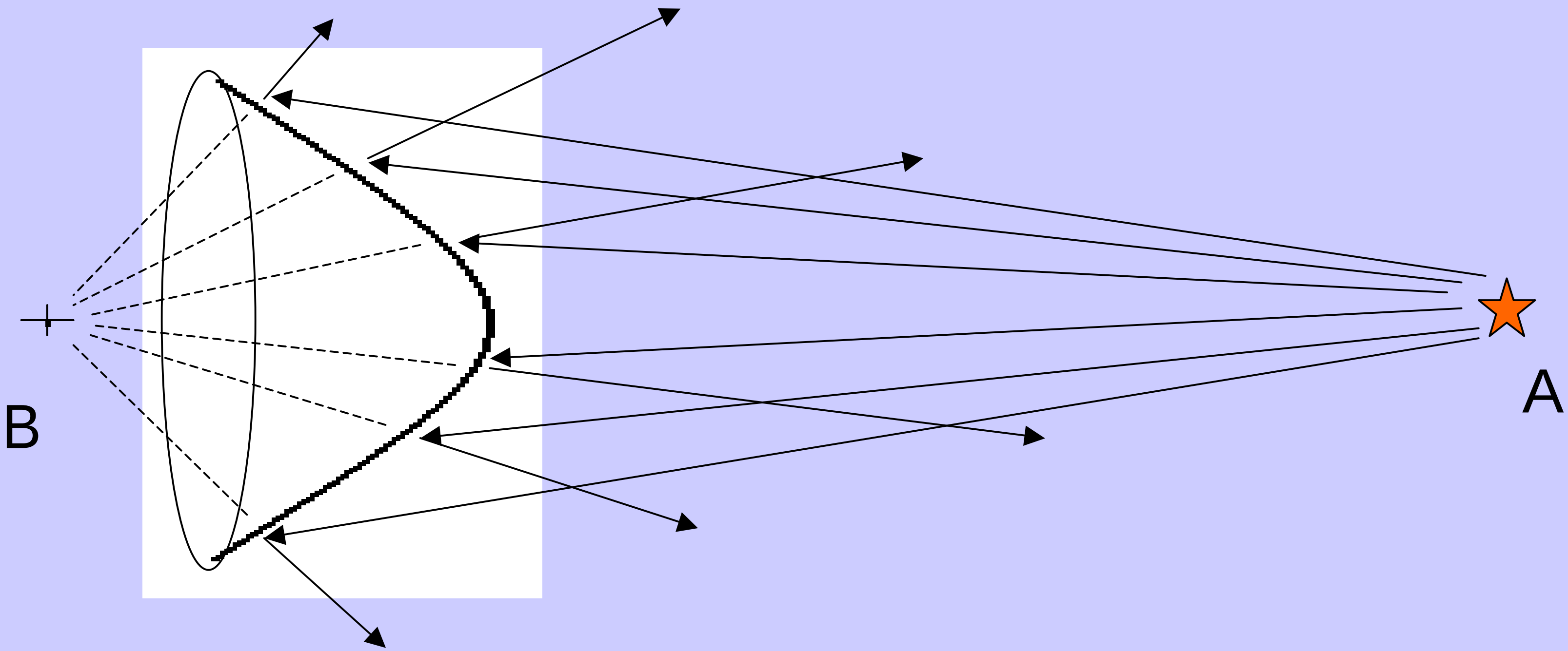


A parabolic reflector

adds all the fields from a surface = aperture

at a focal point.

## Hyperbolic reflector:

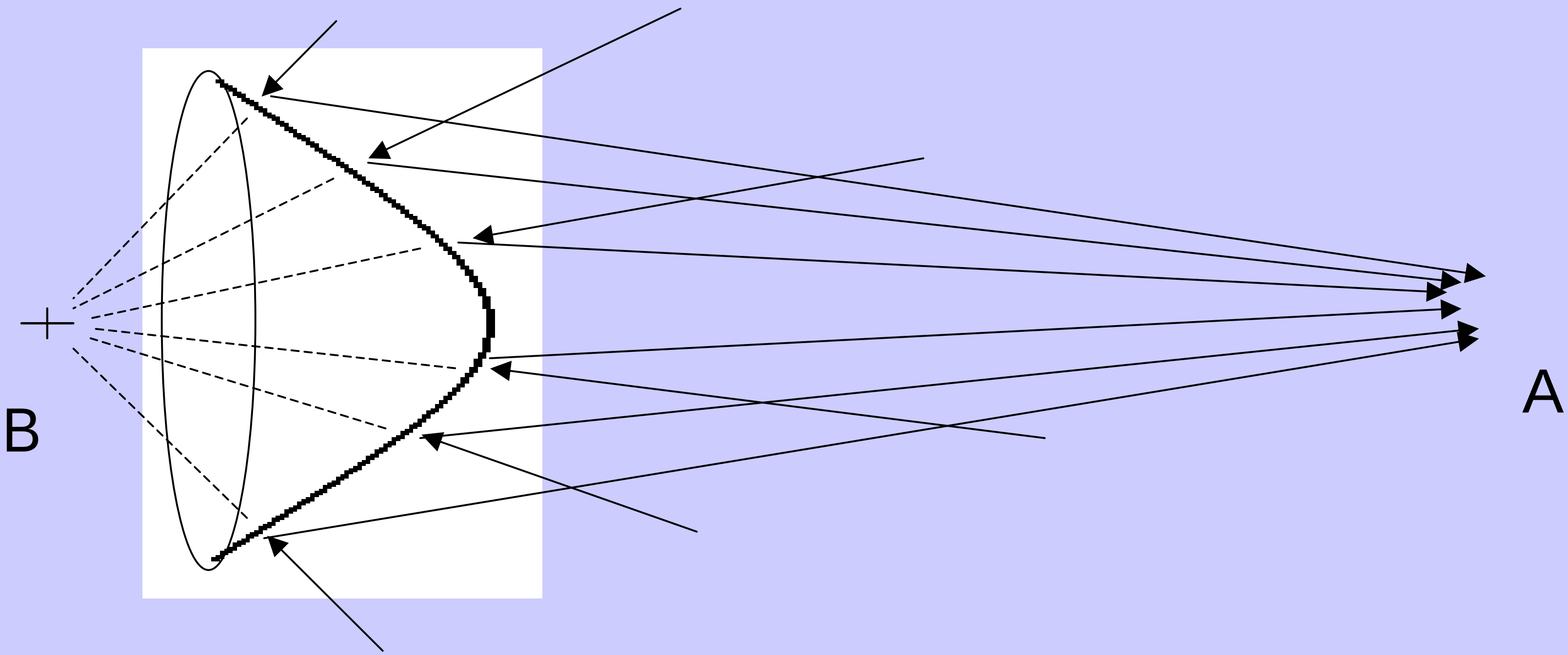



Light from the point A

reflecting off the hyperbola

appears to come from point B

Hyperbolic reflector:

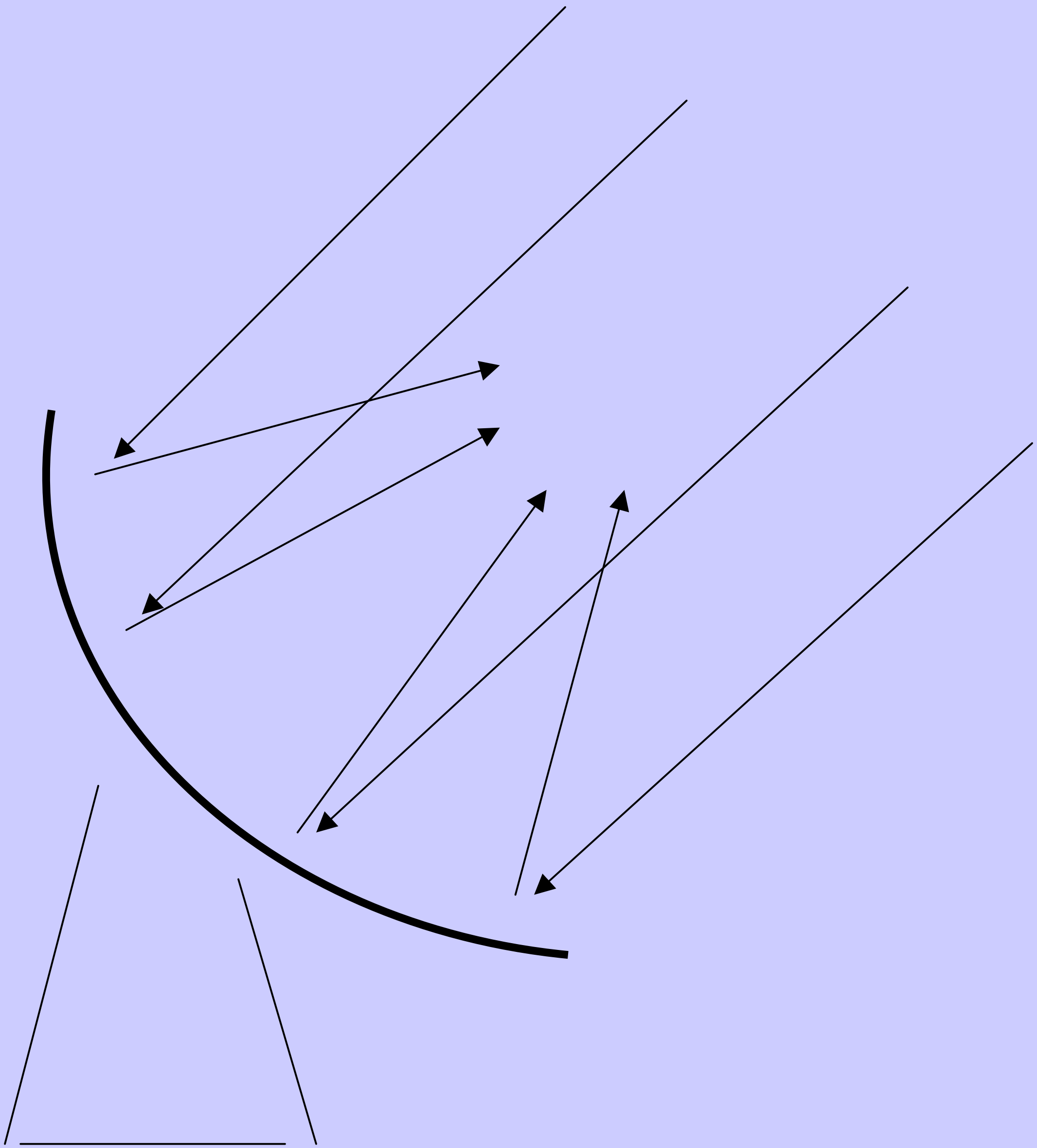


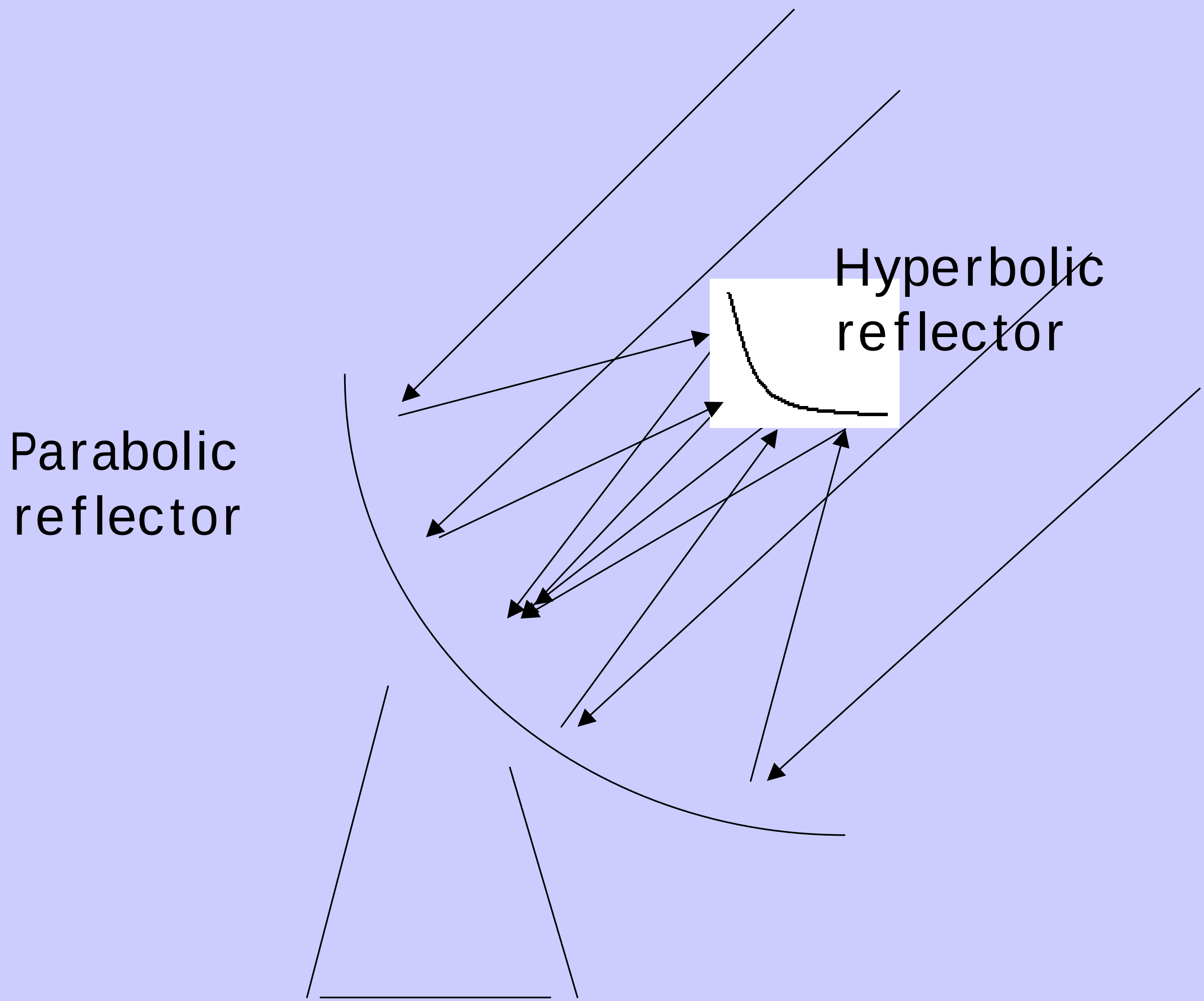

Light converging towards B

reflecting off the hyperbola

converges at A

Parabolic reflector




Hyperbolic reflector
Parabolic reflector

Parabolic primary & Hyperbolic secondary:

‘**Cassegrain**’ antenna

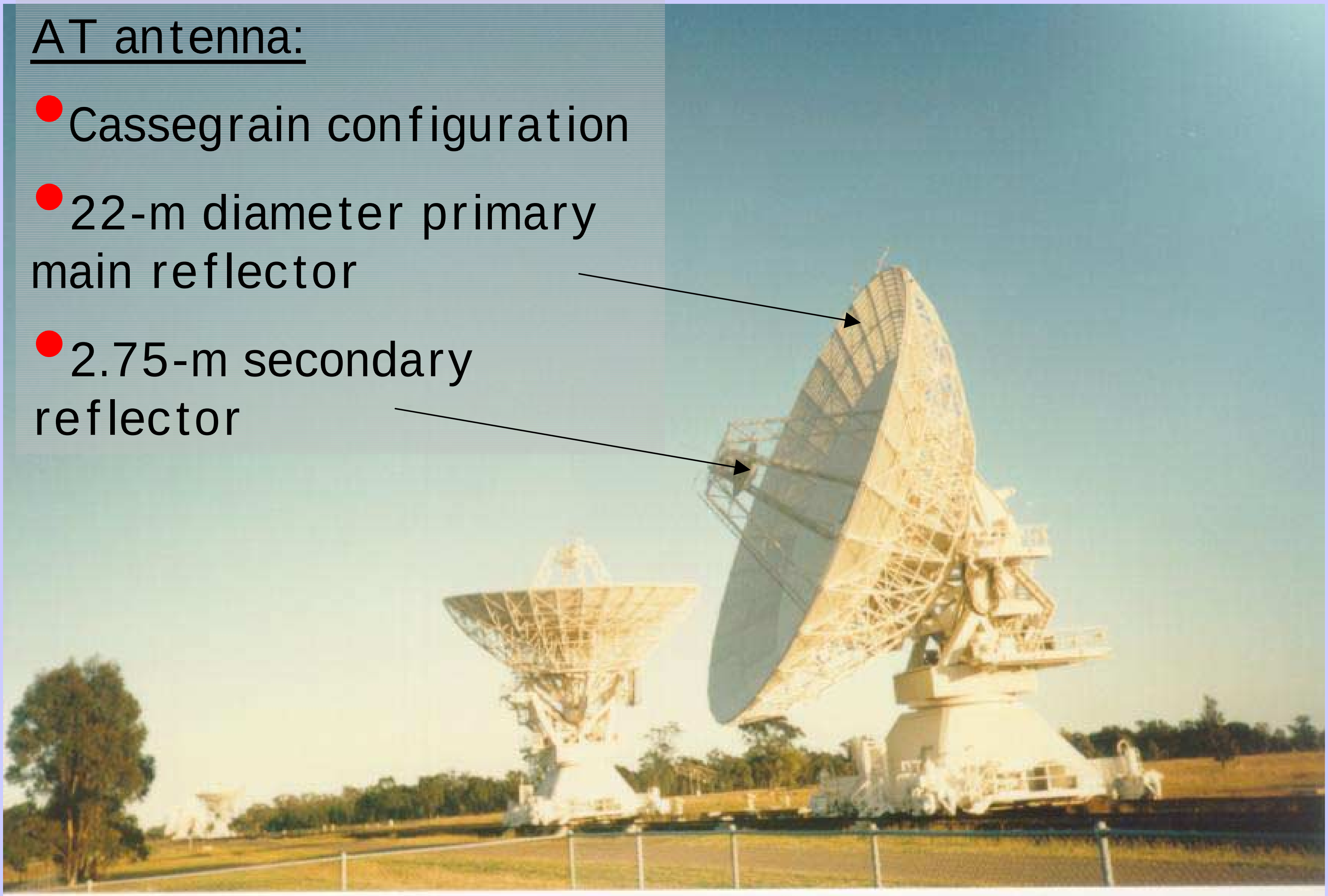
Newton’s comments on the Cassegrain design:

“....You see therefore, that the advantages of this design are none; but the disadvantages so great and unavoidable that I fear it will never be put in practice with good effect”

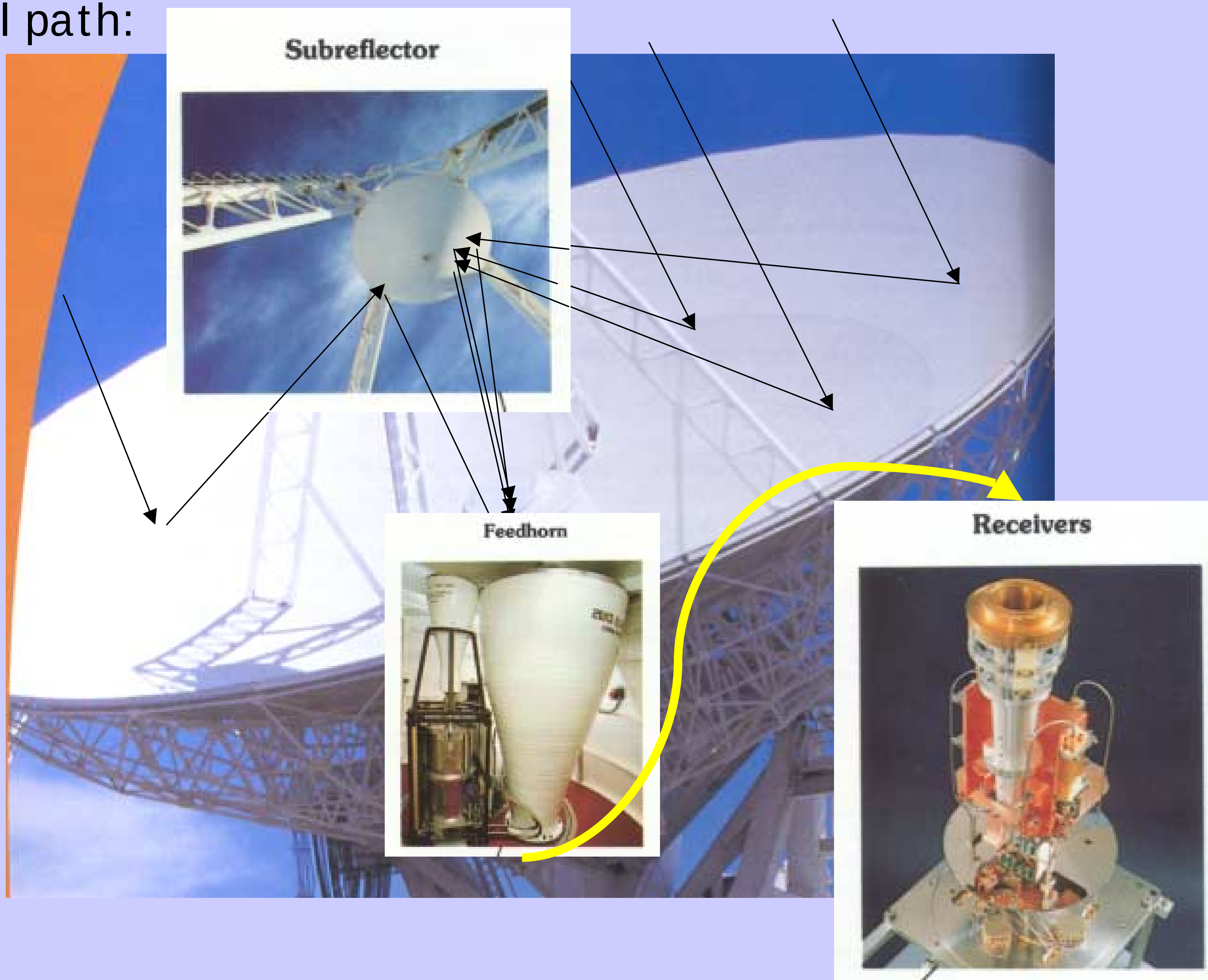
Phil. Trans. Royal. Soc. London. 7, 4056 (1672)

AT antenna:

- Cassegrain configuration
- 22-m diameter primary main reflector
- 2.75-m secondary reflector



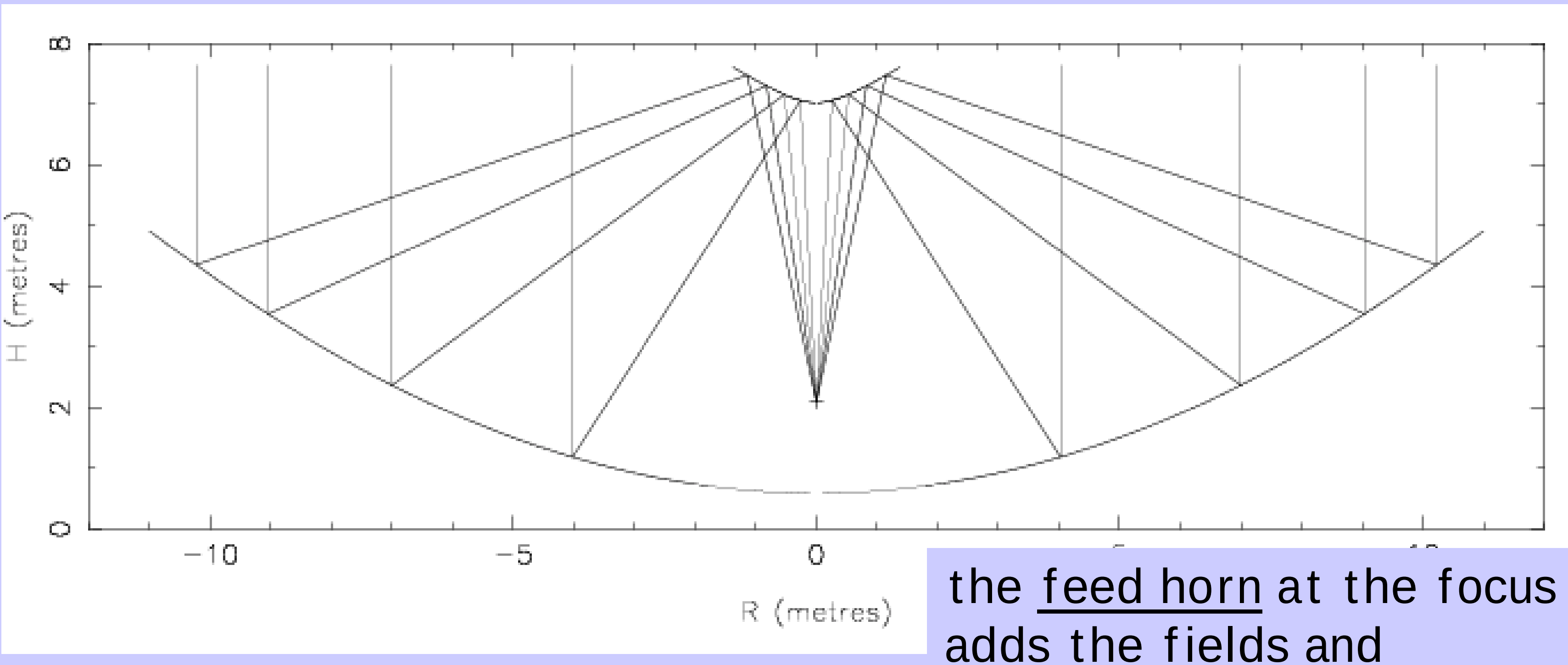
# Signal path:



The antenna collects the E-field over the aperture
at the focus

The focus is a fixed spot at all frequencies.

The reflector antenna is achromatic.



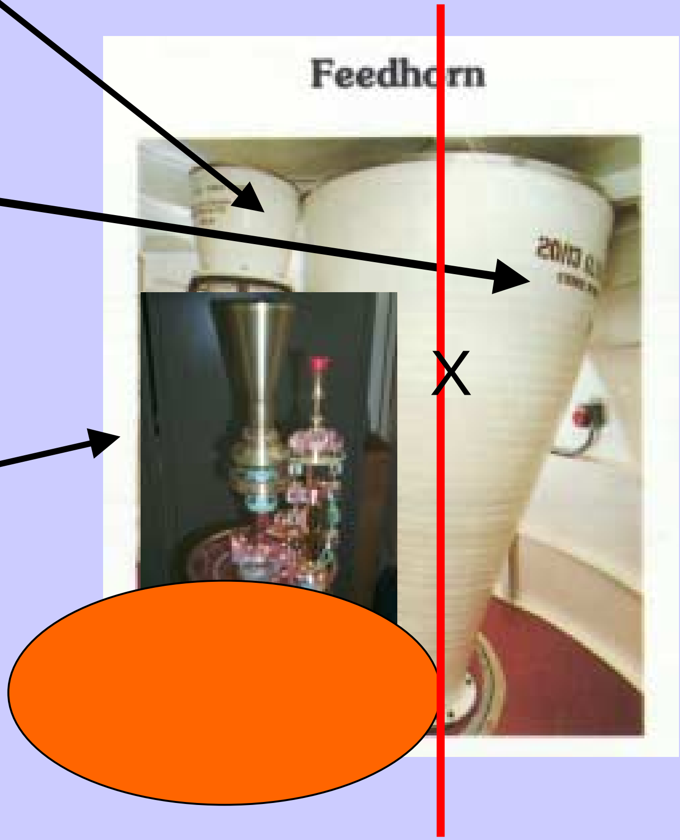

the feed horn at the focus
adds the fields and
gives the sum to the receiver
as a voltage.

Feed horns: at the focus located in the vertex room of the antenna

- 4.4-9.2 GHz = C & X bands
- 1.25-2.5 GHz = L & S bands

MNRF upgrade:

- 16-25 GHz = K band
- 85-115 GHz = W bands

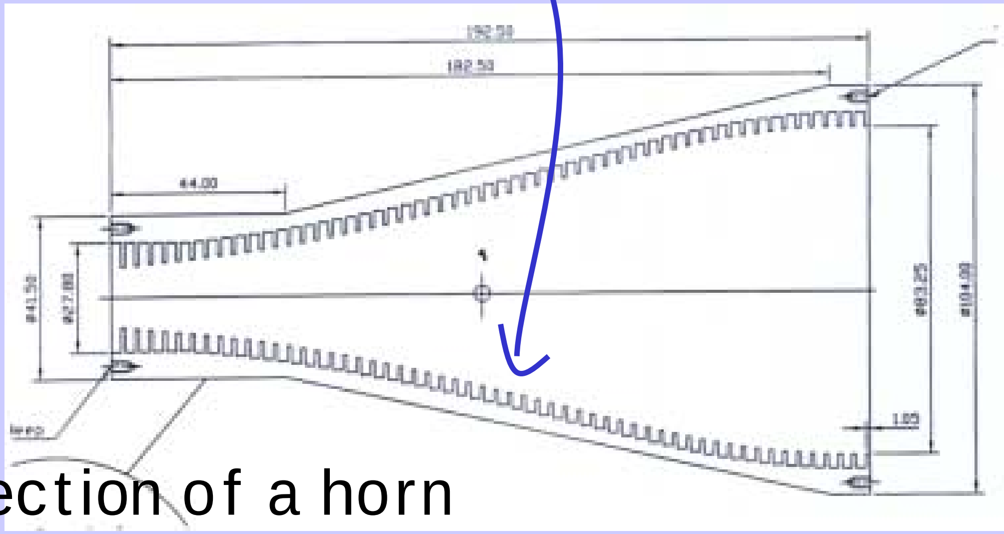



The feeds are mounted on a rotating turret.

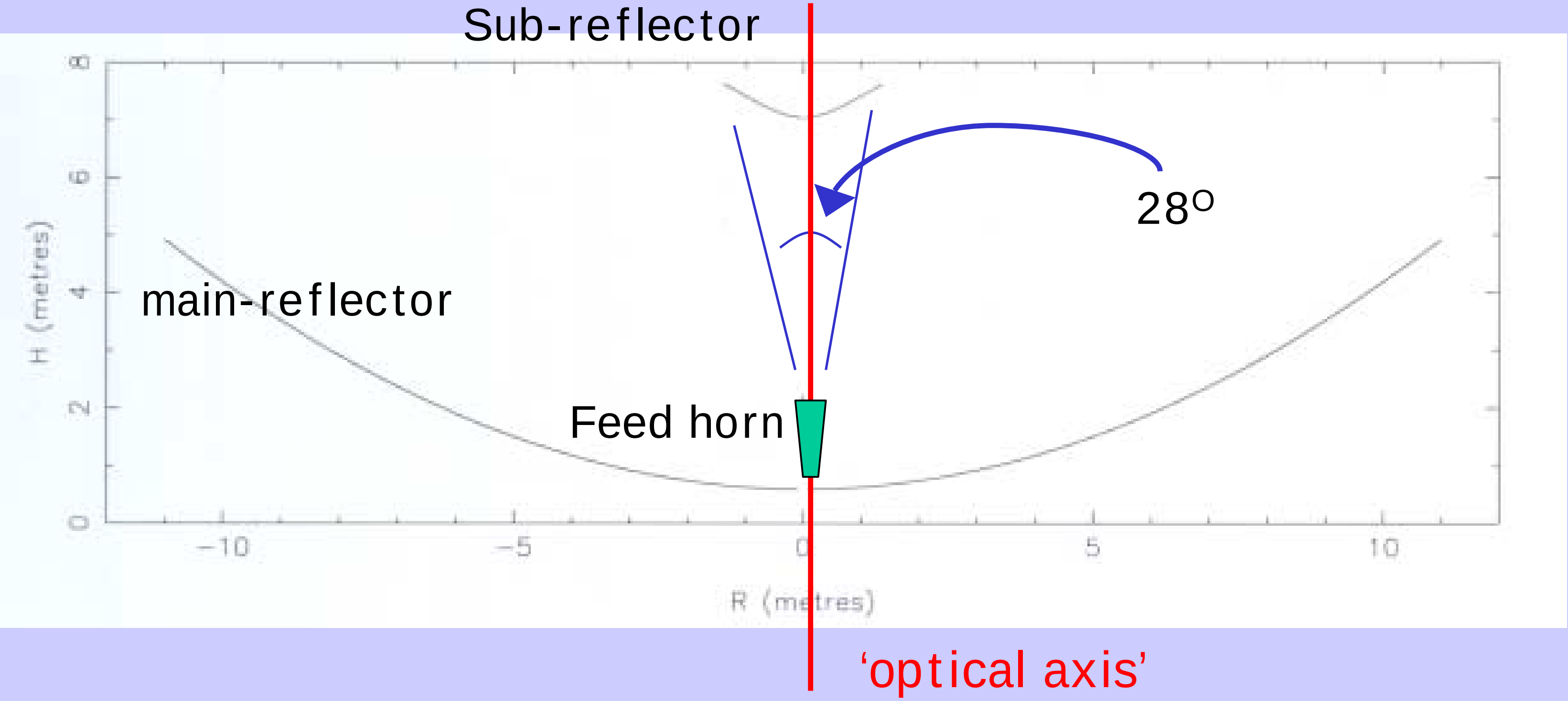
# Feeds are ‘compact’ and ‘corrugated’ horns

The inner profile is curved

The inner surface has grooves



Cross-section of a horn

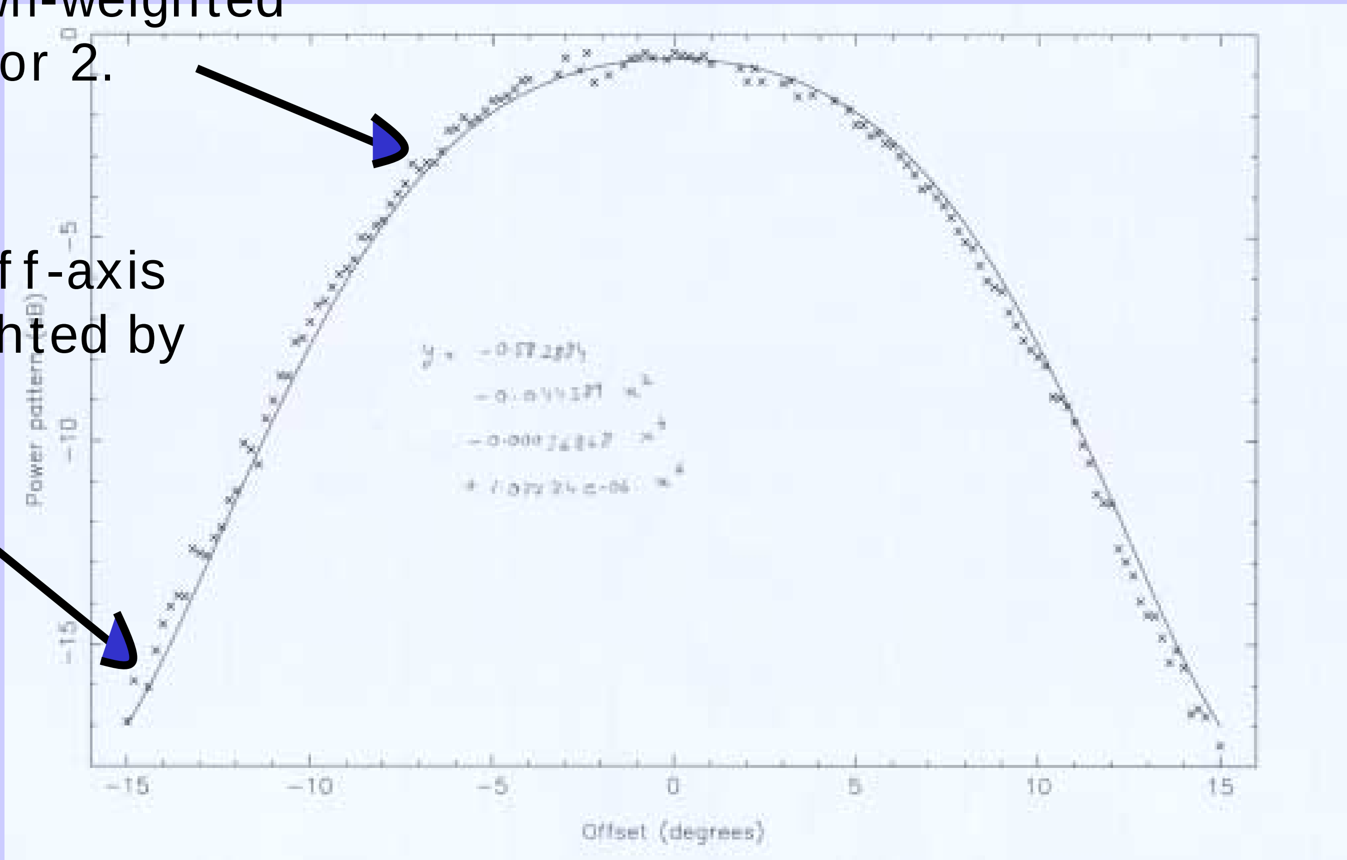



The feed horn adds all the rays that come from the 28 deg. wide sub-reflector.

The feed down-weights rays that come off-axis.

Rays 9 deg. off-axis are down-weighted by factor 2.

Rays 14 deg. off-axis are down-weighted by factor 6.



The feed down-weights rays that come off-axis.

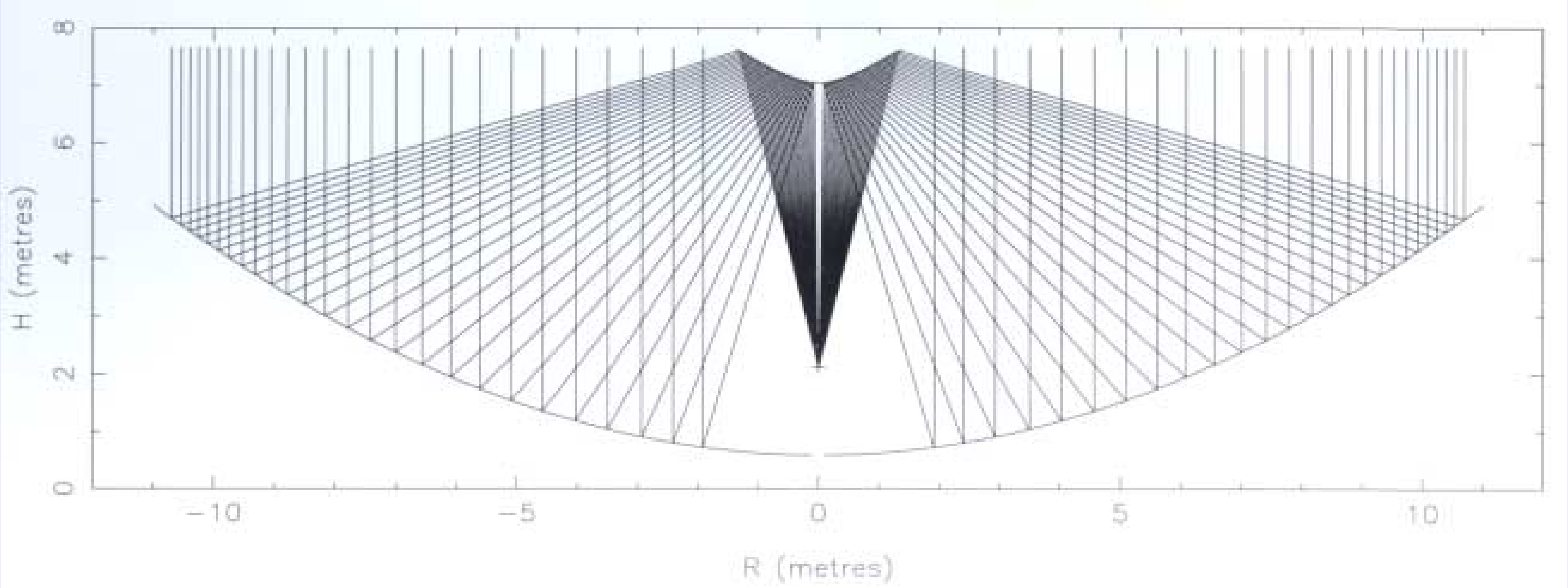
Therefore the main and sub-reflectors have been SHAPED

(the surfaces are not exactly parabolic/hyperbolic)

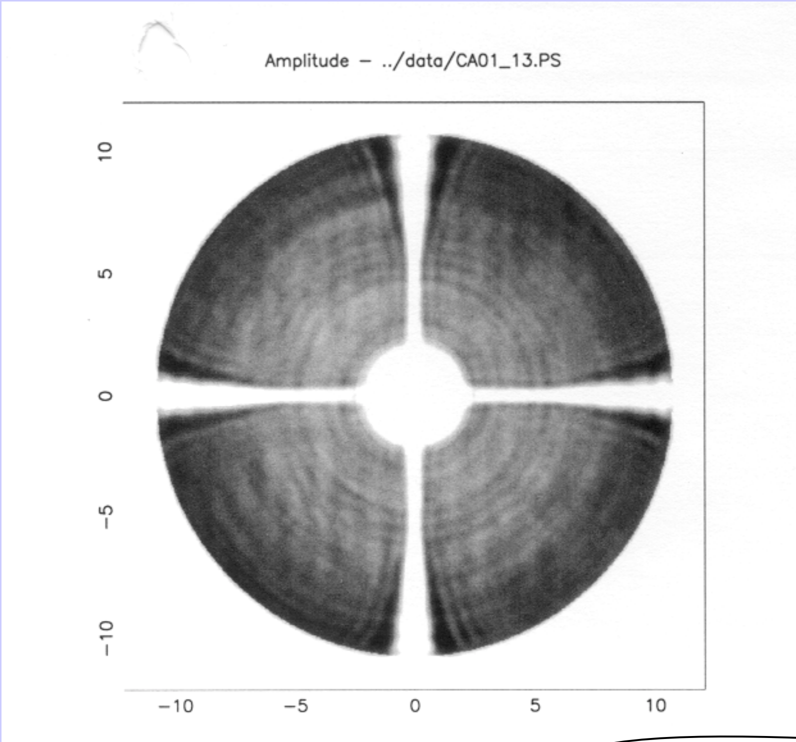
1. more numbers of rays are gathered from the edge of the sub-reflector=edge of the main reflector.

2. the ray paths all have equal length and the rays from the aperture surface arrive at the focus ‘in-phase’

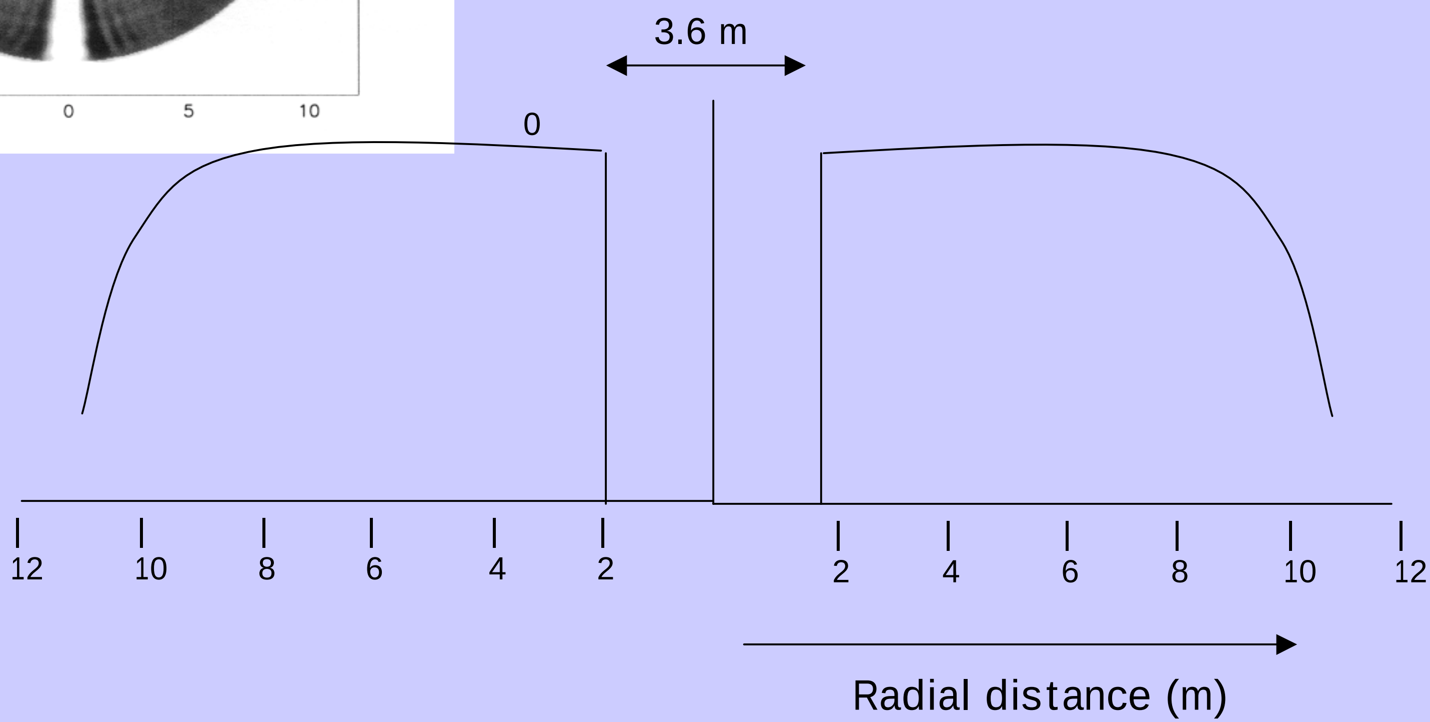
The shaped reflectors gather more rays from the edge




This compensates for the lower weight that the feed gives to off axis rays.




Resulting sensitivity of the antenna across the aperture

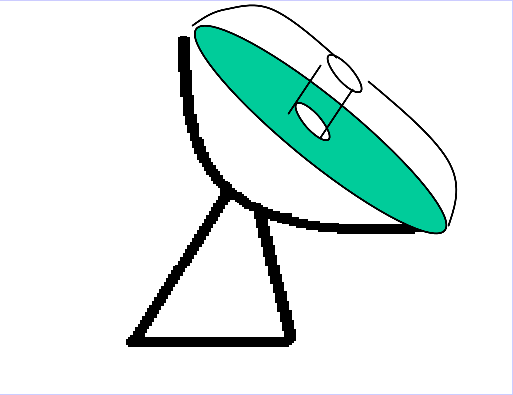


Instead of measuring the similarity (coherence) between the EM fields at two points in space,

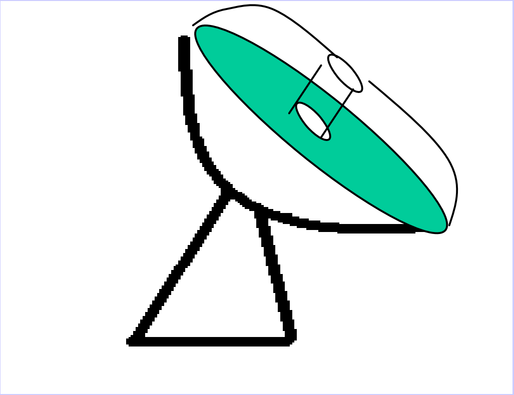
in practice,

the interferometer measures the coherence between the EM fields averaged over

two regions of space = antenna apertures.



$$V1(t) \propto \sum E(\underline{r1})$$



$$V2(t) \propto \sum E(\underline{r2})$$

$$V1 \times V2 \propto \left(\sum E(\underline{r1})\right) \times \left(\sum E(\underline{r2})\right)$$

$$\propto \sum \left( E(\underline{r1}) \times E(\underline{r2}) \right)$$

The interferometer measures the summation of the coherence between every element of aperture 1 with every element of aperture 2.

The measurement of the coherence between one pair of aperture elements

=>

a single point measurement
on the u,v - plane
visibility plane
spatial_frequency plane.

The measurement of the coherence between every pair of aperture elements

=>

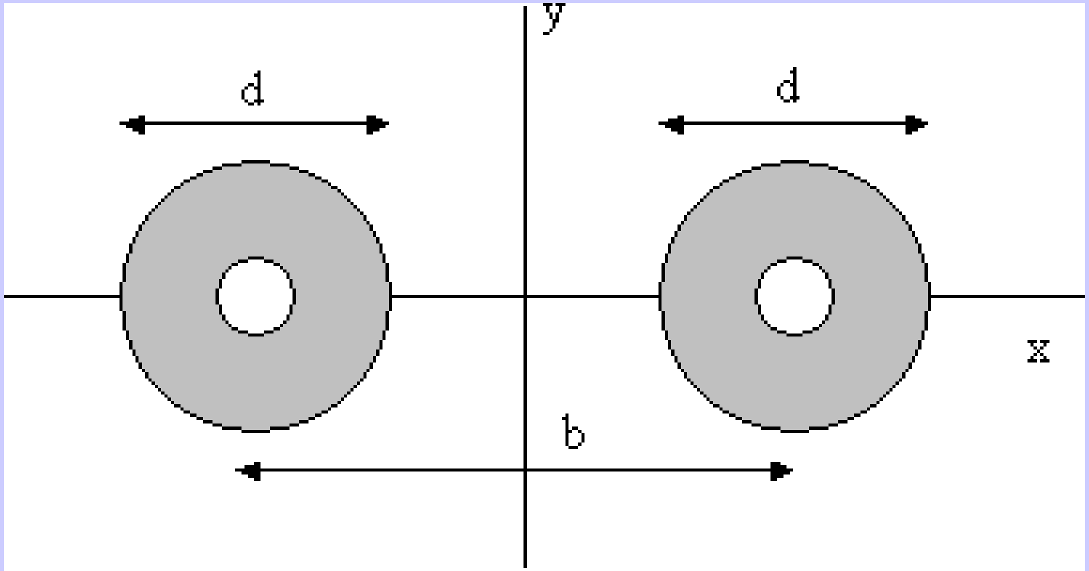
an average measurement over a region

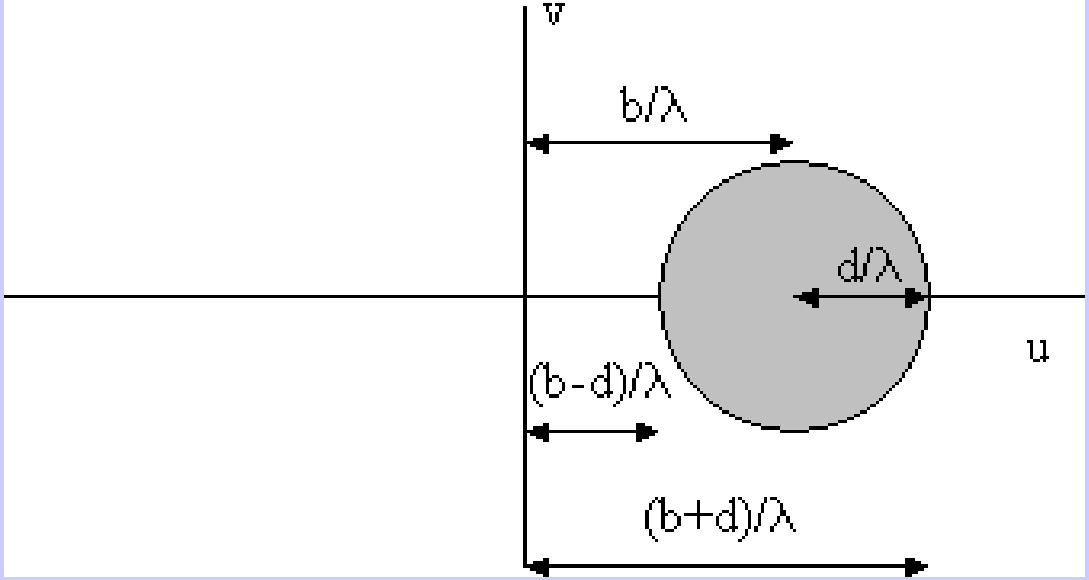
of the u,v - plane

visibility plane

spatial_frequency plane.

The shape of the region = the cross-correlation of the voltage weighting patterns in the two apertures.


y
d
d
x
b


v
b/λ
d/λ
u
(b-d)/λ
(b+d)/λ

For a source offset from the antenna pointing centre by angle

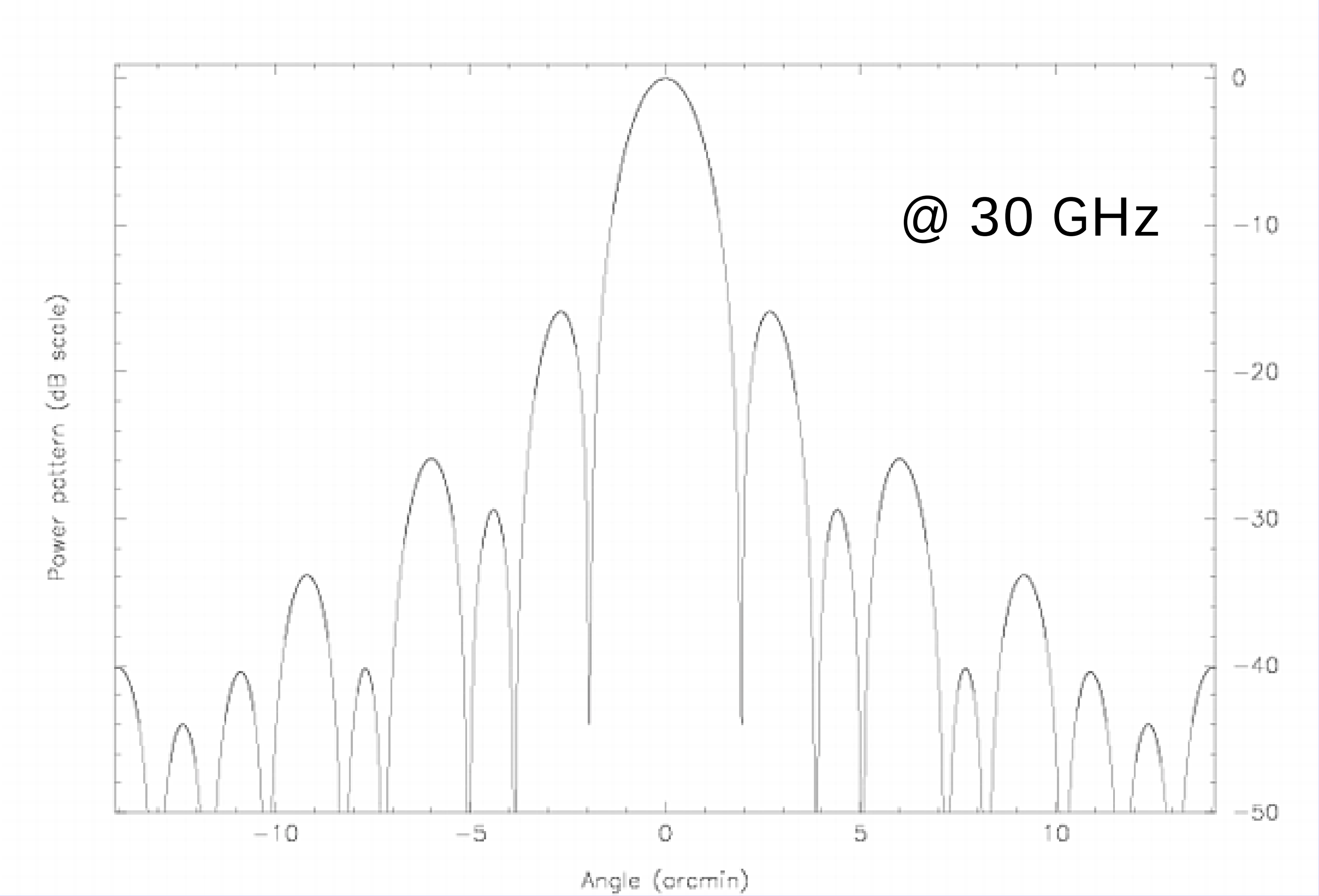
$$\xi = \lambda / (2d) \text{ radians}$$

The phase of the complex coherence function winds through $2\pi$ radians across the sampled region in the visibility plane.

And the interferometer will give zero measurement.

The amount of cancellation depends on the

- Antenna optics and
- Distance of a source from the antenna pointing centre.



Ideally, the antenna sums the EM field vectors over the aperture in phase.

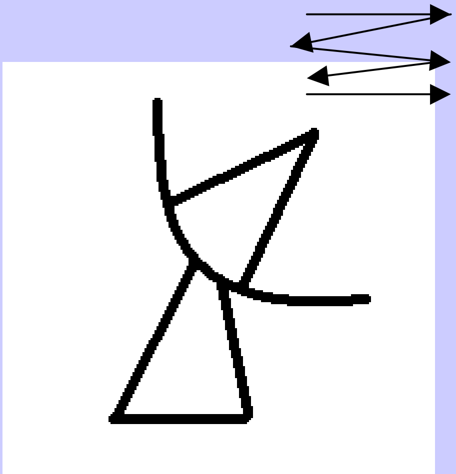
But if

1. the optics is out of focus
2. the feed or SR is off axis
3. the MR is deformed (elevation dependent gravity deformation)
4. the reflector surfaces have small scale irregularities

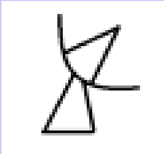
The EM fields will not be in phase when they propagate from the aperture plane to the feed.

The cancellation will result in a loss of signal.
The loss might depend on the position of the source.

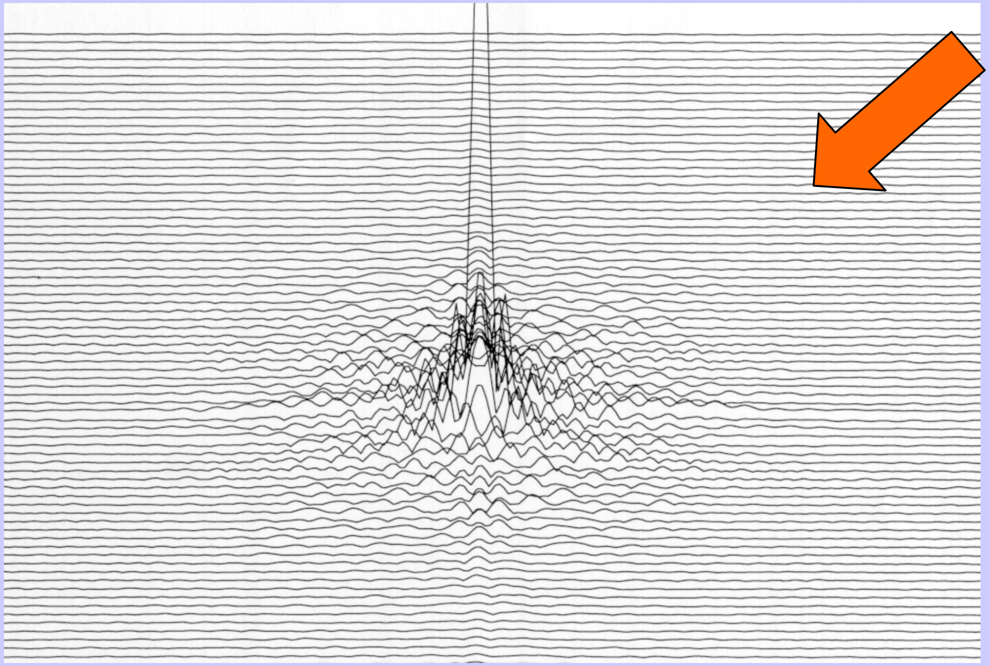
# **‘Holography’**



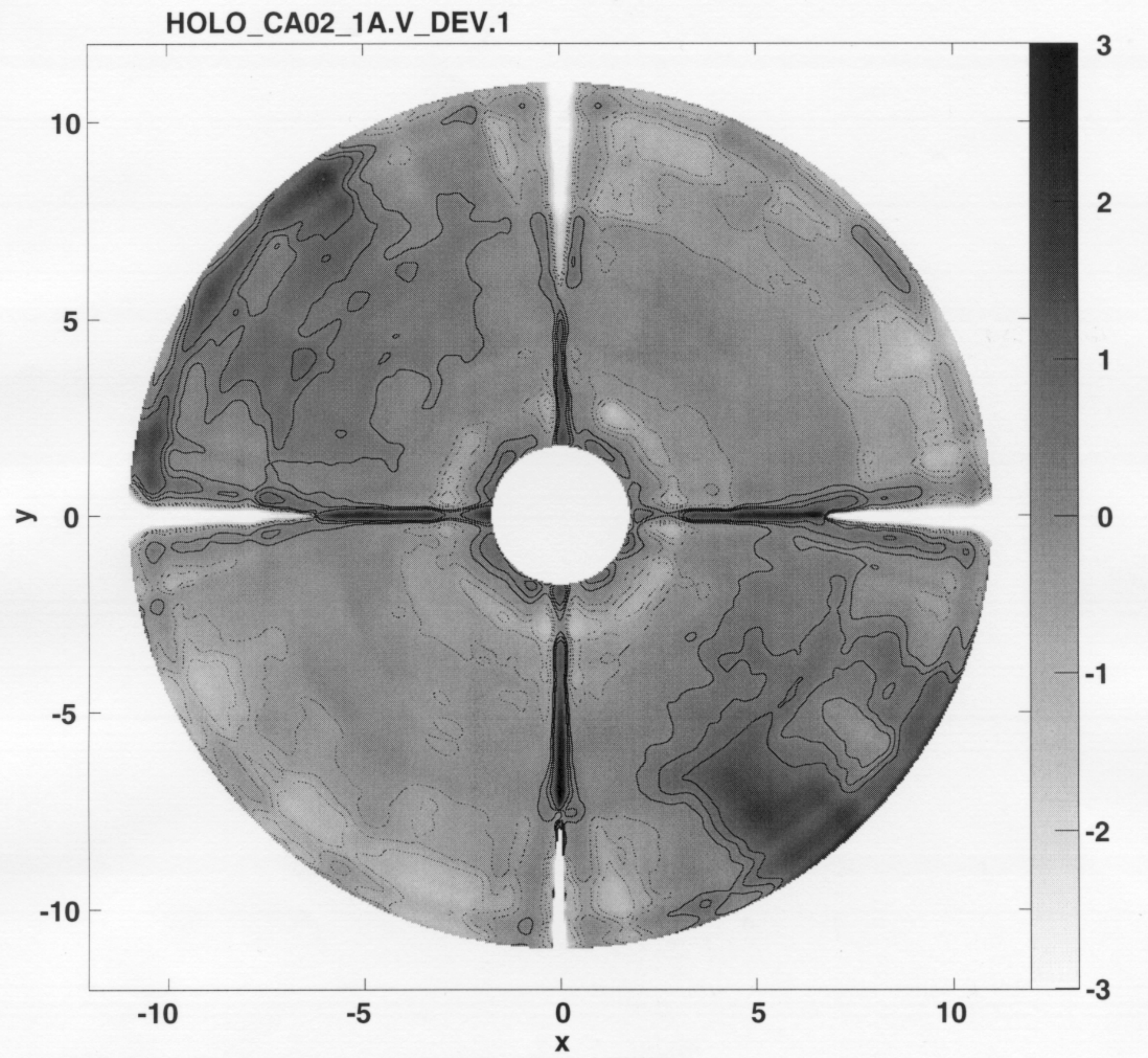
Antenna scanning satellite



Reference antenna tracking satellite

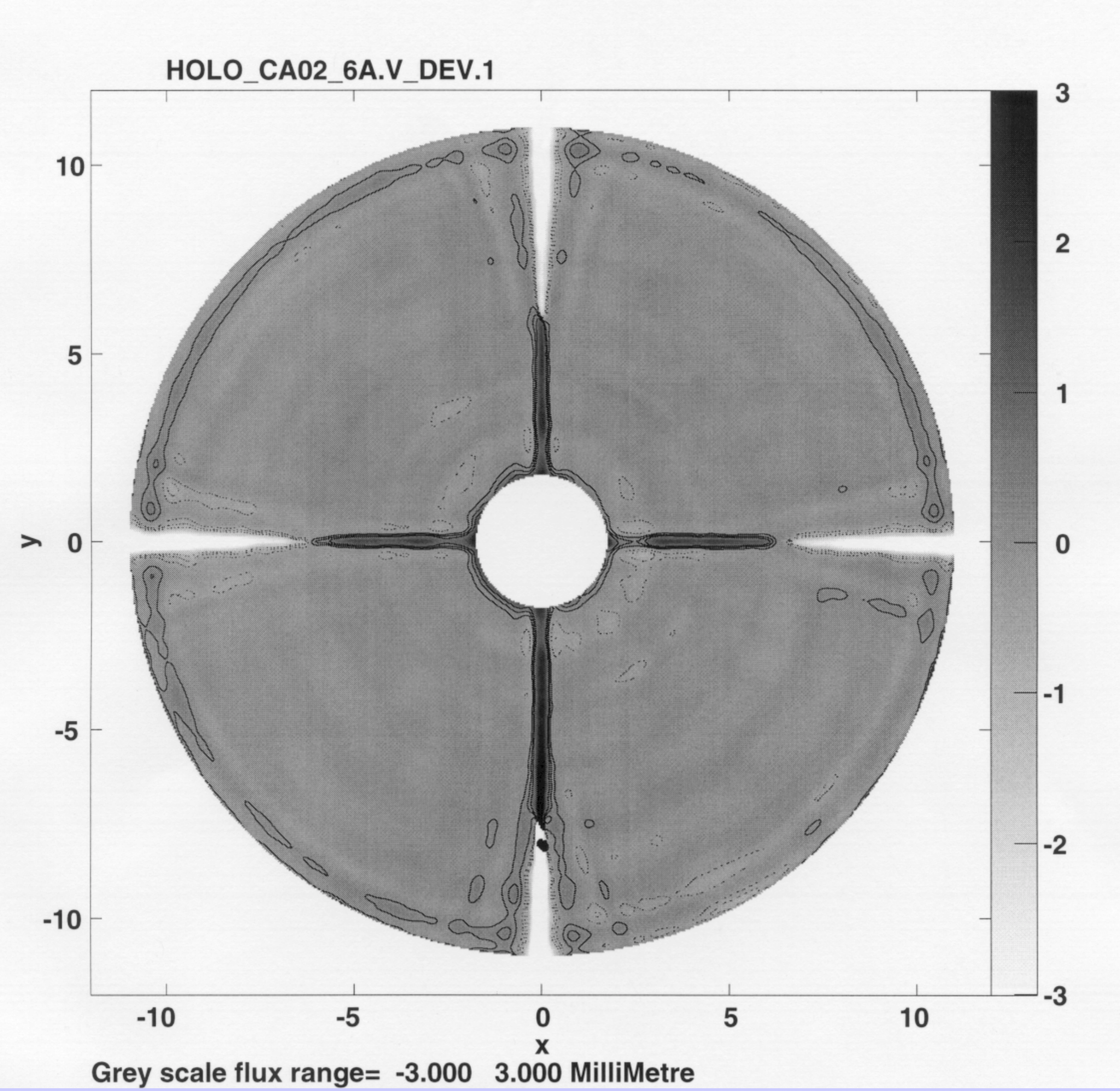


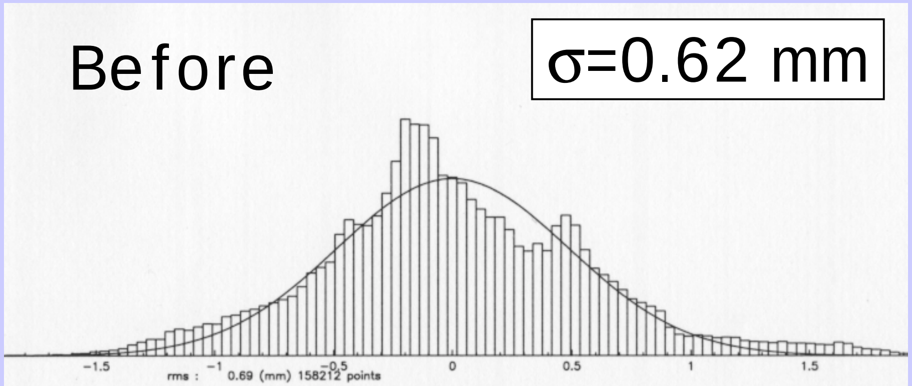
# Surface deviation map:

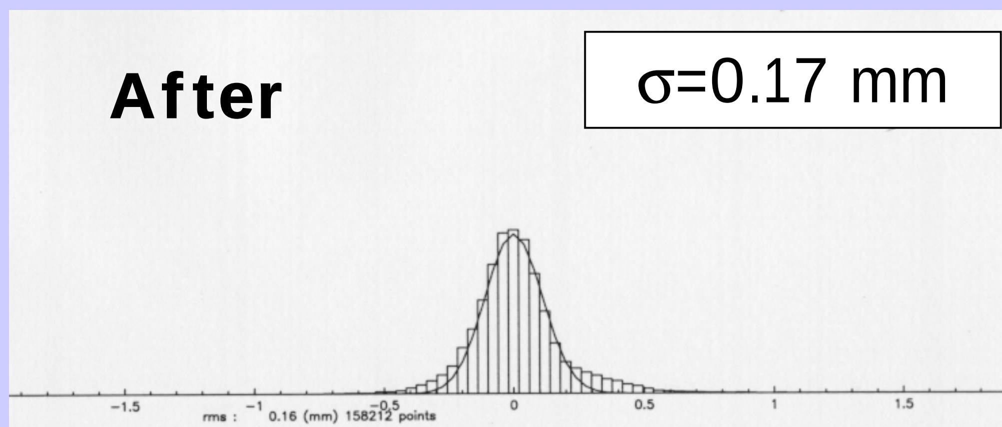


# Panel adjustments

# After adjustments:




Before
σ=0.62 mm
−1.5 −1 −0.5 0 0.5 1 1.5
rms : 0.69 (mm) 158212 points


After
σ=0.17 mm
−1.5 −1 −0.5 0 0.5 1 1.5
rms : 0.16 (mm) 158212 points

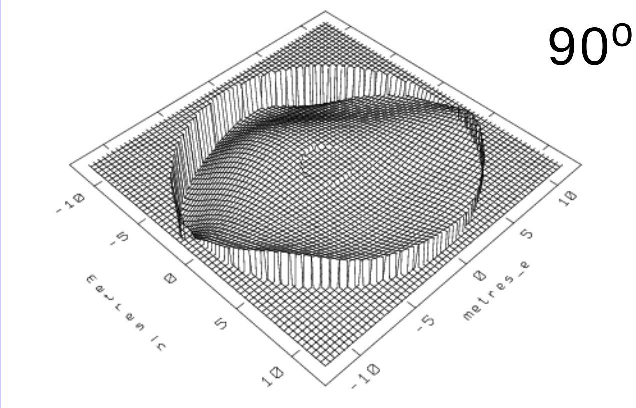
Loss in antenna sensitivity due to surface irregularities:

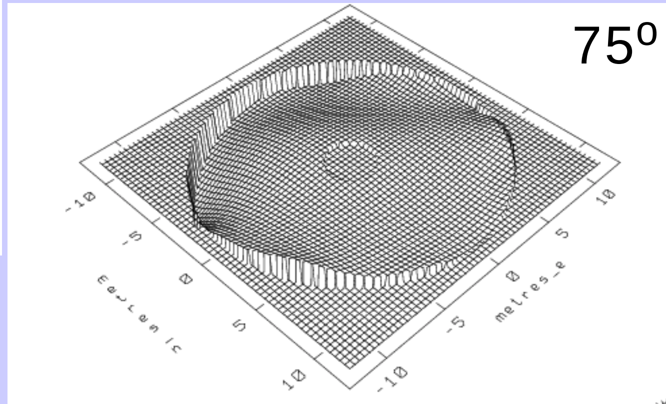
$$K_g = \cos^2(\Delta\phi)$$

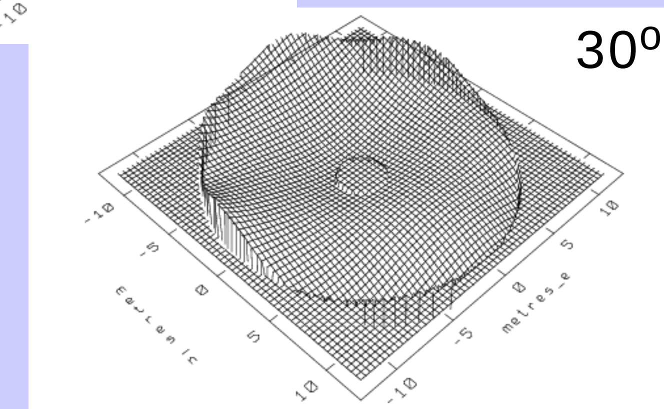
Twice the reflector surface rms in wavelengths

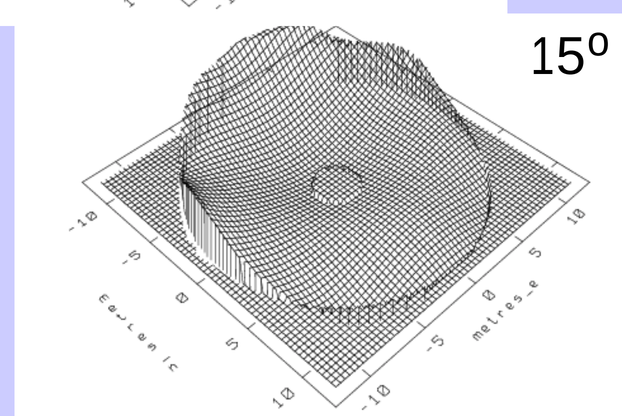
$\sigma$=0.17 mm

| | $\Delta\phi$ | $K_g$ |
|---|---|---|
| 3 cm band | 4 deg. | 0.996 |
| 12 mm band | 8 deg. | 0.98 |
| 3 mm band | 40 deg. | 0.57 |




Gravity deformation of the antenna:

Measured using photogrammetry

Correction proposed using tilts to the SR