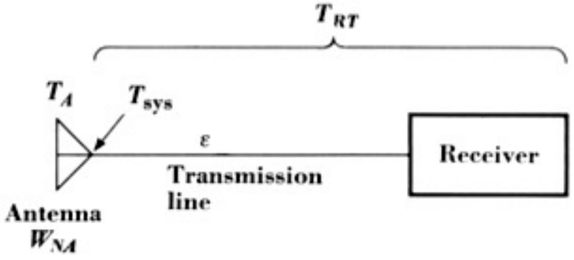
Strumentazione Astronomica: Radioastronomia



$$T_A^* = T_A e^{-\tau_{TL}} + T_{TL}(1 - e^{-\tau_{TL}})$$

Fig. 7-7. The antenna, transmission line, and receiver contribute to the system temperature.

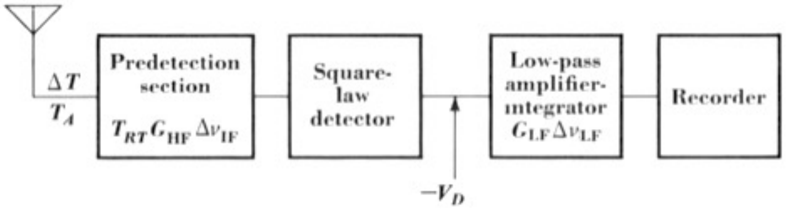


Fig. 7-8. Total-power receiver.

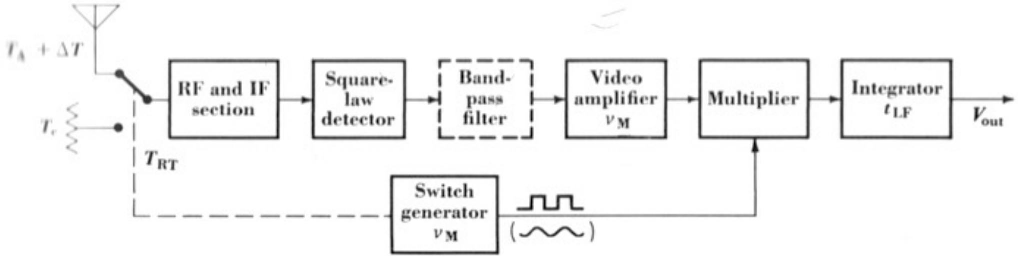


Fig. 7-13. Switched or Dicke receiver (bandpass filter optional).

Ricevitore tipo Dicke
Efficienza di osservazione del cielo 50%

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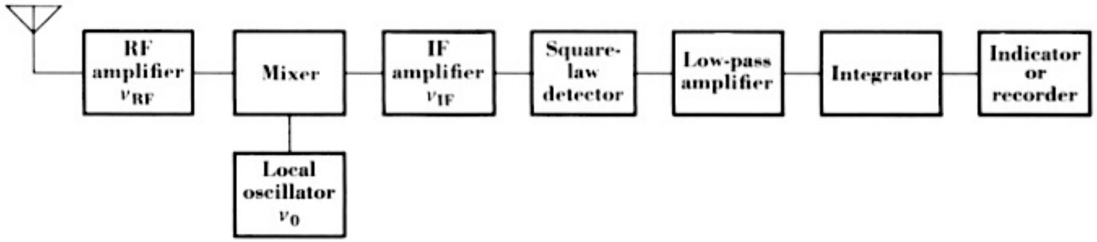

Fig. 7-2. A superheterodyne radio-telescope receiver.

Funzionamento del mixer (componente a risposta non lineare, in prima approssimazione quadratica)

$E_{RF} + E_{LO} = E_{RF}^0 \sin(2\pi\nu_{RF} t + \delta) + E_{LO}^0 \sin(2\pi\nu_{LO} t + \varphi)$ Segnali in ingresso al mixer

La risposta quadratica del mixer da in uscita

$$(E_{RF} + E_{LO})^2 \propto E_{RF}^0 E_{LO}^0 \sin[2\pi(\nu_{RF} + \nu_{LO})t] + E_{RF}^0 E_{LO}^0 \sin[2\pi(\nu_{RF} - \nu_{LO})t]$$

Con un filtro passa basso si elimina la somma delle frequenze e si tiene la differenza

$$\nu_{IF} = \nu_{RF} - \nu_{LO}$$

Il segnale a frequenza intermedia è processabile in maniera più semplice

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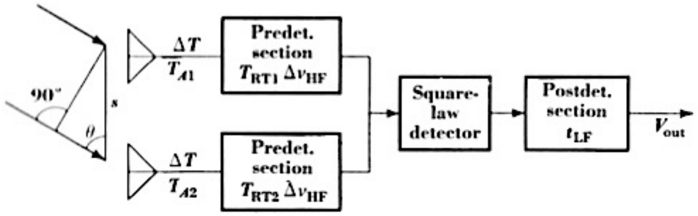


Fig. 7-18. Simple interferometer receiver.

$$\Delta T_{\min} = \frac{T_{Sys}}{\left(1+\cos\phi\right)\sqrt{\tau\cdot\Delta\nu}} \qquad (\phi=90-\theta)$$

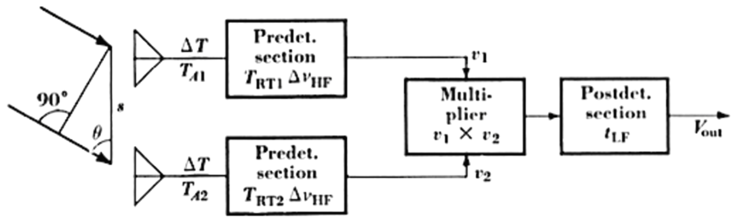


Fig. 7-19. Interferometer with correlation receiver.

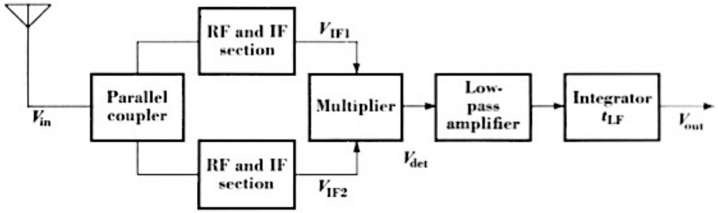


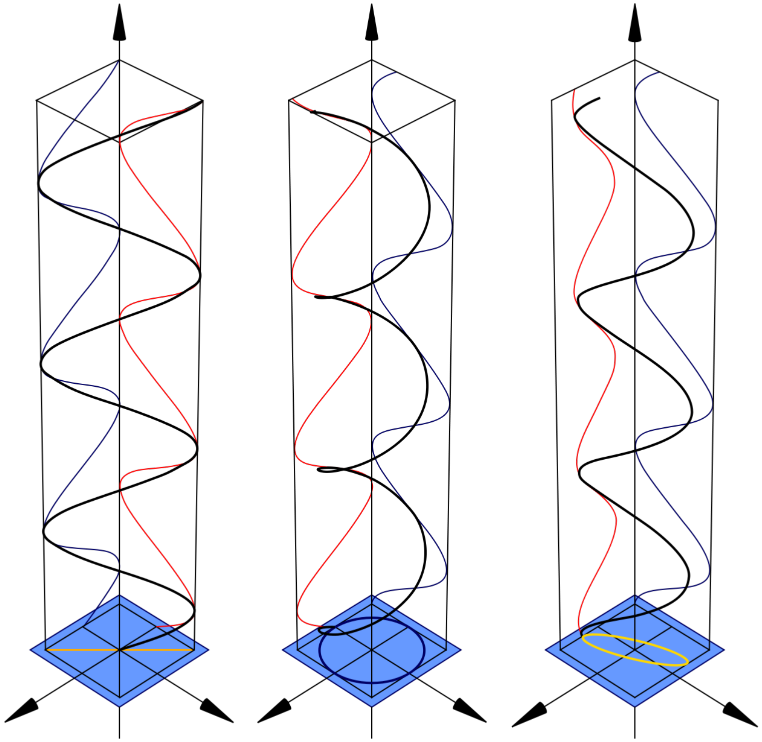
Fig. 7-21. Correlation receiver.

$$E\left\{x(s)\,y(s+\tau)\right\} = Rxy(\tau) = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T} x(s)\,y(s+\tau)\,ds$$

Strumentazione Astronomica: Radioastronomia

Radiazione Polarizzata
Parametri di Stokes

Una radiazione elettromagnetica si dice polarizzata quando il piano di vibrazione del campo Elettrico non è casuale.
Se il piano di vibrazione è costante nel tempo e nello spazio, la
polarizzazione dell'onda e.m. è detta LINEARE
Se il piano di vibrazione ruota attorno alla direzione del vettore di propagazione,
la polarizzazione dell'onda e.m. è detta CIRCOLARE



Un campo di radiazione costituito da radiazione polarizzata linearmente e circolarmente
ha una polarizzazione detta ELLITTICA. Questa combinazione si può ottenere anche con
due polarizzazioni lineari sfasate di 90 gradi e di ampiezza diversa.

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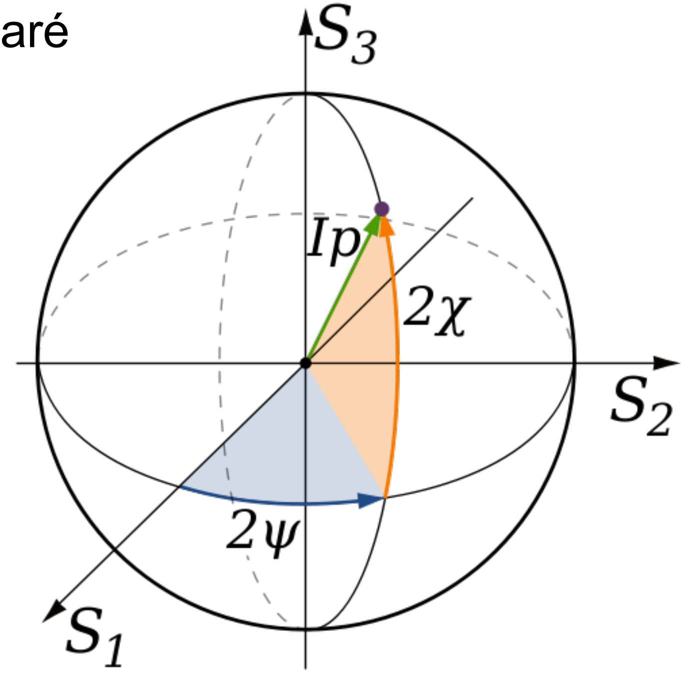
$$S_0 = I$$

$$S_1 = I_p cos2\Psi cos2X$$

$$S_2 = I_p sin2\Psi cos2X$$

$$S_3 = I_p sin2X$$

Sfera di Poincaré



$$\vec{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

Parametri di Stokes

$$\begin{pmatrix} 1 \\ \pm 1 \\ 0 \\ 0 \end{pmatrix} \begin{matrix} + \rightarrow \\ - \uparrow \end{matrix} \quad \begin{pmatrix} 1 \\ 0 \\ \pm 1 \\ 0 \end{pmatrix} \begin{matrix} +\pi/4 \\ -\pi/4 \end{matrix} \quad \begin{pmatrix} 1 \\ 0 \\ 0 \\ \pm 1 \end{pmatrix} \begin{matrix} +RHCP \\ -LHCP \end{matrix} \quad \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \text{UNPOL}$$

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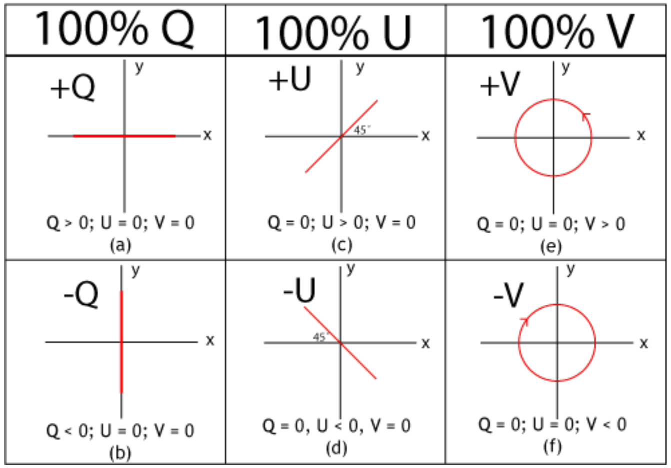
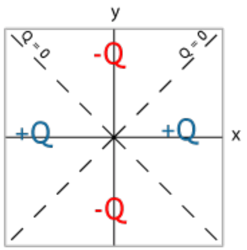


$$I = |E_x|^2 + |E_y|^2 = |E_a|^2 + |E_b|^2 = |E_l|^2 + |E_r|^2$$

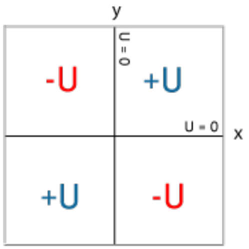
$$Q = |E_x|^2 - |E_y|^2 = -2Re(E_a^* E_b) = 2Re(E_l^* E_r)$$

$$U = 2Re(E_y^* E_x) = |E_a|^2 - |E_b|^2 = -2Im(E_l^* E_r)$$

$$V = -2Im(E_y^* E_x) = 2Im(E_a^* E_b) = |E_l|^2 - |E_r|^2$$



Sign of Q
(a)

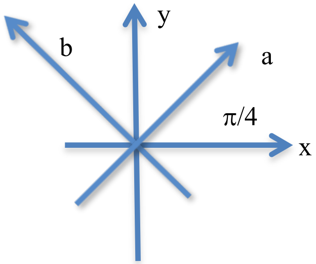


Sign of U
(b)

Counter-clockwise Rotation
Left-handed

Clockwise Rotation
Right-handed

Sign of V
(c)



$$\hat{l} = (\hat{x} + i\hat{y})/\sqrt{2}$$

$$\hat{r} = (\hat{x} - i\hat{y})/\sqrt{2}$$

$$I^2 \geq Q^2 + U^2 + V^2$$

$$I_P^2 = Q^2 + U^2 + V^2$$

Grado di Polarizzazione $= \frac{I_P}{I}$

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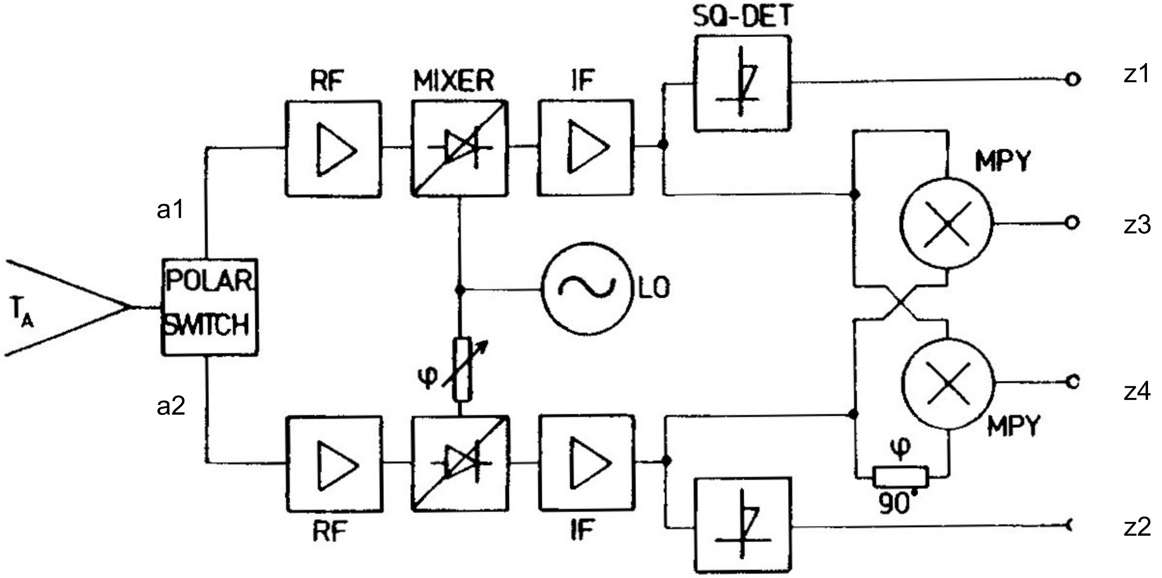

Fig. 4.22. An analog polarization receiver with four outputs, which are the four Stokes parameters

$$I = \langle a_1 \rangle^2 + \langle a_2 \rangle^2 \propto z_1 + z_2$$

$$Q = \langle a_1 \rangle^2 - \langle a_2 \rangle^2 \propto z_1 - z_2$$

$$U = 2\langle a_1 a_2 \cos\delta \rangle \propto 2z_3$$

$$V = 2\langle a_1 a_2 \sin\delta \rangle \propto 2z_4$$

Parametri di Stokes

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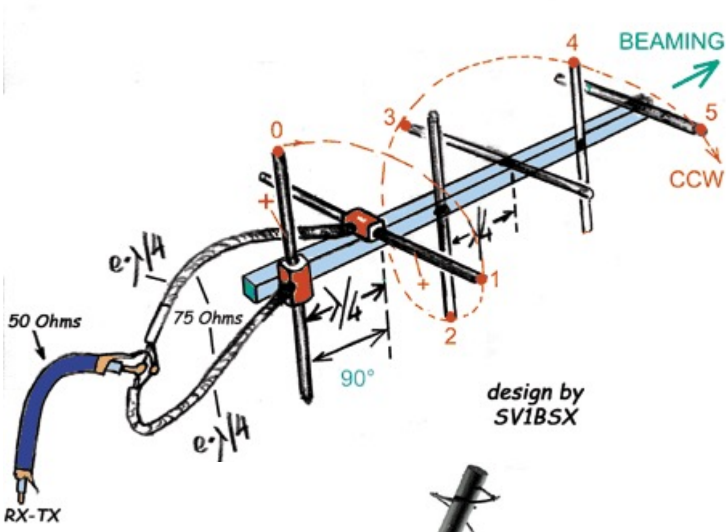

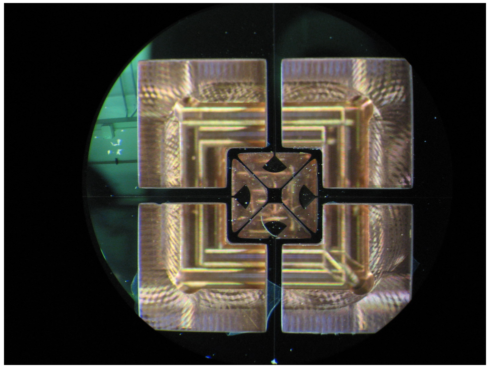

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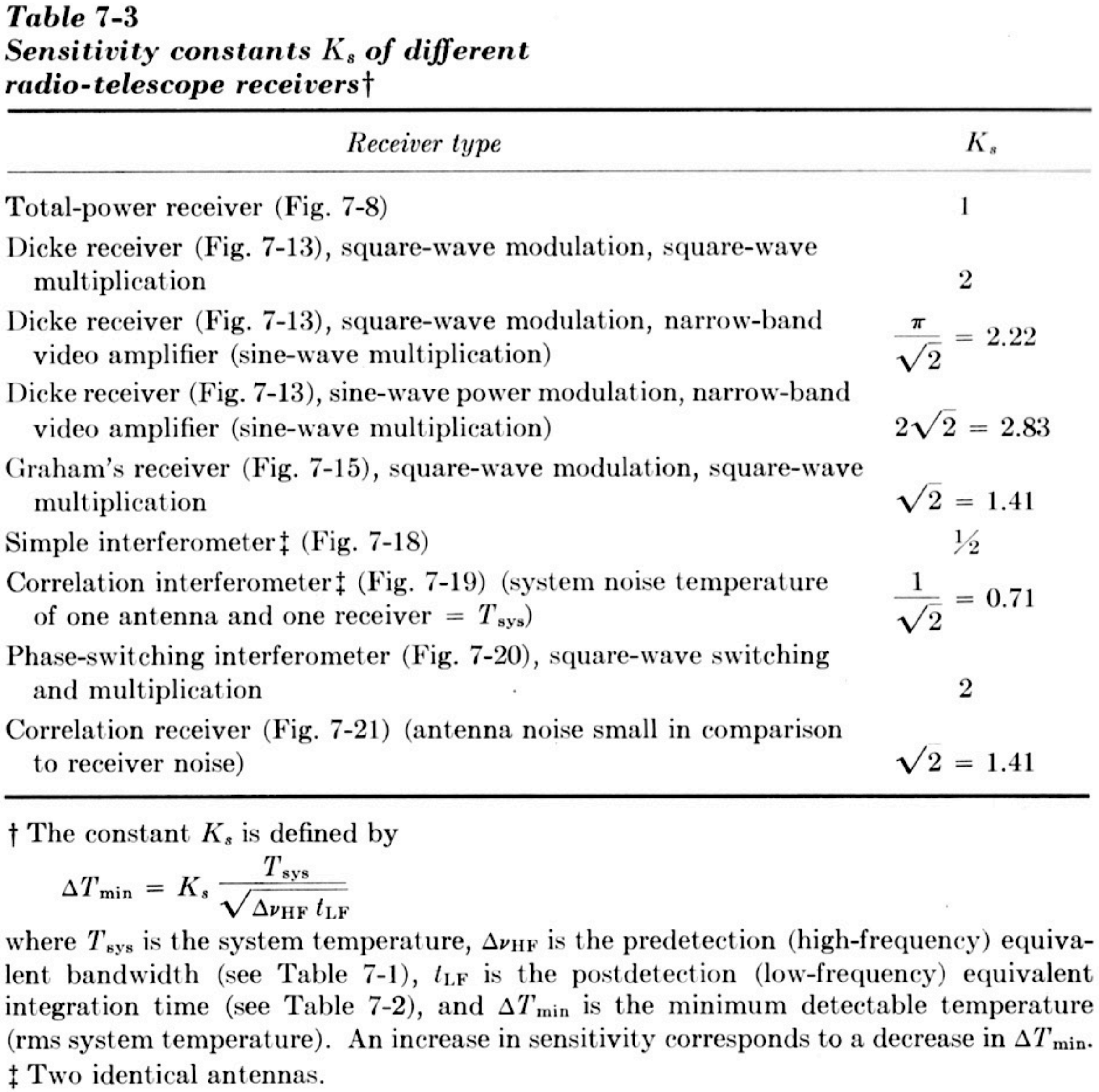

Table 7-3
Sensitivity constants K_s of different radio-telescope receivers†

Receiver type	K_s
Total-power receiver (Fig. 7-8)	1
Dicke receiver (Fig. 7-13), square-wave modulation, square-wave multiplication	2
Dicke receiver (Fig. 7-13), square-wave modulation, narrow-band video amplifier (sine-wave multiplication)	$\frac{\pi}{\sqrt{2}} = 2.22$
Dicke receiver (Fig. 7-13), sine-wave power modulation, narrow-band video amplifier (sine-wave multiplication)	$2\sqrt{2} = 2.83$
Graham's receiver (Fig. 7-15), square-wave modulation, square-wave multiplication	$\sqrt{2} = 1.41$
Simple interferometer‡ (Fig. 7-18)	½
Correlation interferometer‡ (Fig. 7-19) (system noise temperature of one antenna and one receiver = T_{sys})	$\frac{1}{\sqrt{2}} = 0.71$
Phase-switching interferometer (Fig. 7-20), square-wave switching and multiplication	2
Correlation receiver (Fig. 7-21) (antenna noise small in comparison to receiver noise)	$\sqrt{2} = 1.41$

† The constant K_s is defined by

$$\Delta T_{\min} = K_s \frac{T_{\text{sys}}}{\sqrt{\Delta\nu_{\text{HF}}\, t_{\text{LF}}}}$$

where T_{sys} is the system temperature, $\Delta\nu_{\text{HF}}$ is the predetection (high-frequency) equivalent bandwidth (see Table 7-1), t_{LF} is the postdetection (low-frequency) equivalent integration time (see Table 7-2), and $\Delta T_{\min}$ is the minimum detectable temperature (rms system temperature). An increase in sensitivity corresponds to a decrease in $\Delta T_{\min}$.

‡ Two identical antennas.

Kraus "Radio Astronomy"

Strumentazione Astronomica: Radioastronomia

Il piano (u,v) è perpendicolare
alla direzione del flusso S_0 e
tangente la volta celeste.
u è orientato verso est e
v verso nord.

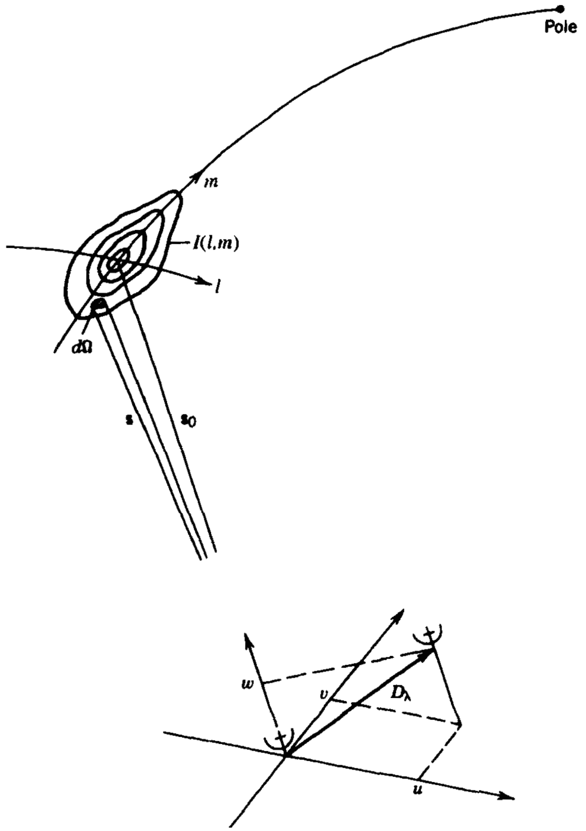

Figure 3.2 Geometric relationship between a source under observation $I(l, m)$ and an interferometer or one antenna pair of an array. The antenna baseline vector, measured in wavelengths, has length D_λ and components (u, v, w).

Funzione di visibilità di un interferometro

$$V(u,v) = \iint P_n(x,y)\,B(x,y)\,e^{i2\pi\frac{ux+vy}{\lambda}}\,dx \cdot dy$$

L’uscita del correlatore di un interferometro fatto di due antenne è la funzione di visibilità V che non è altro che la Trasformata di Fourier della distribuzione di brillanza B della sorgente pesata per il diagramma d’antenna dell’interferometro. (Teorema di Van Cittert-Zernike)

Ogni baseline (coppia di antenne) costituisce un punto dello spazio (u,v). Un interferometro con N antenne ha, in linea di principio, N(N-1) baselines indipendenti

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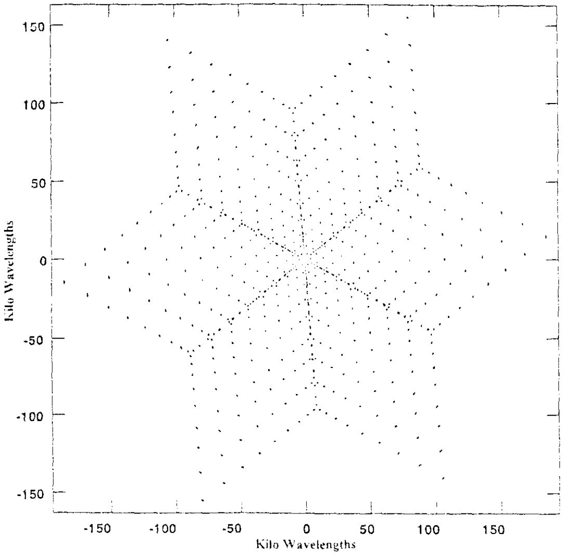


Fig. 6.5. The instantaneous coverage, or 'support', in the u,v-plane, of the VLA, for an observation at the zenith.

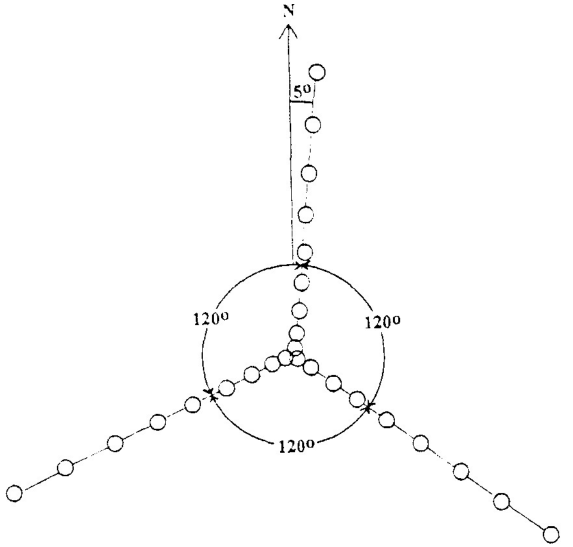
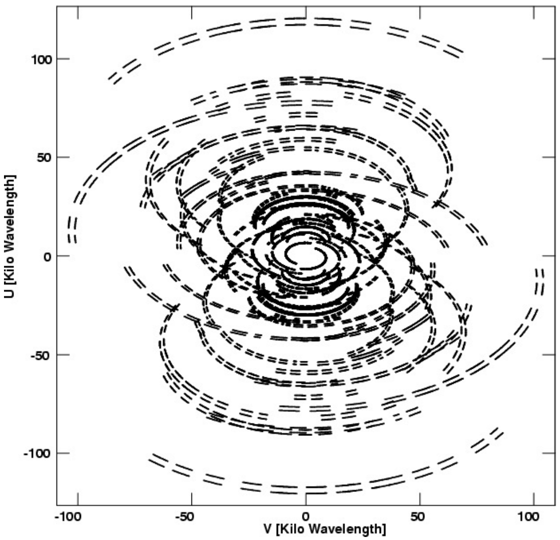


Fig. 6.1. The 27 antennas of the VLA. Each arm of the 'Wye' is 20 km long.



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IRAM Plateau de Bure Interferometer

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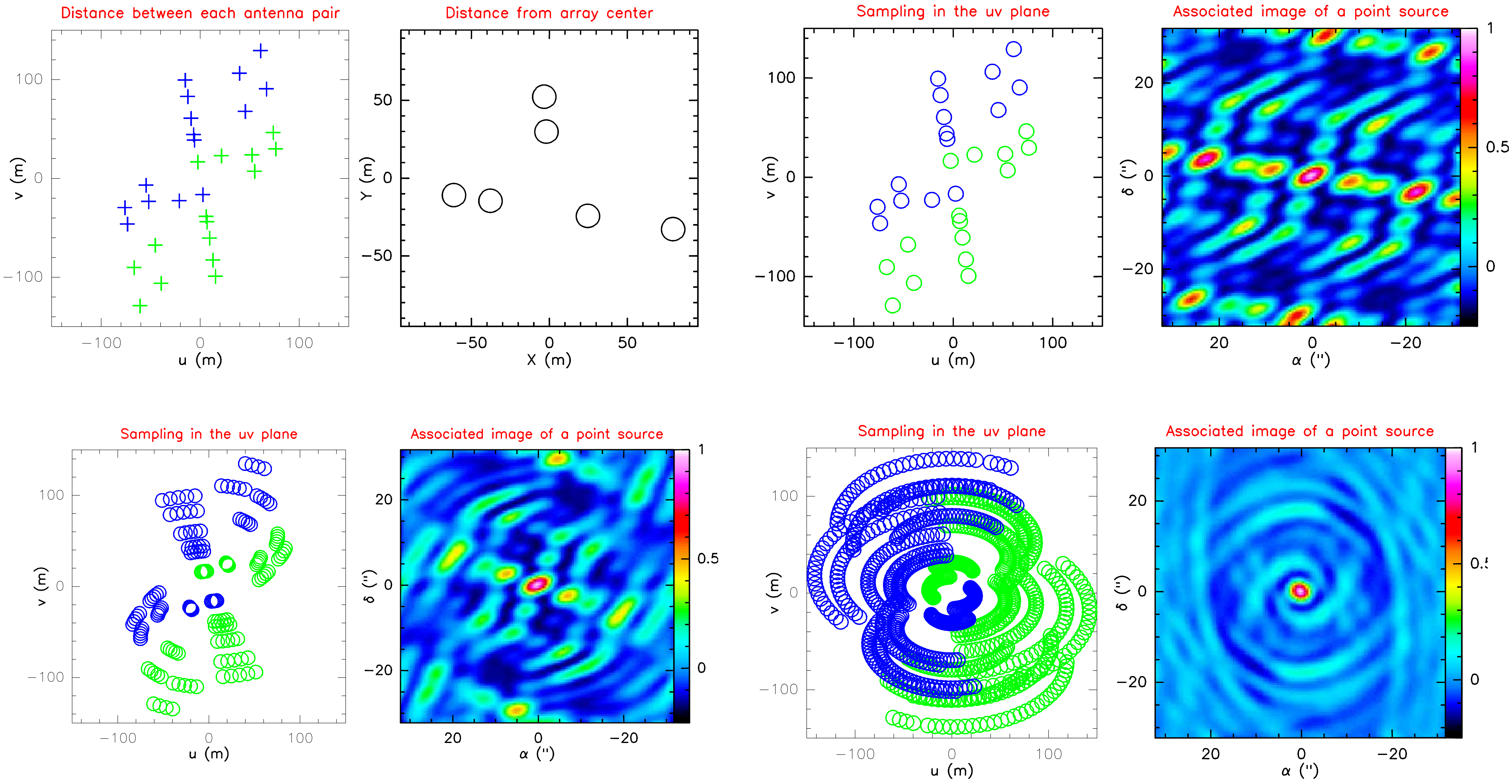
Distance between each antenna pair

Distance from array center

Sampling in the uv plane

Associated image of a point source

Sampling in the uv plane

Associated image of a point source

Sampling in the uv plane

Associated image of a point source

IRAM Plateau de Bure Interferometer

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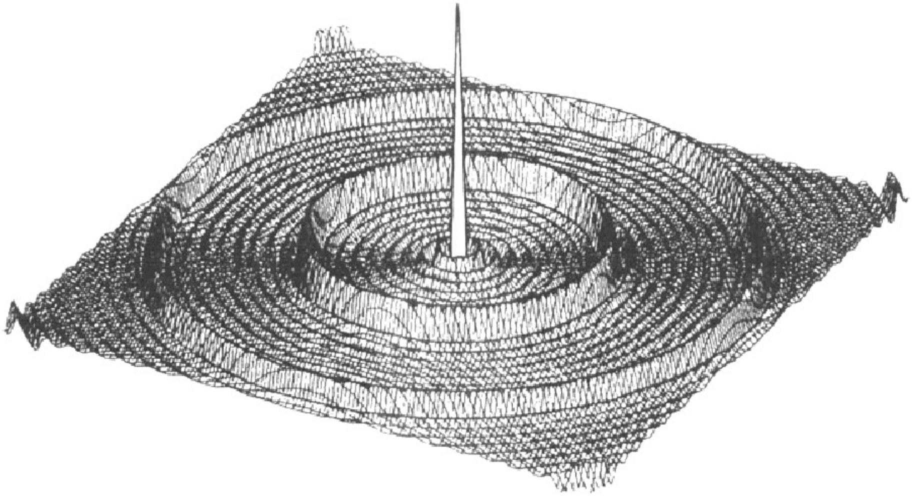

Figure 5.15 Example of ringlobes. The response of an array for which the spatial transfer function is a series of nine circles concentric with the (u, v) origin, resulting, for example, from observations with an east–west linear array with 12 h tracking at a high declination. The radii of these circles are consecutive integral multiples of the unit antenna spacing. The weighting corresponds to the principal response discussed in Section 10.2 under *Weighting of the Visibility Data*. From Bracewell and Thompson (1973).

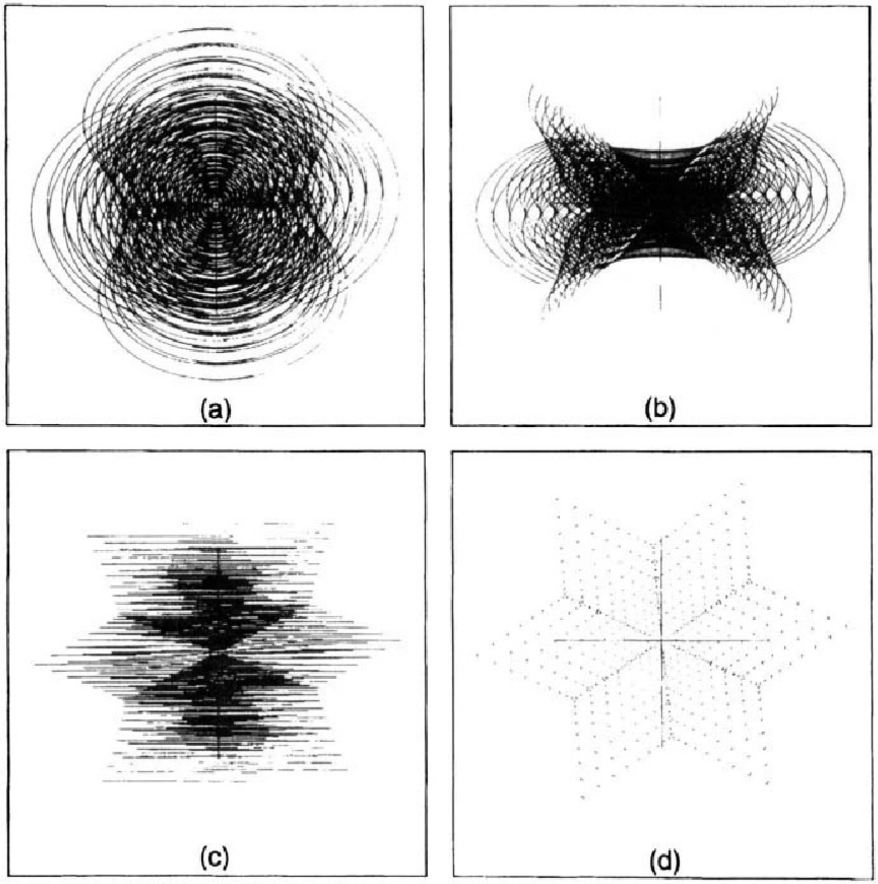

Figure 5.18 Spatial frequency coverage for the VLA with the power-law configuration of Fig. 5.17b: (a) $\delta = 45°$; (b) $\delta = 30°$; (c) $\delta = 0°$; (d) snapshot at zenith. The range of hour angle is ±4 h or as limited by a minimum pointing elevation of 9°, and ±5 min for the snapshot. The lengths of the (u, v) axes from the origin represent the maximum distance of an antenna from the array center, that is, 21 km for the largest configuration. From Napier, Thompson, and Ekers (1983), ©1983 IEEE.