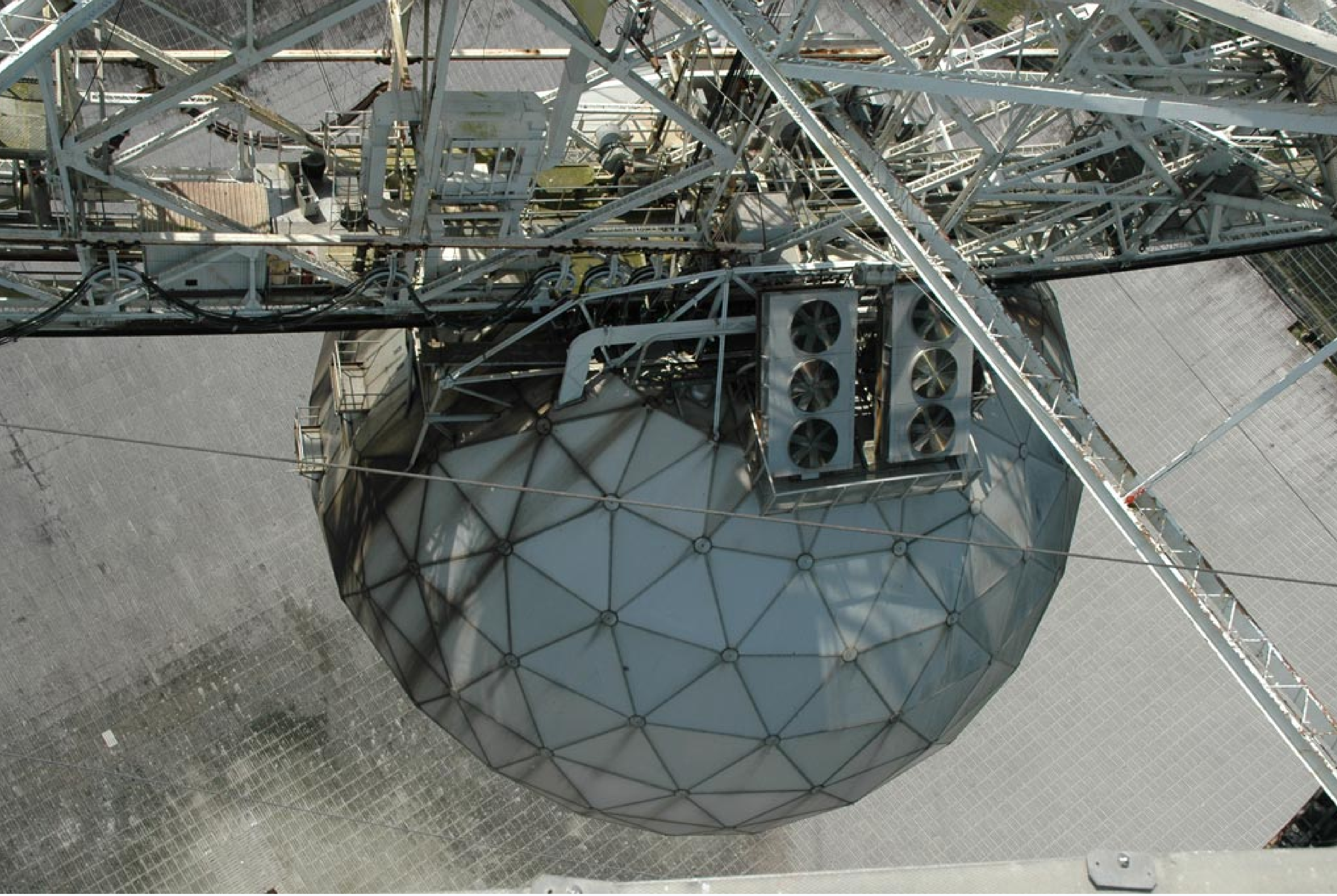
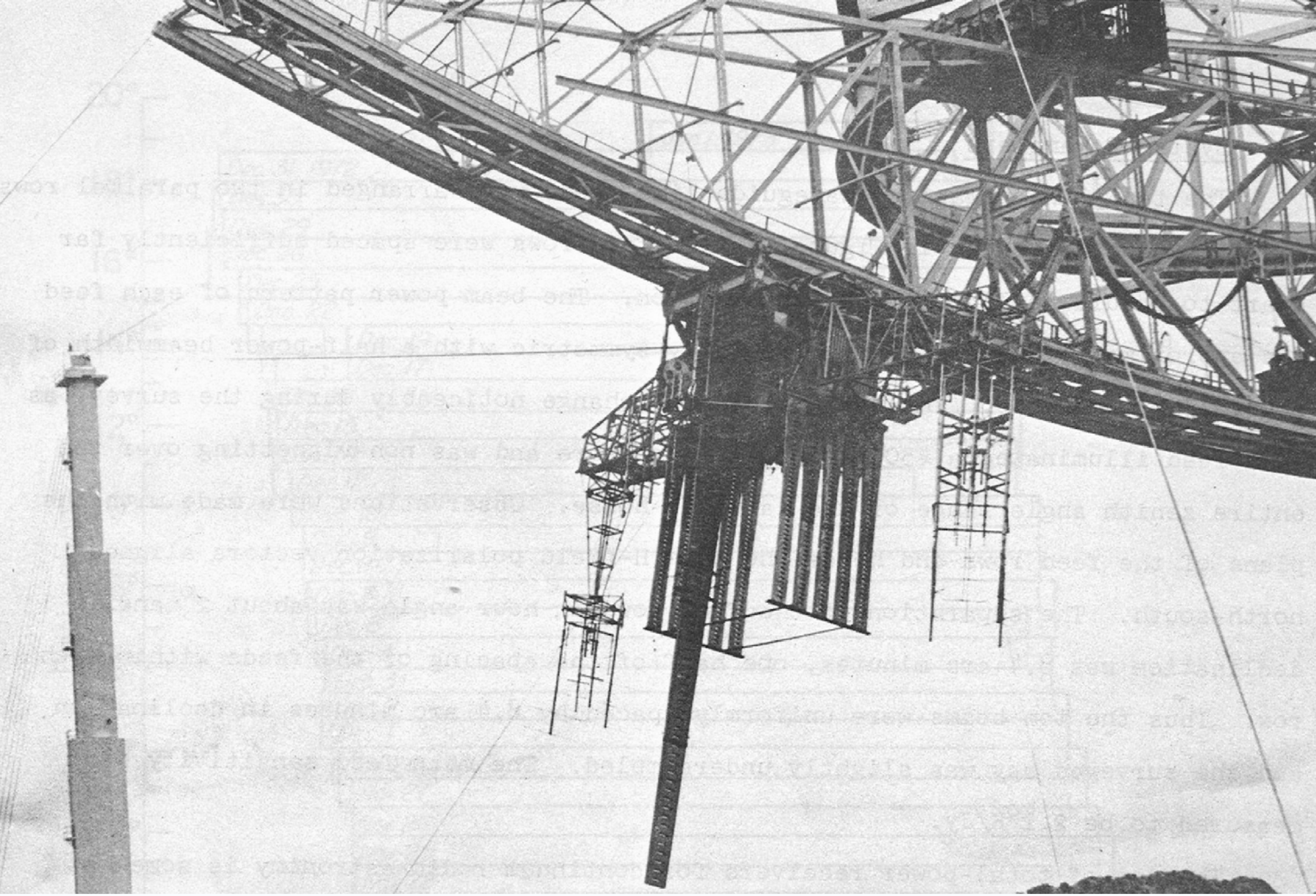
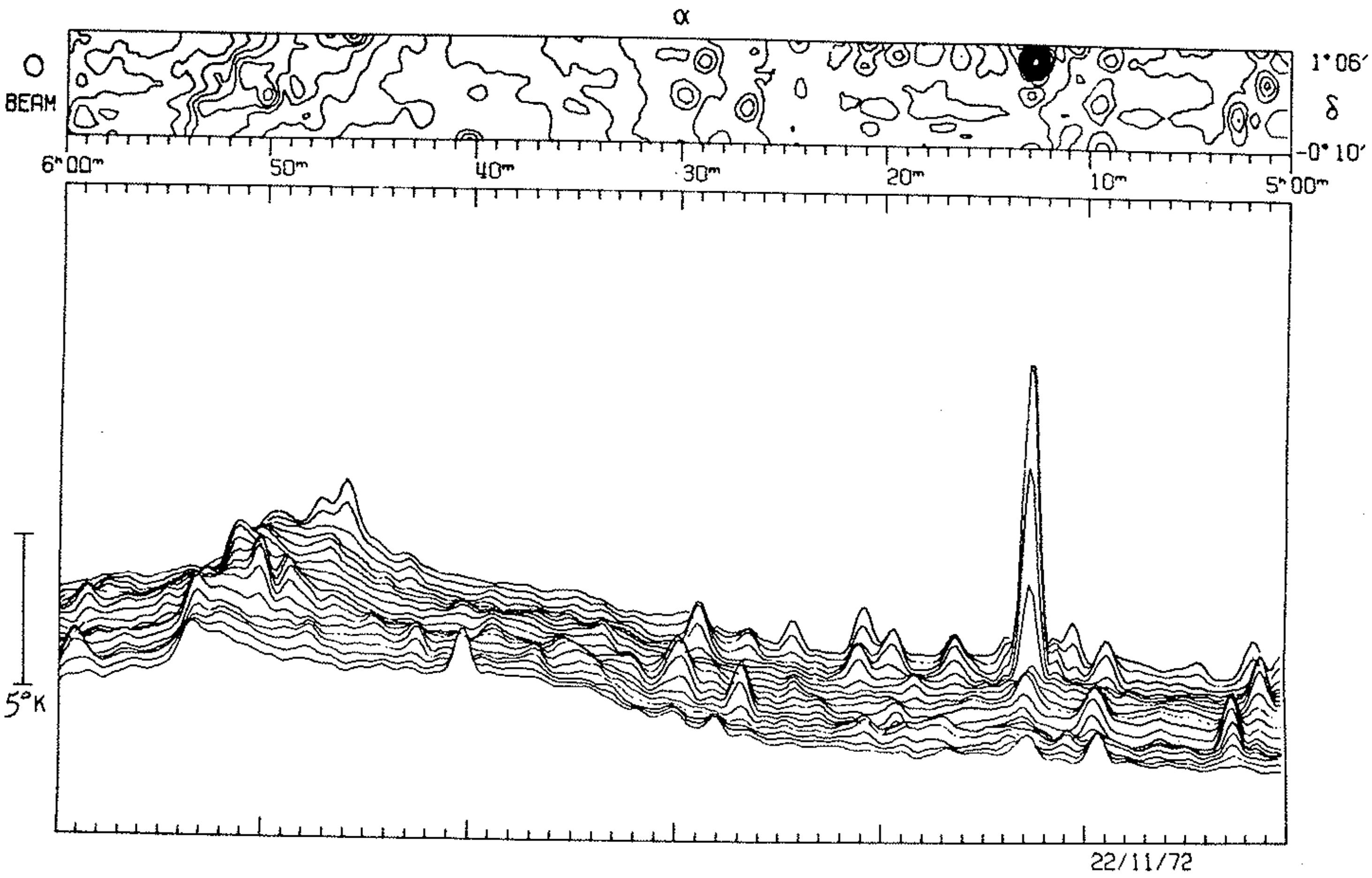
Multiple Point Feeds for Spherical Telescopes

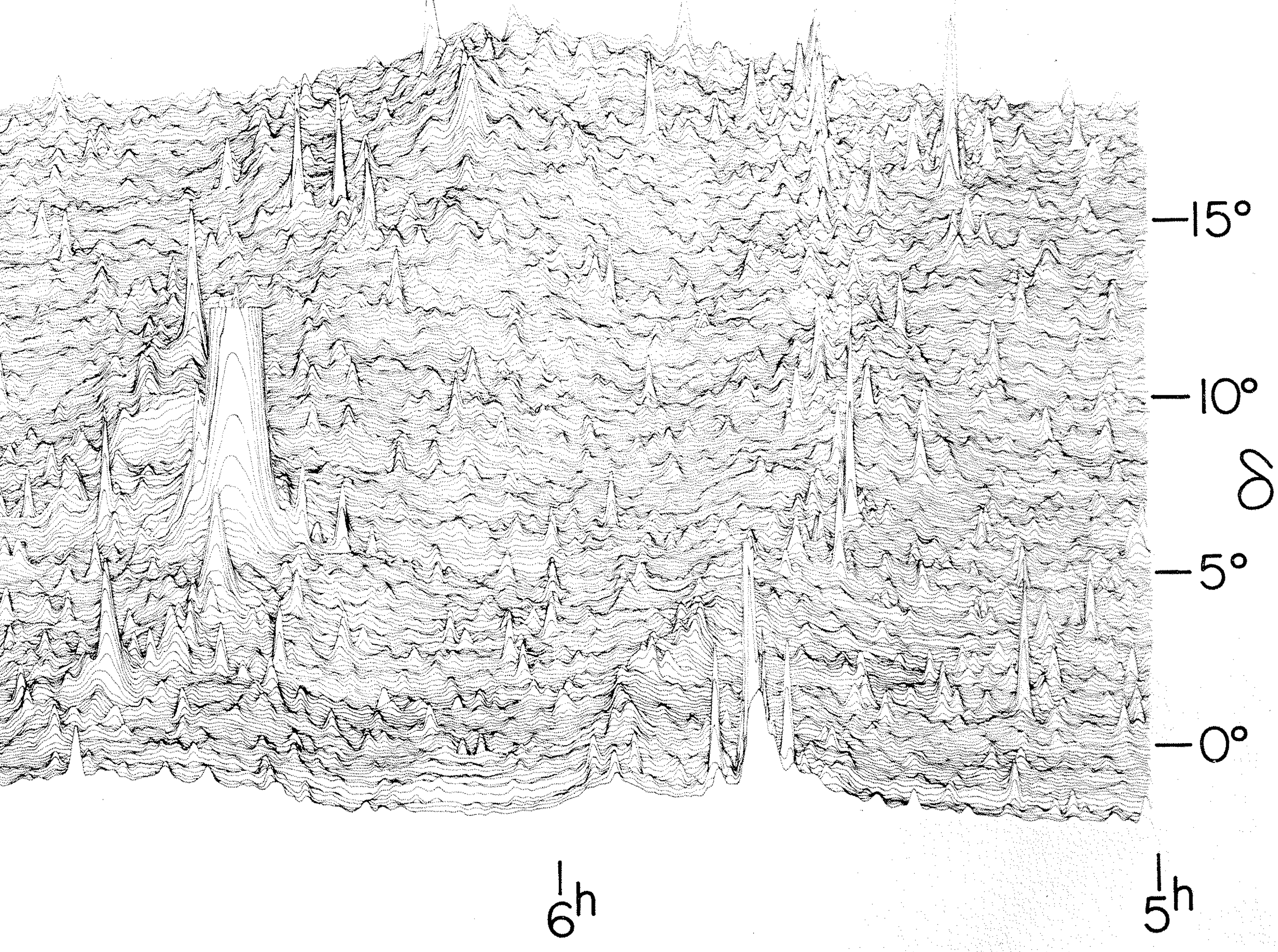
Jim Condon





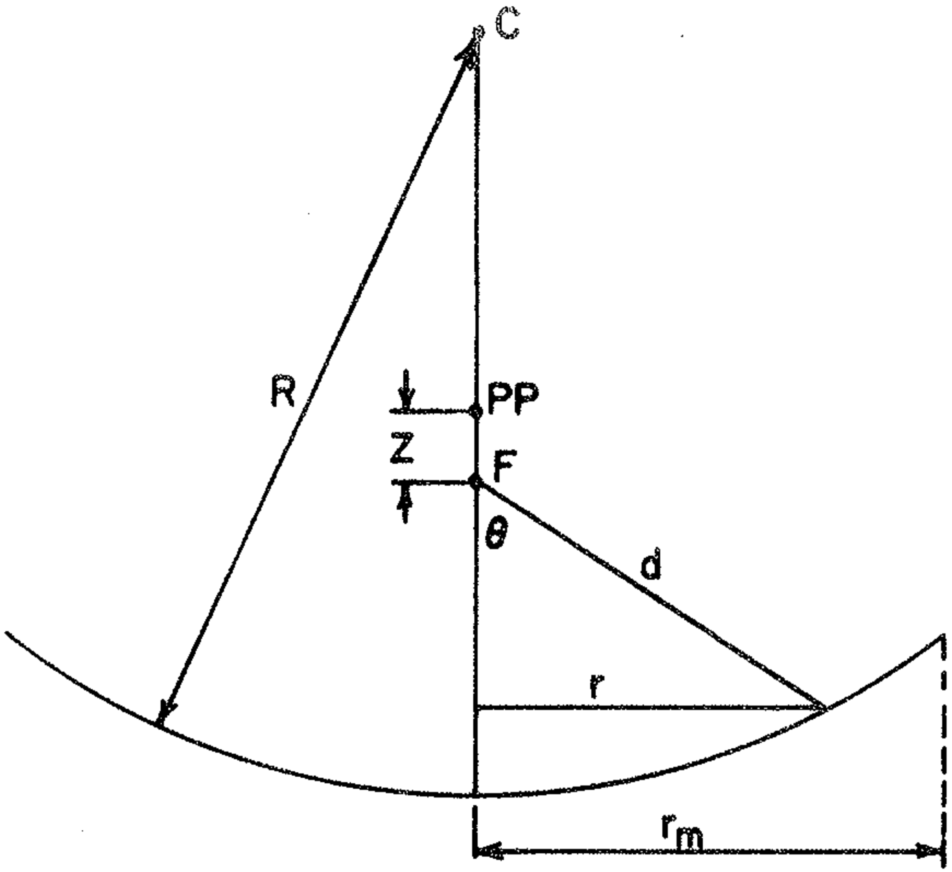
One hour of data, 611 MHz drift scan, 10 beams, ~13 arcmin FWHM, declination separation ~ 0.6 FHWM





−15°
−10°
δ
−5°
−0°
6h
5h

Point Feeds for a Spherical Reflector



$P \propto \cos^2(B\theta)$

Optimum:

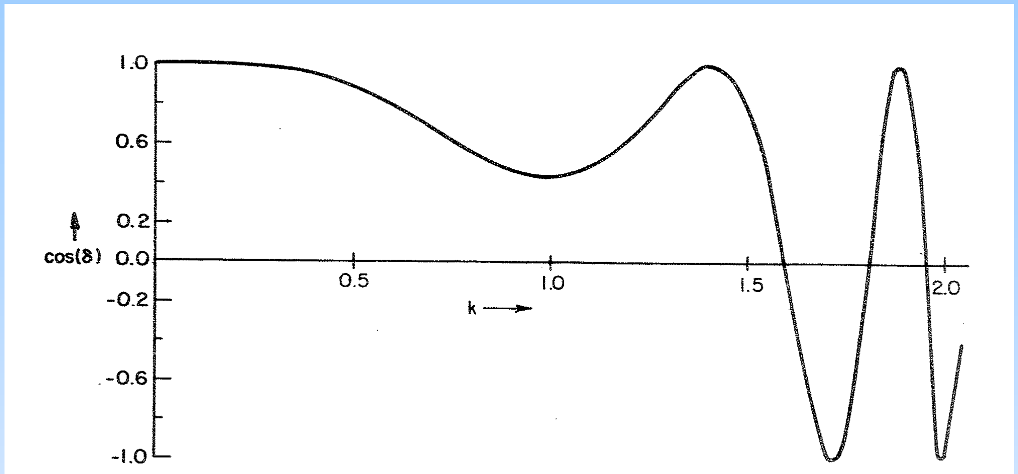
$B \approx 0.52\ (R/\lambda)^{1/4}$

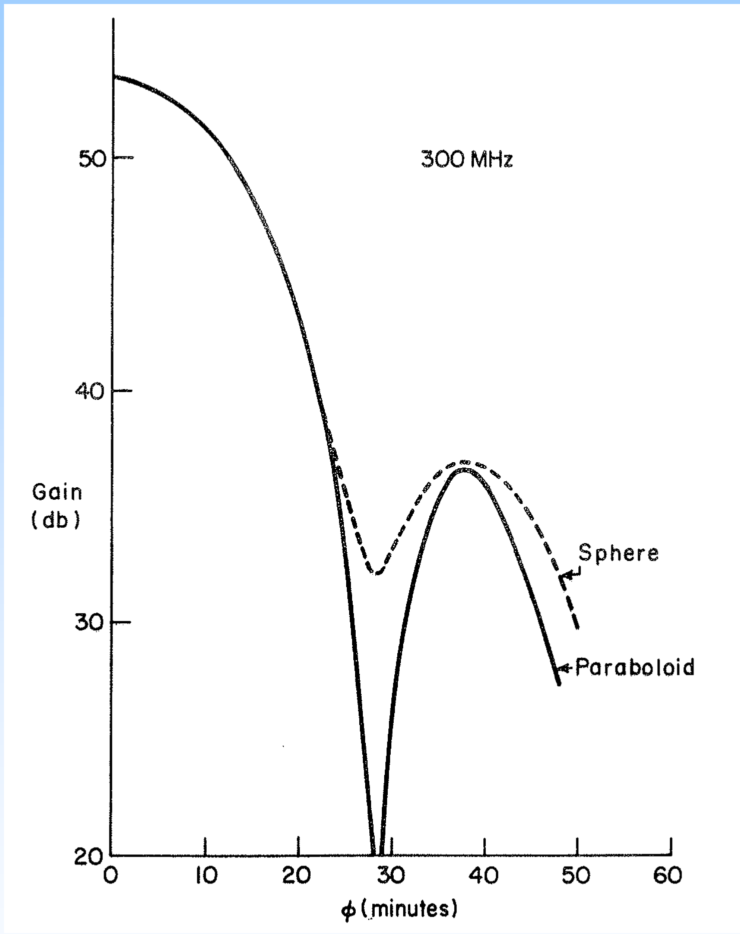
$z \approx 0.21\ (R\lambda)^{1/2}$

(Condon, J. 1969, CSUAC 182)

FAST R = 300 m

Best Performance





$\eta \approx 0.81$ (phase errors)

Similar to uniformly illuminated paraboloid having

$A_{eff} \approx 4.1\ (\lambda R^3)^{1/2}$

$D_{eff} \approx 2.26\ (\lambda R^3)^{1/4}$

Performance on FAST (R = 300 m)

Equivalent paraboloid with on-axis $P \propto \cos^2(B\theta)$ feed has diameter

$D \approx 194\ \lambda^{1/4}$ (m)

(both gain and beamwidth)

ν (GHz)	λ (m)	D (m)
0.3	1.0	194
1.4	0.21	132
5.0	0.06	96

D = 100 m is not small

Telescope figure of merit: R (rate) $\propto (\Delta t)^{-1}$ t = time

For observing a single unresolved source:

$\Delta S = (\Delta S / \Delta T)\ \Delta T$ S = flux density, T = temperature

$(\Delta T / \Delta S) \propto A_e \propto D^2$ A_e = effective area

$\Delta T \propto T_{sys} (B\ \tau)^{-1/2}$ D = diameter, B = bandwidth,

τ = integration time = Δt

so for a given T_{sys}, B, and ΔS, R $\propto (\Delta t)^{-1}$ and

$$R \propto D^4$$

For a survey covering given large $\Omega >> N_b\Omega_b = \Omega_{fov}$ with a given sensitivity ΔS:

N_b = number of beams, Ω_b = beam area, and

Ω_{fov} = field of view

$A_e \Omega_b \propto \lambda^2$ (conservation of energy)

$\Delta t = \tau\ \Omega / \Omega_{fov} \propto D^{-4} / (N_b D^{-2})$

$$R \propto N_b D^2$$

$R \propto B N_b D^2$

VLA $D \sim 120$ m

$N_b = N_{rcvr} = 27$

$B = 100$ MHz

EVLA, ALMA B's much higher so

A single dish is not enough

For a survey with a given τ:

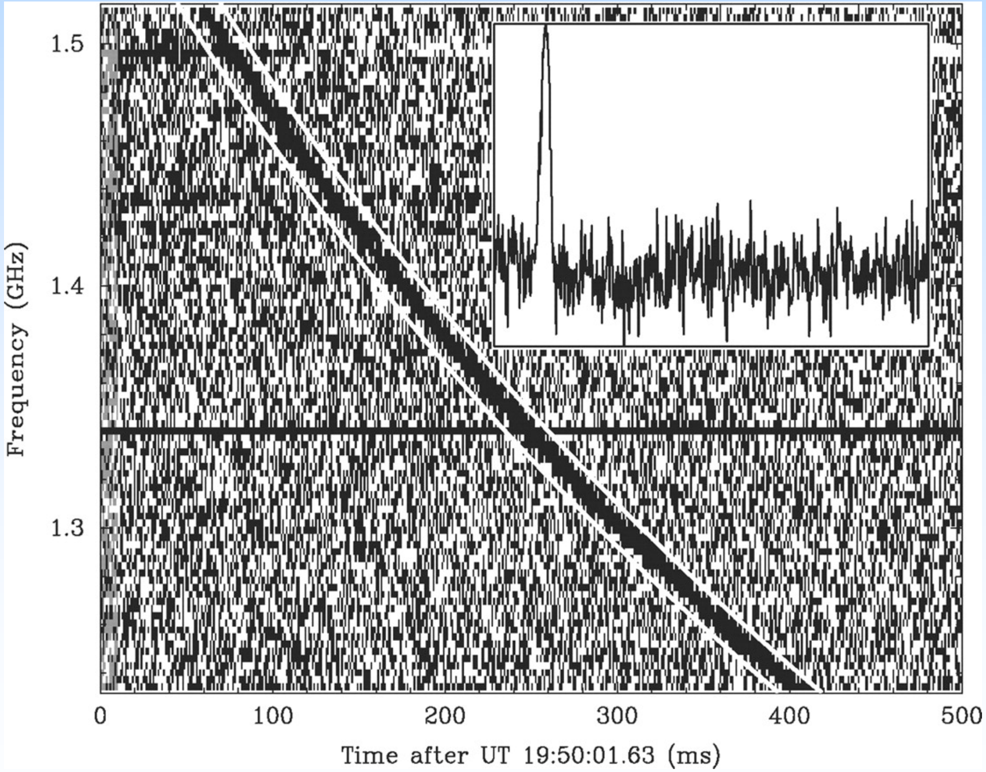
$\Omega \propto N_b \Omega_b = \Omega_{fov}$

N_s = number of detected sources/events $\propto \Omega(\Delta S)^{-3/2}$

$N_s \propto N_b D^{-2} (D^{-2})^{-3/2} \propto N_b D^1$

$R \propto N_s$

$$R \propto N_b D^1$$



For a long survey with a given scan rate (e.g., drift or slew):

$\tau \propto D^{-1}$

$\Omega \propto N_b \Omega_b / \tau \propto N_b D^{-2} / D^{-1} \propto N_b D^{-1}$

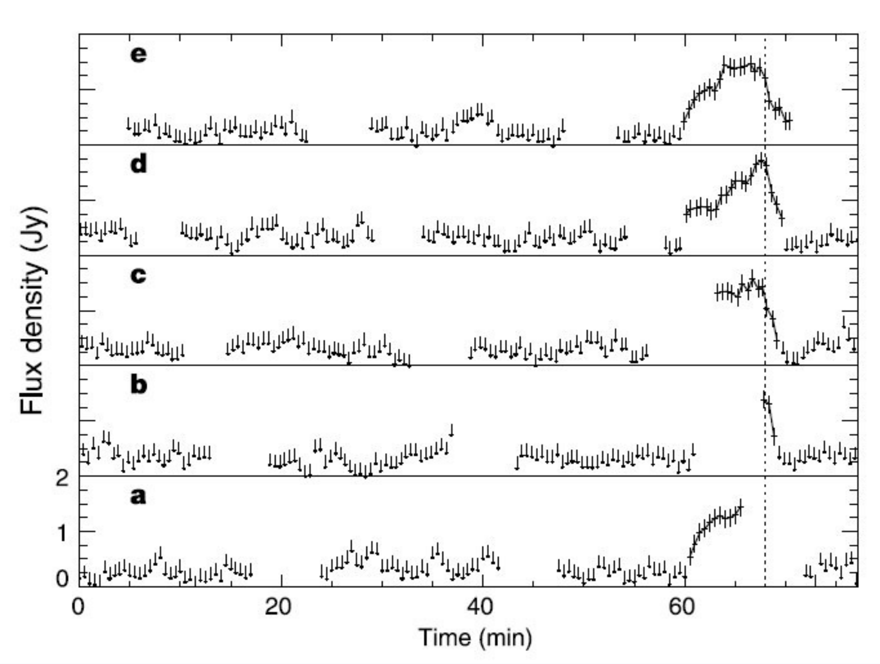
$N_s \propto \Omega (\Delta S)^{-3/2}$

$\Delta S \propto D^{-2} \tau^{-1/2} \propto D^{-3/2}$

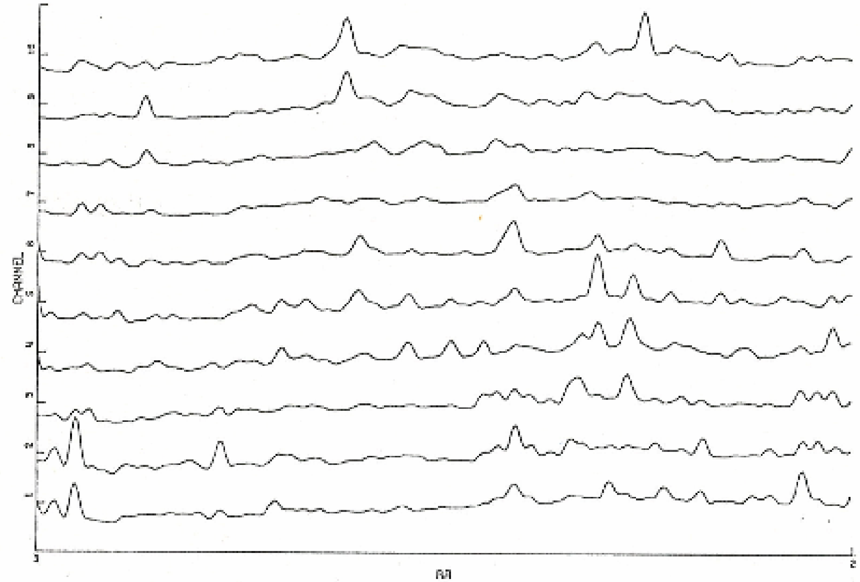
$N_s \propto N_b D^{-1} (D^{-3/2})^{-3/2} \propto N_b D^{5/4}$

$R \propto N_s$

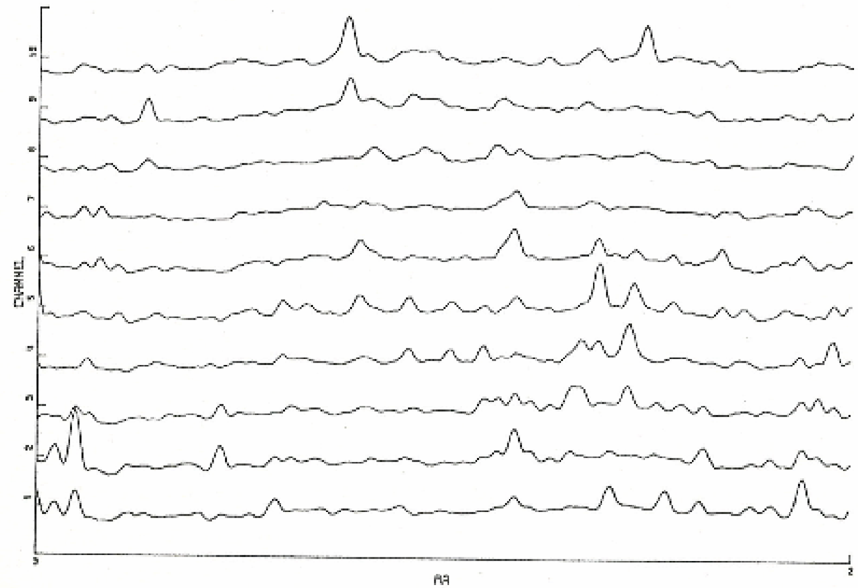
$$R \propto N_b D^{5/4}$$



Two confusion-limited 611 MHz scans on successive nights from the Arecibo 611 MHz multibeam survey: detecting low-frequency events below the confusion limit with a large filled aperture.



(Figure 1.6b)



(Figure 1.6c)

Summary

- Spherical reflectors have no axis of symmetry, permitting multiple simultaneous beams and “commensal” observing
- Point feeds are good for large-N_b, small-D surveys for sources and/or events
- Point feeds can be used if the actuators are not fast enough or are not working
- Keep design options open for point feeds (e.g., allow for more than one feed array at a time, don’t design out $z < 10$ m)