RadioTelescopes – a field guide

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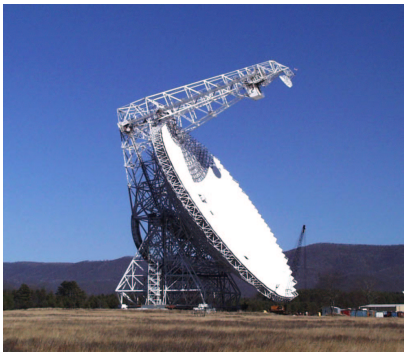
24/September/2001

Conventional telescopes

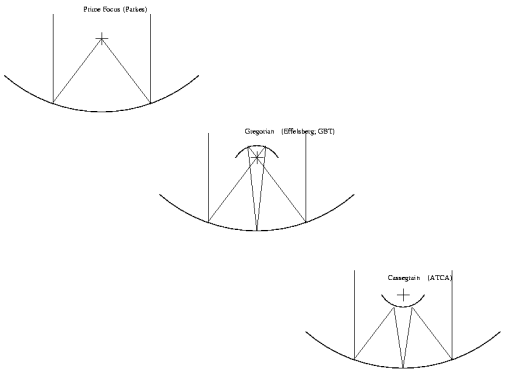
- Main reflector; possibly a secondary
- Focal plane
- single-pixel camera
- Fully-steerable

Parkes 64m

Effelsberg 100m

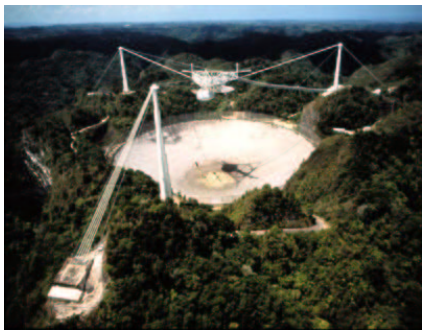


Green Bank 100m



Fixed Spherical Reflector

- Large focal plane
- “Steering” : probe the focal plane
- Simplified mechanical structure



Arecibo – 300m

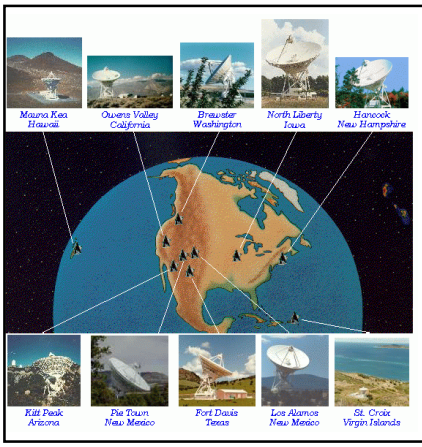
Nancay 200m x 40m

Conventional Imaging Arrays

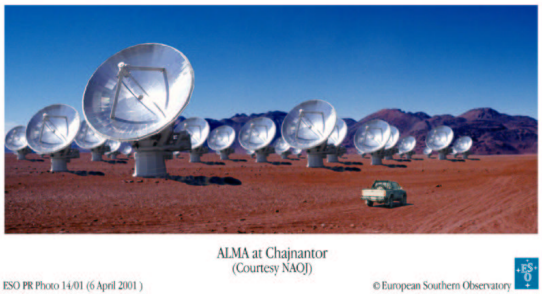
- Multiplicity of antennas – multiplicity of baselines

ATCA
6 x 22m
6 km baseline

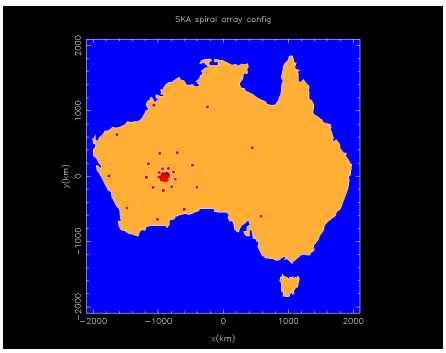
VLA (NRAO)
27 x 25m antennas
Up to 36 km baseline



VLBA (NRAO)
10 x 25m antennas



64 x 12m high precision antennas



(one possible)
SKA – N antennas; up to 3000 km baselines

Unconventional arrays

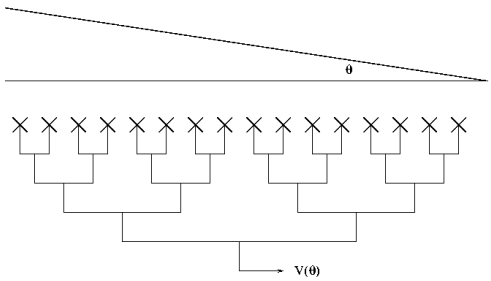
Molonglo (U. Syd)
1 mile x 40 ft. (843 MHz)

Mauritius
2km and 1km arms (151 MHz)

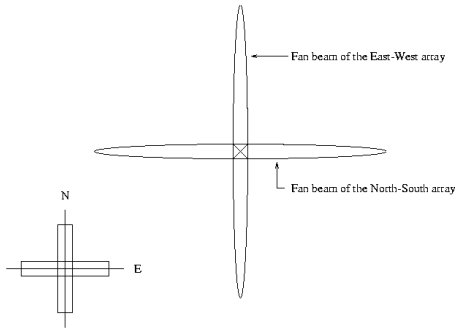
Evolution : Mills Cross -> VLA

Linear array -> fan beam

Correlation between orthogonal fan beams ->
high resolution pencil beam
= central pixel of the array's synthesised image.



$$V(\theta) = \sum_{n=-N}^{N} e^{j\frac{2\pi}{\lambda}(n\Delta x)\sin(\theta)} \sim \frac{\sin(\pi L\theta/\lambda)}{(\pi L\theta/\lambda)}$$



Procedure:

- Correlate the EW arm against the NS (multiply and average)
- Since each source on the sky has its own noise signal, only sources common to the two beams give a non-zero signal

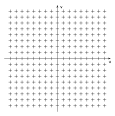
Relate to Synthesis Array : $P(\underline{u}) = \int S(\underline{\theta}) e^{j2\pi(\underline{u}\underline{\theta})} d\underline{\theta}$

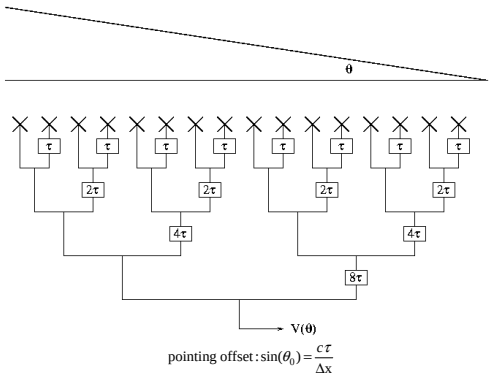
$S(\underline{\theta}) = \int P(\underline{u}) e^{-j2\pi(\underline{u}\underline{\theta})} d\underline{u}$

Mills Cross :

$$\begin{aligned} \langle V_x V_y^* \rangle &= \sum_n \sum_m \langle v_x(n) v_y^*(m) \rangle \\ &= \sum_n \sum_m \int S(\theta,\phi) e^{j2\pi(n\theta - m\phi)} \\ &= \sum_n \sum_m P(\underline{u}) \\ &= S(0,0) \end{aligned}$$

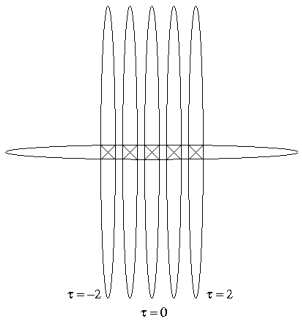
The (u,v) plane :





pointing offset : $\sin(\theta_0) = \frac{c\tau}{\Delta x}$

Mills Cross with multiple E-W beams



Fully implemented Mills Cross :

Given enough hardware, we could map a square patch of sky, each pointing defined by τ_x EW and τ_y NS – we are doing the FT in hardware.

$$\langle V_x V_y^* \rangle = \sum \sum \langle v_x(n) v_y(m) \rangle e^{-j(n\theta_x - m\phi_y)}$$

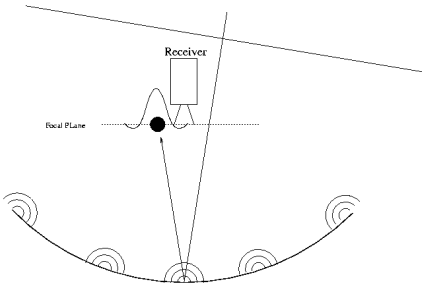
$$= \sum \sum P(\underline{u}) e^{-j(n\theta_x - m\phi_y)}$$

$$= S(\theta_x, \phi_y)$$

$$(\theta_x = c\tau_x / \lambda)$$

Single Dish – equivalent to superimposed arrays.

An incoming wavefront excites currents on the surface – these re-radiate, and combine in a phased way at the receiver.

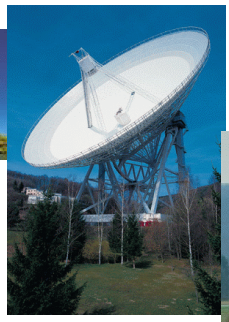


A correctly focussed antenna has constant path length for all rays from wavefront to the focus -

Rx output = $\langle V(\underline{x}) V^*(\underline{x}) \rangle$

Westerbork
14 x 25m antennas
2.7 km E-W baseline

Parkes, 64m



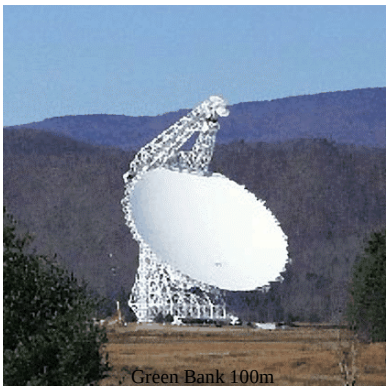
Effelsberg, 100m

Green Bank, 100m

Arecibo, 300m

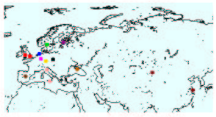
Nancay, 200x40m

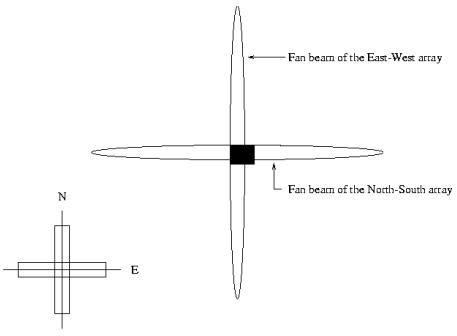
Parkes 64m



Green Bank 100m

The European VLBI Network





common to both beams $=< V_{EW} V_{NS}^{*} >$

Molonglo Synthesis Telescope :

2 East-West arms, each ½ mile long. Continuous tracking (part mechanical, part electrical, adjusting the delays).

Equivalent to an East-West array (eg, ATCA).